OCCLUSION

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WRIGHT · BRISTOL

Occlusion

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Preface

SAMUEL GOLDWYN once said to a crusading young writer in the thirties: 'If you gotta message send it by Western Union.' The substance of the cinema has enlarged since then but Mr. Goldwyn's arrow still serves to deflate many a balloon of reforming zeal. Nothing daunted, this book has a message which is directed at the dental patients of this world and their dentists. It is a message so simple that one might question the need of a book to say it. The message reads: leave your teeth alone. And it should be simple enough to send by telegram. To avoid misinterpretation this might be more aptly phrased: keep your teeth apart. Like many a preventive exhortation, however, it is deceptively simple and requires an efficient and comfortable occlusion of the teeth to achieve it. The teeth are for mastication and the occlusion between them is for swallowing. But when the teeth are uncomfortably related to each other they sometimes become forcefully occluded and troubles ensue. Today caries and periodontal diseases are the main concerns of the dental profession but both are in sight of cure by prevention. The chief task of the dentist may then be to keep his patients' teeth apart. Already my balloon is hissing. But the far-off hills are greenest and there is a little information on the way.

The study and teaching of occlusion are hindered because of the difficulty of seeing contact between the teeth in three dimensions. Too often they are seen only as line diagrams without an appreciation of overlap and overjet, without realizing that a cusp and fossa have three dimensions and not two. It is also difficult to appreciate that occlusion is a momentary function of the teeth and that the mandible which provides these various and momentary occlusions is moving in three dimensions. The 3D approach, therefore, has to exist in the minds of teacher and student, of writer and reader.

Two further difficulties are often encountered in the study of occlusion. First, because of the difficulty of seeing contacts between the teeth various forms of articulators have evolved so that occlusion can be seen on casts of the teeth. But there still exists the masking overlap, both buccal and lingual. Secondly, there is the confusion in communication created by terms which are not fully understood and which are dominated by the adjective *centric*. Never has a word had so many meanings and no doubt it will be a long time before the profession relinquishes it. But a start will be made in the text of this book. Besides, most of the terms introduced have been used in Scandinavia for many years. It is hoped that dogma and pedantry will seem to be minimal.

Another term discarded is *model* in favour of *cast*. The North American influence is admitted but it seems more fitting to make a cast not a model from an impression in spite of a cast also being something with which you catch a fish or have in your eye. There are those who will object to *upper* and *lower* when *maxillary* and *mandibular* are more scientific. On this point an apology for inconsistency is offered but justification is claimed in terms of chairside usage and of using two syllables instead of four in each word. For the same reason jaw relationship is preferred to maxillo-mandibular relationship. But top and bottom are excluded. Two words with similar meanings and separate implications require definition. *Registration* is used to mean the act of relating upper to lower jaw by means of a setting material placed between the teeth or occlusal rims. *Record* is the set material which is used to transfer the jaw relationship to an articulator. Here again the North American influence is acknowledged as it is throughout much of the text but in equal measure with that from Britain and Scandinavia.

Repetition of principles, concepts and precepts may be a source of exasperation to some but has seemed to be necessary because of the organization of material in the book. Tissues and their functions, positions and movements, occlusion and articulation, articulators, disturbances and disorders, diagnosis and analysis, and treatment measures in four separate categories are all treated in separate chapters but the same principles apply to each. It therefore seemed desirable to re-state the recurring themes for each application. 'What I tell you three times is true', the Bellman cried, certain but sensitive, intentionally vague but practical in his hunt for the Snark (Carroll).* Association with the celebrated Bellman invites accusations of nonsense in the hunt for an understanding of occlusion and the treatment of its problems, and it is hoped that Occlusion will not softly and suddenly vanish away in the manner of the Snark.

An apology is courteously extended to members of the Women's Liberation Movement for the use of the pronoun *he* when referring to a patient. It prevents the clumsy and disrespectful use of (*or she*).

The limitations of any textbook are that seeing is more profitable than reading and doing than seeing. It is hoped that reading may lead to seeing and doing.

* Carroll, Lewis, *The Hunting of the Snark*, Chatto & Windus.

Acknowledgements

IT is my good fortune to be the son of a dentist whose ability, patient care and enthusiasm for dentistry gave me a pride of profession for which I shall always be grateful. The other early and beneficial influence in practice was Gerald Leatherman whose integrity in the assessment of his patients' requirements was a quality I have tried to emulate.

The invitation to write this book was accepted in the hope that some aspects of occlusion could be presented which had not already been covered by such acknowledged authorities as Ramfjord and Ash, Posselt, Kraus, Abrams and Jordan, Schweitzer, Krough-Poulson, Beyron, Boucher, Brewer, Lauritzen and by the gnathologists McCollum, Stuart, Granger, Thomas, Lucia and their successors. The result has been an absorption of these men's work and teaching with some extensions and changes of emphasis. To them goes gratitude not only for their work, but, in many instances, for their friendship over the years. The original stimulus goes back to John R. Thompson whose essentially simple teaching, based on function, at Northwestern University was a genuine inspiration. The visits of Henry Beyron and Allan Brewer to London twenty or so years ago provided new concepts and practical applications. These inspirations were sustained and developed for me by Clifford Ballard at the Institute of Dental Surgery who developed concepts based on biological behaviour which have influenced orthodontic teaching in many parts of the world and which are now reaching the realms of prosthodontics. John Lee at the Institute was the first to recognize Ballard's influence on the construction of dentures and in turn presented continuing challenges to established principles. These challenges have been taken up by many of the younger generation of dentists and, in particular, I should like to acknowledge the inspiration and help provided by Peter L'Estrange and Brian Parkins at the Institute whose influences are now being felt. To the latter I also extend gratitude for many hours of reading and critical suggestions and to Alan Newton (University of Liverpool) for his inspiration to write Chapter 3 and for providing constructive criticism. These are busy men but find time to assist colleagues. I acknowledge the encouragement and tolerance afforded by Alan Mack as Professor and Head of the Department at the Institute.

Special acknowledgement is gratefully made to the late Sir Wilfred Fish whose example as clinician and scientist has encouraged the chairside dentist to train himself in the observation of phenomena and the discipline of testing hypotheses. The liveliness and curiosity of his mind till the last days of his life were qualities which the profession will not forget. With the advent of scientists to our profession Sir Wilfred's plea has always been for the closest co-operation between them and the clinician. His offer to write a foreword to this book was a typical gesture of encouragement which I hope will be justified.

Grateful acknowledgements are made to James Morgan in the Photographic Department at the Institute for the production of photographs from a chaotic collection of slides and clinical material. Not all the photographs were taken by him and the poor ones are mine. To Edward Pullen-Warner for his painstaking drawings and diagrams (many times cheerfully redrawn), and to Judith Hook for her expertise on the typewriter (many times for retyping, with equal cheer), I am equally grateful. To Margaret Cowperthwaite and, before her, Patricia Flor, I extend my thanks for their searches in the library. Finally, it is never out of place to acknowledge the long-suffering acceptance of a husband and father whose home care has declined, to say the least.

Foreword

Sir E. Wilfred Fish

THIS BOOK is the record of a diligent search for the rules that govern the achievement of perfect occlusion. The inquiry is not confined to the natural dentition, with or without the provision of fillings, inlays or bridges, but extends also to the design of the occlusal surfaces of dentures, whether partial or full. It is clearly the account of a comprehensive inquiry, the report of an unusually thorough example of purely clinical dental research, and therefore it has a special significance.

It has become our habit these days to think of research in dentistry as being exclusively related to histopathology, bacteriology, biochemistry or microbiology, and as being pursued by experts in these fields in specially equipped laboratories; but here we have an example of exclusively clinical research which accordingly has a direct practical value. An immediate practical application cannot always be detected in the case of laboratory research. Scientists have on occasion been known to overlook the fact that the essential purpose of medical or dental research is, or should be, to improve and support clinical practice, though admittedly this purpose is still achieved if, as in some cases, the clinical application is likely to emerge only at a much later date.

The absence of applicability is not, however, a misfortune that can occur when, as in this instance, the investigator of a clinical problem is himself a clinician—confronted daily by the problems about which he writes. The present investigation of the problems of occlusion is accordingly of immediate concern to every clinician, a point which is made abundantly clear if the question be posed: 'What would be the use of teeth, however beautiful, if they did not meet effectively?'

There is a real need for encouraging investigations of the fundamental problems of our daily practice, particularly when, as in this case, the investigations are meticulously thorough; for although it may be possible to prove a negative proposition such as 'This particular kind of occlusion is *not* the best possible', it is quite impossible to prove a positive one such as 'This particular kind of occlusion *is* the best possible', since a better one might at any time be discovered. It is therefore in conformity with the highest traditions of research that in the pursuit of some better way to solve a problem the research worker, whether scientist or clinician, should continually seek to question the value of such results as have been obtained (whether by himself or by somebody else) and it is in this tradition that Hamish Thomson has approached his formidable task.

Chapter 1

Terms, influences and concepts

THE functions of the masticatory system are more varied than its name implies. In addition to eating and drinking the system provides for speaking and singing, for smiling and snarling and all the expressions which between them lie. Then there is fighting, loving, tasting, touching, looking handsome and venting rage. There is the dry mouth of fear and the watery anticipation of food. There is the mouth breathing of strenuous exercise with the possibilities of tooth clenching. There are the early stages of digestion and the swallow which follows thus initiating the processes of metabolism and nutrition. In the gospel according to St. Matthew (8 : 12) there was to be weeping and gnashing of teeth. And on one occasion when this text was preached a saddened, elderly parishioner exclaimed, 'Them as 'as 'em, gnash 'em'. And so to *occlusion* which, in other spheres is shutting, closing, or retaining, in teeth is touching. Whether gnashing or nibbling, grinding food or swallowing it, to occlude is to touch the teeth with the teeth.

If the term 'occlusion' can be accepted as contact between the teeth, without food or other agencies between them, it will be obvious that several occlusions are possible depending on the position of the mandible. To be descriptive the term has to be qualified. The occlusal surfaces of the teeth which make contact with each other have occlusal shapes and no two are exactly similar except that those on the left tend to be mirror images of those on the right side of their respective arches. In spite of their dissimilarities there is always one occlusion in which there is maximal contact between opposing occlusal surfaces and this is called *intercuspal occlusion* (IO). In the dentitions called normal (Angle's Class I) all the teeth make contact with opposing teeth by means of cusps, fossae and marginal ridges in the posterior teeth and by incisal edges and lingual surfaces in the anterior teeth. Such a yardstick of normal is said to be limited to 60 per cent of dentitions and the term 'intercuspal occlusion' means the greatest possible contact between the teeth. Thus, in cases of so-called 'anterior open bite' there may only be contact between opposing molars on the intercuspal occlusion. Similarly, in 'posterior open bite' there may be contact only between incisors. The position of the mandible when the teeth are in intercuspal occlusion is called the *intercuspal position* (IP), and the mandible is in intercuspal relation to the maxilla.

The mandible is capable of many movements and positions and a limited occlusion is possible in certain of its positions. Thus the terms *lateral occlusion*, *protruded occlusion* and *retruded occlusion* are used to describe the contact between the teeth while the mandible is in lateral, protruded and retruded occlusal positions. While in these positions the mandible is in lateral, protruded or retruded relationship to the maxilla.

Lateral and protruded occlusions may occur at several lateral and protruded positions of the mandible but usually one is chosen when required. The *retruded occlusal position*, however, is constant and is usually limited to one contact on each side between the furthest back teeth. This contact will change, however, with the loss of those teeth or the alteration of their occlusal surfaces. This occlusion is also referred to as the *retruded contact* (RC) and provides a guide for the mandibular movement on the retruded axis. Retruded contact can be experienced by pulling the mandible back from IP until the last possible contact is felt. *The Oxford English Dictionary* (1971) classes *retruded* as obsolete but gives it the meaning 'thrust backward'. On the other hand, *protruded* is in current use and means 'thrust forward'. It is hoped that the dental profession may continue to revive this neglected partner of protruded. For one reason the words have a common derivation (*trudere*, to thrust) and for another they may jointly help to replace the vague and abused 'centric' and 'eccentric'.

The case against centric

Centric occlusion is a synonym for intercuspal occlusion and suggests that the teeth or the mandible are centrally placed in occlusion. This is not descriptive of the teeth or the mandible, neither of which can be said to have central positions or relationships. While the term 'intercuspal occlusion' may not imply maximal contact between the teeth it does describe occlusion between cusps and does not presume to indicate a position. 'Maximal occlusion' would be a better term but intercuspal is widely enough used to prevent the need to introduce a new term. Intercuspal occlusion, therefore, indicates maximal occlusion irrespective of the position of the teeth or of the mandible. Centric occlusion suggests too many misleading possibilities.

Centric relation is a synonym for the retruded relationship of the mandible to maxilla. Here, the mandible has been thrust backward and there is even less cause for the mandible to be described as centrally placed. Confusion has been added to this term by the introduction of the qualifying adjectives 'strained' or 'unstrained' and no one seems certain which should apply. For some people the thrust backward may induce a feeling of strain and for others the thrust is not possible because of tired or stiff muscles. In order to reach it effort is required by healthy muscles and the relationship is useful because, with healthy muscles, it is reproducible. Centric relation has also been described as the backmost, midmost and uppermost positions of the mandibular condyles which describes the retruded relationship of the condyles to the glenoid fossae but adds confusion to the abused centric. By the same reasoning, 'eccentric' cannot be helpful, and 'eccentric excursions' may well provoke mirth. As a noun *centric* does little credit to a learned profession and causes further confusion to its practitioners. It is true that Humpty Dumpty said, 'When I use a word it means just what I choose it to mean—neither more nor less'. But this does not serve the needs of communication in a difficult subject.

Occlusion and articulation in mastication

Occlusion is contact between the teeth and refers to the moment and place of contact and not to the teeth themselves. It is visualized with the mandible stationary and this is not a natural function. All occlusal positions are moments of contact in a series of movements of the mandible and the term *articulation* is given to the contact that exists between the teeth while the mandible is moving. Occlusion and articulation are usually seen as tooth contacts in the empty mouth and are used for purposes of diagnosis and treatment of the dentition. The incidence of occlusion and articulation during mastication will be discussed several times throughout the text but the only time when contact takes place for certain is during the act of swallowing food or saliva. And even this occlusion can be avoided without harm if the food is well chewed. The study of occlusion is, therefore, faced with the paradox that occlusion is not necessary for mastication. This apparent contradiction is based on the strict definition of occlusion as contact between the teeth. This is not to say that teeth are unnecessary for effective mastication. On the contrary, the more complete the dentition and efficient the occlusion the less the teeth need touch. Food is most efficiently masticated between well-formed cusps which slide past each other while only the bolus makes contact with the teeth. The less the teeth touch during mastication the more efficient will be the functions of the masticatory system and the healthier its tissues.

Occlusal function, parafunction and dysfunction

With these thoughts in mind the term *occlusal function* is introduced to mean the contact that exists between the teeth and between the teeth and food during the functions of mastication and swallowing. The term *parafunction* (wrong or irregular function) is also introduced to mean the contact that exists between the teeth in the empty mouth during the habits of clenching, tapping, grinding or sliding the teeth together and of holding or chewing pencils, pipes and other outside agencies. Parafunction is preferred to *bruxism* which, though widely used, implies forceful occlusion and an associated disturbed emotional state. *Dysfunction* in the masticatory system is defined as functional movements of the mandible which cause a disturbance or disorder (*see* p. 127) in the system.

Retruded condyle axis (hinge axis)

One further group of terms and definitions is mentioned and this concerns the retruded occlusal position (or retruded contact) and the movements to it and from it. While the mandible is retruded (thrust backward) it is capable of an arc of movement about an axis which runs through its condyles. This is called the *retruded condyle axis* (RCA). If the masticatory muscles are free from disability the midpoint of the lower incisors can move on an arc for a distance of up to 20 mm. (Posselt, 1952) about this condyle axis. This is the *retruded arc* having as its centre the retruded condyle axis (RCA). As the teeth occlude on the retruded arc there is usually one contact on each side. The mandible then moves forwards and upwards to the intercuspal position. During this movement the inclined surfaces of the teeth first in contact maintain articular contact. Conversely, the mandible can slide backwards and downwards from IP to RC. With healthy muscles the relationship between the mandible and maxilla on the retruded arc is reproducible and this relationship is of great value in diagnosis and treatment of occlusal disturbances as will be evident throughout the text. As has been pointed out, the alternative term used for all mandibular positions on the retruded arc is *centric relation* to the maxilla. The retruded condyle axis is also known as the *terminal hinge axis* or *hinge axis*.

Retruded intercuspal occlusion (IP at RC)

It is seldom that intercuspal occlusion exists on the retruded arc but the opinion is expressed that this does take place in childhood and that subsequently the permanent teeth move forwards as they develop. The retruded arc and axis remain unchanged but the IP of the mandible has moved forwards. Thus it can be said that all adult intercuspal positions are habitual and are in a state of potential change as teeth wear and become lost. This tendency to forward movement of the teeth is known as the *anterior vector of force* and support for the existence of this movement is to be found in the interproximal wear that can be seen in the extracted teeth of adults. An extension of this forward tooth movement throughout life is the belief that, sooner or later, the front teeth will move forwards or will be worn by parafunctional grinding.

On this topic Ingervall (1968) has reported from a study of 42 children (mean age 11 years 3 months) that there was a reproducibility of retruded contact and intercuspal position when measured in the sagittal plane. Thus if IO occurs on the retruded arc in childhood it must occur before the age of 11. However, this hypothesis remains to be proven.

Aspects of study

The study of occlusion involves the student not only in the shapes and relationships of the teeth but also in the positions and movements of the mandible that provide the relationships. It involves a separation between occlusal function and parafunction and the effects which they may have on the tissues of the masticatory system. The student will be required to transfer his attention away from the teeth and attempt to understand the muscles and neuromuscular function of the system so that he can appreciate the activities of the muscles which provide jaw movement and the consequent contact between the teeth. Movement of one bone in relation to another is not possible without a joint, and a study of the mandibular joint tissues and their function will also be made in order to assess the relationships between the mandibular joints, the musculature and the teeth in function.

Occlusion and gnathology

By some dentists occlusion is considered to mean reconstruction of the dentition by crowning all its teeth or adjustment of them by grinding. These procedures are associated with costly articulators which are a source of fascination to some dentists, objects of adverse criticism to others, and of great value to those who know how to use them. This aspect of occlusion has been abused by both practitioners and critics, but it has a part to play in the treatment of a minority of patients for whom the alternative is dental and sometimes mental breakdown. The part has to be played by an expert, however, and he is not easily trained. This is a reference to the subject of *gnathology* which, in its simplest meaning, is the study of the jaws, especially their alveolar processes. In dentistry this study began with attempts to transfer the movements of the mandible to instruments which could be adjusted to copy them and the names of McCollum, Stallard, Stuart and Granger will always be associated with its origins. After fifty years gnathology has prospered and, although inevitably associated with affluent patients because its applications are time consuming and costly, it has provided methods of diagnosing and treating disorders of occlusion which no other approach to these problems has solved. Gnathology and its procedures, therefore, form an integral part of the study of occlusion.

Occlusion, particular and general

It has been pointed out that occlusion is contact between the teeth and this definition is necessary when separating occlusal contact from occlusal function and articulation. The term 'occlusion', however, has broader implications which class it as a subject for the study of tooth contacts, both stationary and mobile, both functional and parafunctional, of the tissues that provide these functions, of the disturbances that can happen to the tissues and of the treatment procedures devised to restore them to health. Occlusion, thus enlarged, provides mastication for the masticatory system and an essential part of nutrition and health. This system also includes tissues which take part in the functions of digestion, respiration, speech, facial expression and the transmission of affection. As in all other human systems the tissues and functions of the masticatory system are subject to adaptation, abuse, wear, ageing and disease. Occlusion, is therefore, a changing condition and the responses to change vary between healthy adaptation and total disorder.

INFLUENCES AFFECTING THE DENTITION AND OCCLUSION

The teeth and supporting tissues develop as a result of genetic influences which do not always provide for health and adequate function. The size and number of teeth are not always accommodated in the bones provided for them. The result is overcrowding and this can promote caries, lesions of the interdental epithelium and periodontium, and disturbances of the occlusion, all of which may be inter-related. The masticatory and orofacial muscles and the nervous function which controls them behave according to endogenous patterns and respond to innumerable stimuli in order to provide the movements required in the system. These movements often have to be protective and can be harmful for various reasons. The system is subject to systemic, dietetic and emotional influences and to surgical and restorative procedures which are not always helpful in providing optimal function. Genetic and environmental factors, nature and nurture, play their part in the health of the masticatory system and, in particular, of the occlusion.

THE DENTITION IN EVOLUTION

The place which the dentition occupies in the evolution of man has some connexion with the study of occlusion. The adoption of the upright posture was the first and major change in the animal skeleton which led to the evolution of man. This necessitated profound changes in the structure and function of almost all parts of the body. The heart had to pump blood against gravity to the head, neck and arms. The pelvic girdle had to transmit the weight of the head and trunk to the legs; the head and trunk had to support themselves and the adaptive problems which this provided are much in evidence today for which there is no better example than man and his aching back. The forelimbs became arms and many functions for them were found so that the upright species could survive. With man came the enlarged brain and, among many other developments, the consequent adaptive refinements of his arms and hands.

The loss of bodily speed and the ability to fight were thus replaced by skills, and manufactured weapons took the place of teeth. In addition, tools for agricultural and domestic crafts were evolved and the phenomenon of cooking further reduced the need for teeth. Thus, whereas the forelimbs found other functions to perform the teeth did not and it can be argued today that they are vestigial tissues.

With the development of cooking came the refinement of food. Eating became a pleasure as well as a requirement, and a discerning palate became a a symbol of man's prestige in society as well as one of his chief enjoyments in living. The refinement of food together with certain bacteria in the flora of the mouth led to the disease of caries. The discomfort and loss of teeth which this disease caused gave rise to further refinement of food and the vicious cycle which we know today developed. Thus, after perhaps two million years since the upright posture was adopted, the dentition was relegated to the function of mastication and even this role can be considered unnecessary. Certainly, the species can survive without it.

This diminishing function of the dentition can be used to explain the non-adaptive part played by the teeth during the past two million years of man's evolution. Apart from the inevitable increase in the range of variation of almost all human traits and tissues, including the teeth, no changes have taken place in the dentition which suggest that it has had to adapt to the environment. Its nature has remained unaffected by nurture except to bow to disease.

The dentition today

These observations are accepted by the public and dental profession alike, partly with cynicism and partly with individual hope for his own dentition, his own practice. Certainly, the British public has made a brave attempt in the past twenty-five years to look to its teeth, and the profession has responded with millions of fillings. The value and comfort of a healthy mouth are unquestionable assets for speech, appearance, the exchange of affection and for the full enjoyment of eating. The disease of caries is within sight of cure, the diseases of the periodontium can largely be prevented by orthodontics and hygiene, and the outlook for the dentition, however vestigial, is good. There is, however, a problem in the otherwise healthy mouth to be solved and this concerns the behaviour of the teeth in contact with each other.

Perhaps the diminishing needs for this fully developed system have led to the development of extra-masticatory functions (parafunctions) or simply, clenching and grinding habits common in the empty mouth. These can emanate from minor upsets in the central nervous system and may be stimulated by minor disturbances between the teeth. Whatever the cause this irrelevant muscle activity may be seen as a replacement for natural masticatory function or an expression of emotional tension. The alterations to tooth contacts which may be the cause or the effect of this activity make the diagnosis and treatment of occlusal disturbances an essential part of dental practice today.

Life can be sustained without teeth but contemporary man finds them a desirable if not an essential part of his digestive and emotional life. There are those who become preoccupied with the function of their teeth and who are willing to spend excessive time and money on their maintenance; and there are those who look on the loss of teeth as a welcome relief from pain and disease. Between these extremes are the dentists and their patients who look upon mouth health as an integral part of general health and who place a high value on comfort and efficiency in function and a good appearance of the teeth. For them, good occlusal function is a justifiable requirement, one which is manifest by minimal awareness of teeth and the occlusion between them.

CONCEPTS AND PRECEPTS

If a *concept* is a general belief representing a class of ideas or objects and a *precept* is more in the nature of a forthright maxim then there are some of both in the study of occlusion. The variables of human behaviour were never more manifest than in the masticatory system and it is hoped that the concept will be more in evidence than the precept. Some of the beliefs on the topic of tooth contact and function will now be expressed with a view to providing an outline for the text.

Occlusion is optimal when minimal. This is more a precept than a concept but it provides the keynote of the composition which follows. Perhaps it is too much to ask of man that his teeth occlude only when he swallows. However, this is the command which will help to maintain the stability and comfort of his masticatory system and ranks in importance with all other preventive measures. This precept implies a complete dentition with teeth in minimal surface contact and minimal contact in time.

The natural position for the mandible not in function is with the teeth parted. A common misconception among patients is that the teeth should be in contact when not in use. This supports the previous precept and constitutes an irrelevant muscle activity which will be discussed in Chapter 3. It will be proposed as a treatment measure for the mandibular dysfunction syndrome in Chapter 13.

Cusps are for function and not wear. The belief that cusps are there to be worn off is refuted. Intercuspal occlusion between the ridges that make up the cusps and the opposing ridges which make up the fossae should be on three sides and of minimal area. Thus may food be shredded and the mandible stabilized for the swallow. Worn, flattened cusps lead to inefficient chewing and an insecure intercuspal position which in turn promotes parafunctional movements. The shapes and occlusion which maintain this function will be described in the last section of Chapter 2.

Occlusal positions and articular movements are the product of muscle activity, the shapes of the teeth and the function of the mandibular joints. The features of the teeth, muscles and joints which are relevant to the study of occlusion will be described in Chapter 2 and the neuromuscular function which provides efficient movement will be the subject of Chapter 3. Some of the possibilities for abnormal muscle function will also be outlined in Chapter 3.

The positions and movements of the mandible provide the basis for understanding occlusal function. These can be classed as a series of reproducible or habitual positions and a similar series of movements. Analyses of these movements and positions form an essential part of diagnosis and treatment of occlusal disorders. Mandibular positions and movements will be the subject of Chapter 4.

Articulation is undesirable in occlusal function of natural teeth. The teeth should be free from deflective interferences in the empty mouth. Emphasis has been placed on the classification and requirements of this phenomenon and the care given to its creation in the natural and artificial dentition should result in its minimal use. In the majority of natural dentitions there is neither need to classify articulation nor indications for correction. When the need does arise care should be taken to ensure a clear objective. This topic will be discussed in Chapter 5.

The forces acting on the teeth arise from muscles through the media of food, outside agencies and opposing teeth. The response by the teeth is either by omnidirectional movement and recovery or by reposition. These phenomena will be described in the first section of Chapter 5.

Mastication is best achieved by well-shaped teeth which shred food but do not themselves touch. This repetitive theme is discussed in Chapter 6 and includes the topic of tooth contacts during mastication. The phenomenon of adaptation based on an understanding of neuromuscular function is also included and will reappear many times since on it depends the healthy response of the masticatory system to the various functions it performs.

The articulator provides a means of copying mandibular positions and movements with varying degrees of accuracy. Articulators have been variously classified according to their ability to adjust to interocclusal records of jaw relationships made in the mouth. The movements they provide have to be viewed in reverse since it is the upper member (the maxilla) which moves and the various interpretations of jaw movements have to be made against the obvious difficulties of copying the neuromuscular system. This will be the subject of Chapter 7.

A *disturbance* of occlusal function is an alteration of its established function and a *disorder* is a pathological response to a disturbance. These terms are introduced in an attempt to classify the many inter-related conditions which affect the occlusal relationships between the teeth. These conditions are separated from the treatment prescribed for them in the text since more than one disturbance is often involved and treatment is sometimes general rather than specific. The outline of disturbances and disorders occupies Chapter 8 and treatment has to be sought later in the book.

Analysis and diagnosis are the basis of treatment and can provide an endless source of interest, questions and sometimes disillusion to the practitioner. In the abuses of occlusion he can recognize disturbances which require warnings to his patient and the need to prevent disorders. And in disorders he can provide treatment based an analysis and diagnosis. Of such is the content of Chapter 9.

All restorations involving the occlusal surfaces of teeth require a consideration of occlusion, articulation and occlusal function. Whether required to retain existing good function or to correct harmful or lost function restorative dentistry should be directed at integrating the functions of the teeth with those of the masticatory system as a whole. From the simple amalgam filling to the reconstruction of the dentition the patient should be permitted to eat comfortably and to be unaware of his teeth. These are the objectives in Chapter 10 for the natural teeth and in Chapter 11 for the artificial dentition.

Occlusal adjustment of the natural teeth is indicated where cusp interferences cause a deflection of the mandible leading to an altered intercuspal position. Pathological responses in one or more of the tissues of the masticatory system may provide the need for treatment. There are indications and contra-indications which should be carefully observed and the procedures used should be based on a carefully developed treatment plan. The hasty or haphazard abuses of this treatment measure can be harmful to the teeth or musculature and it should not be forgotten that dental enamel is irreplaceable. This is the subject matter of Chapter 12.

Treatment of occlusal disorders is based on an analysis of signs, symptoms and pathological responses. Procedures can extend from complex appliances to simple advice on the correct use of muscles. The mandibular dysfunction syndrome takes its place as a disorder of the masticatory system in this class and, together with certain other disorders requiring specific care, are considered for treatment in Chapter 13.

The case for intercuspal occlusion on the retruded arc as an objective in the reconstruction of the natural dentition or in complete dentures is one which will be advocated from time to time. It implies effort to reach the intercuspal position of the mandible but, because it is a reproducible position, it can be reached each time and therefore is reliable. The reproducibility depends on healthy muscles and the effort required implies that the position will not be maintained for longer than the time required to swallow. Thus the concept of minimal occlusion is upheld. Intercuspal occlusion on the retruded arc requires careful attention to a secure occlusion between cusps and opposing fossa. Any flatness of cusps will produce a tendency to slide out of intercuspal occlusion and to promote parafunction. In the reconstructed natural dentition this tendency is prevented by the development of articulation in the anterior segment only for all articular movements away from IP. This causes parting of the posterior teeth (disclusion) and discourages further articular movements. This is not so simple a task in complete dentures where balanced articulation is often necessary for reasons of stability. These concepts will be discussed in Chapter 5 and in the chapters on treatment procedures.

Comment

The objective in any health measure is to prevent disease. The establishment of good function is an essential requirement in the prevention of occlusal disturbances in the masticatory system. Through the adolescent years when the dentition is developing the dentist has an obligation to ensure freedom from caries and periodontal diseases, to provide a pleasing appearance of the teeth, and to establish hygiene as a prevention against recurrent diseases. He also has the responsibility to provide good occlusal function and to prevent habits, both functional and parafunctional, which may disturb the various tissues of the masticatory system. Good function is good prevention.

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Chapter 2

The muscles, joints and teeth

OCCLUSION of the teeth can be expressed as the product of muscle activity, the shape of the occlusal surfaces and the movements permitted by the mandibular joints. The formula $O = M \times S \times J$ is perhaps an oversimplification of this complex and often automatic action, especially when appreciating the nervous function which controls it and which provides for its efficiency through a lifetime of change. The muscles, the shapes of the teeth and the joints are the tissues which the clinician has to know and understand when attempting to diagnose and treat disturbances of occlusal function. The muscles are subject to disturbances, the teeth to loss and change of shape and the joints to disease and dysfunction. Some relevant features of these tissues will be described and discussed which may provide a stimulus to return to the library, to the dissection room or to the mouth with renewed interest.

THE MUSCLES OF MASTICATION

There are several features of muscle function which may help the understanding of the part played by the muscles in occlusal function. Firstly, all the muscles of mastication are in function (either contracting or relaxing) in all movements of the mandible. Secondly, there is a wide area of origin of some of the muscles compared with the area of insertion. This fact combined with the ability of groups of fibres within a muscle to contract make possible innumerable variations in the range of movements. Thirdly, muscles conform to patterns of movement but these are subject to alteration by adaptation, disability and disease: they can be trained, when healthy, to reproduce movements; they will fail to do this when stiff and sore. Fourthly, muscle activity is limited by ligaments but is not guided by them. Finally, muscles and the joints about which they provide movement are tissues and not machines and whereas the movements can be made with precision they are subject to alteration by stimuli, both cerebral and reflex. They are, therefore, unreliable machines and no better example of this feature, in another field of function, is the golf swing so often seemingly mechanical yet so seldom reliable as such.

The muscles of mastication and the movements which they produce can be studied in a number of ways. Electromyographic tracings of the discharge of electrical activity give precise information on degrees of contraction from localized areas of muscles but too much is perhaps made of this source of information when so little muscle activity is recorded. Dissection studies still provide new information and allow deductions to be made on mandibular movements. Histological examinations reveal muscle-fibres in new directions and new places. For the clinical student interested in discerning how the mandible moves this or that way, the use of detailed descriptions with a skull to hand is well tried and worth while. This method is also helpful when attempting to visualize the mandible in function, when dealing with a tough bolus of food or, say, chewing gum, biting a piece of thread, or rotating on its retruded condyle axis.

The muscles of mastication occur bilaterally in pairs. Each muscle runs in a different direction and at different levels. Thus a wide variation of movements is possible. Some of their features relevant to the functions they perform will be described using skull photographs and related diagrams. No attempt is made to present a detailed description of these muscles nor of their nerve and blood supply.

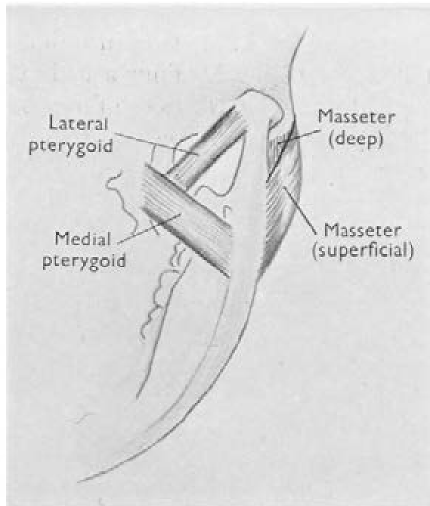
The masseter and medial pterygoid muscles

These are generally called the closing muscles and details of their sites of origin on the skull and insertion on the mandible can be found in any of the standard texts. When viewed from below and behind the skull (*Fig.* 1), it can be seen that

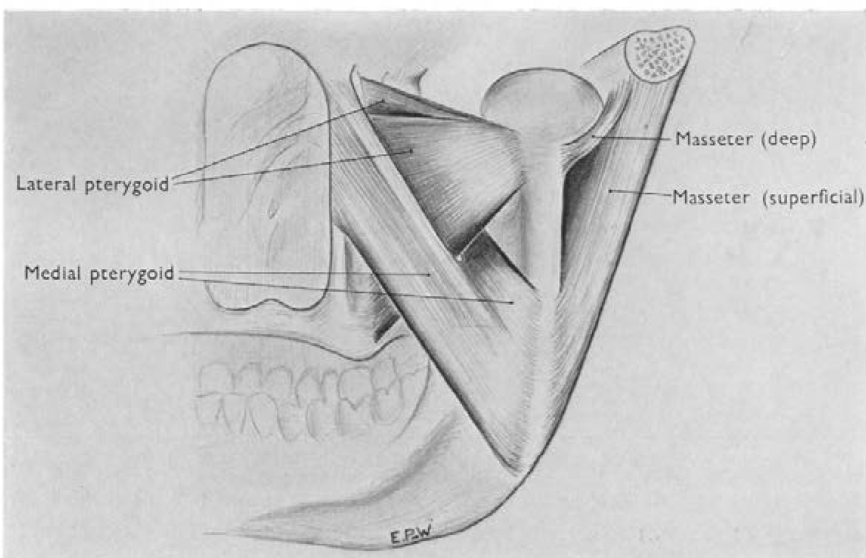
a

Fig. 1. *a*, Skull and mandible from below.

the contraction of all four muscles will result in an upwards pull of the mandible. The fibres of the masseters, however, run slightly inwards as well as downwards from the zygomatic arch to the outer surface of the ramus while the medial pterygoids run outwards as well as downwards from the medial surface of the lateral pterygoid plate to the inner surface of the ramus but at a more horizontal angle than the masseters. The direction of both muscles is also slightly backward so that equal contraction of both pairs produces a forwards as well as an upwards movement. Stronger contraction of the left medial pterygoid and right masseter will result in an upwards and lateral movement of the mandible to the right. This involves a rotation of the right condyle and, in addition, a lateral shift outwards. This lateral shift is known as the Bennett movement and it takes place in lateral closing movements and in lateral movements from IP. In the right lateral movement the left condyle travels down and inwards and for this to happen the lower fibres of the left lateral pterygoid have also to contract since the medial pterygoids have no fibres running upwards from their origins. This serves to emphasize the point made about all muscles being involved in all movements of the mandible.



b



c

Fig. 1 (*Continued*). *b*, Right mandible from below. Muscles. *c*, Right mandible from behind. Muscles.

Viewed from the side (*Fig.* 2) the fibres of the masseter can be seen running downwards and backwards thus accounting for the upwards and forwards arc of closure of the mandible with a centre of rotation in the region of the condyles.

There are two other features of the masseter muscle which have some clinical significance. Firstly, the muscle has three parts, superficial, intermediate, and deep (Last, 1966). The deep fibres, originating on the inside surface of the zygomatic arch, run slightly forwards and downwards to the region of the ramus below the coronoid process. This can produce a backwards pull on the mandible, aided by the distal fibres of the temporalis, and helps to provide the movement which pulls the mandible into its retruded relation to the maxilla

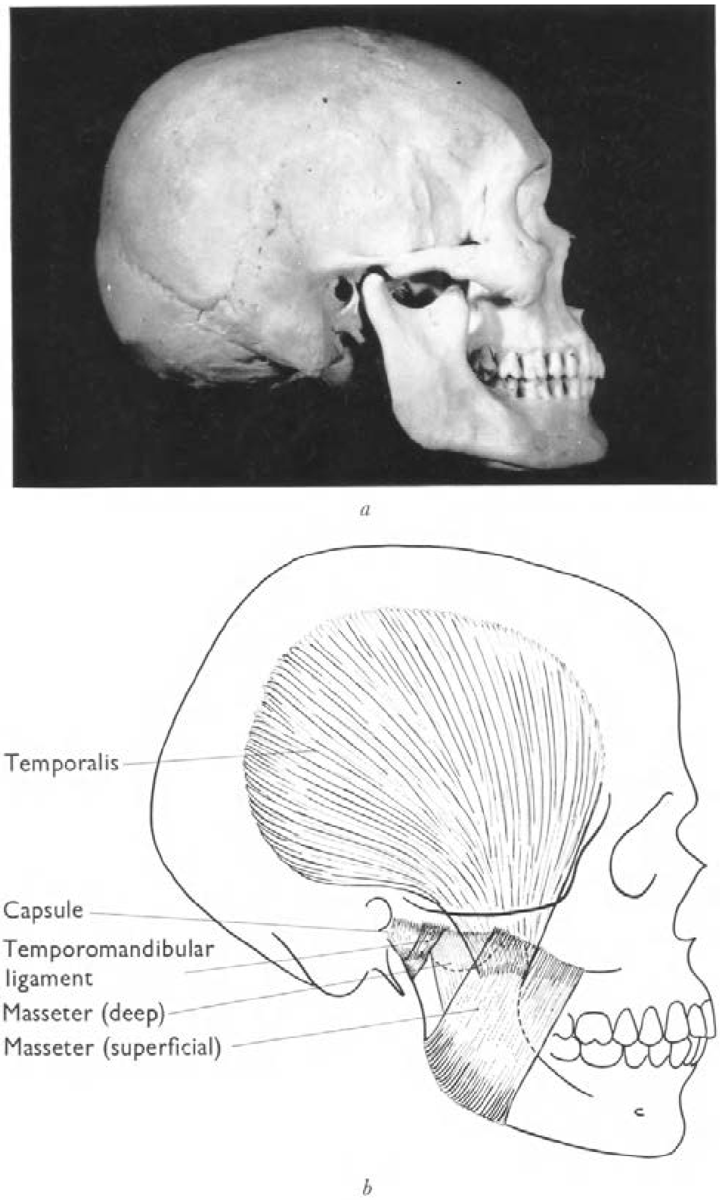
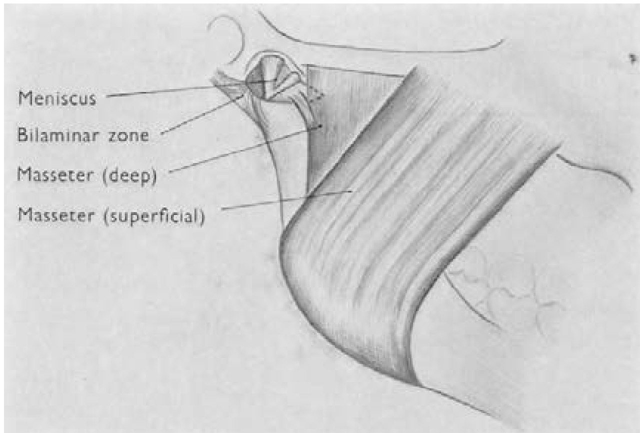


Fig. 2. *a*, Skull and mandible from side. *b*, Muscles, capsule, temporomandibular ligament.

on which the retruded condyle axis rotates. Secondly, there are fibres from the inner part of the muscle which are inserted horizontally into the capsule and meniscus of the mandibular joint. Thus a lateral pull on the meniscus is possible when the horizontal fibres are stimulated to contract. The effect on the meniscus of this contraction is to move it from its usual position on closure and to alter its path of movement on opening. This can alter the relationship between meniscus and articular eminence as the condyle moves forwards and provides a cause of joint click. The variables of condyle and eminence shapes and the number of masseter fibres inserted into the meniscus may explain why this phenomenon



c

Fig. 2. (*Continued*). *c*, Masseter muscle showing fibres from deep layer entering meniscus. Capsule removed.

occurs in some people and not in others. It will be discussed again later in this chapter and in Chapter 7.

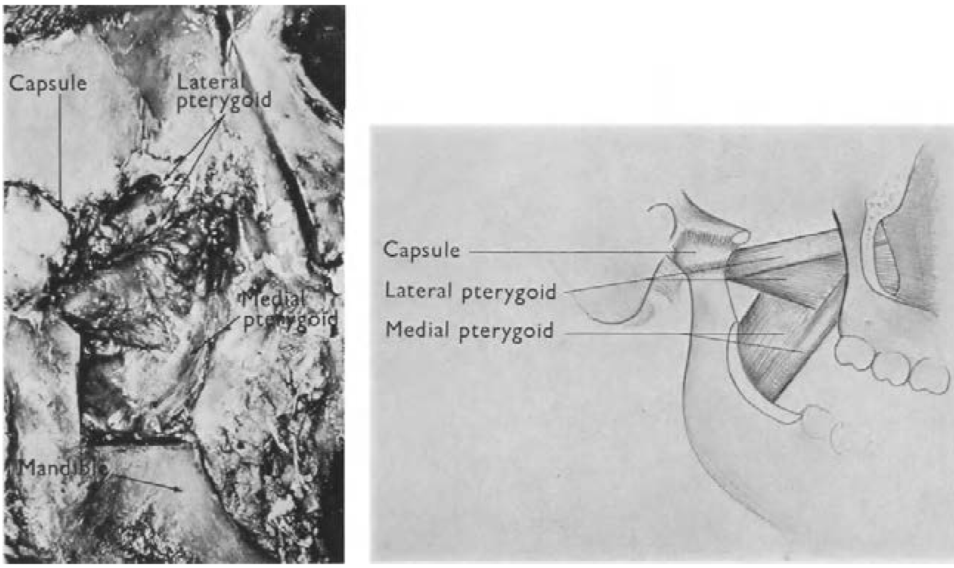
In general, the origins of the masseter muscles are more diverse than those of the medial pterygoids which makes the masseters more varied in the movements they produce. In addition, together with the anterior fibres of the temporalis, they are the muscles which can be seen and palpated in function and this can be helpful in some aspects of occlusal function. The masseter and medial pterygoid muscles are called the power muscles of mastication and can generate considerable force when the needs or abuses of function arise.

The temporalis and lateral pterygoid muscles

These are the muscles which provide for the horizontal movements and positioning of the condyles and mandible as the teeth come into occlusion and for the adjustment to changes of occlusion as teeth tilt, wear and are restored. The *temporalis* muscles spread, in origin, like a fan over the side of the skull (*Fig.* 2) and are inserted into the coronoid process of the mandible providing upward and backward movements of the mandible with less power but with greater possibilities for fine adjustment than the closing muscles. Some temporalis fibres are inserted into the anterior part of the meniscus through the capsule and provide a source of movement for this tissue. Palpation of the anterior fibres in the region of the temples have long been a test of retruded closure of the mandible when registering jaw relationships. If these fibres contract the mandible is in its habitual IP or retruded occlusal positions. If they cannot be palpated in closure there is a protrusive component in the movement.

The wide origins of the temporalis muscles and their relatively small insertions emphasize the control they exert over the position of the mandible and, together with the lateral pterygoids, justify the term 'postural muscles' which has been given to them. This property of control over posture is further emphasized by the ability, mentioned earlier, of groups of fibres within a muscle to contract. Thus they provide fine adjustment of position and movement, both voluntarily and reflexly.

The *lateral pterygoid* muscles, by contrast, have a more restricted area of origin but have an even smaller area of insertion compared with the temporalis (*Fig.* 3). It is a more bulky and therefore more powerful muscle and consists of



a *b*

Fig. 3. *a*, Dissection. Lateral and medial pterygoid muscles. Capsule. Mandible with coronoid process removed. (*Dissection performed by B. J. Parkins, by courtesy of Professor McMinn, Department of Anatomy, Royal College of Surgeons.*) *b*, Diagram. Lateral and medial pterygoid muscles.

two bellies originating on the outer surface of the lateral pterygoid plate and the infratemporal surface of the great wing of the sphenoid bone. The dissection photograph (*Fig.* 3*a*) shows the relatively wide area of origin and emphasizes the power and control which this muscle exerts over the condyle and meniscus. The lower belly runs upwards, outwards and backwards and the upper horizontally in the same direction. Both heads merge into the area of the capsule of the joints and neck of the mandibular condyle. Fibres are inserted into the neck of the condyle, the capsule and into the meniscus itself. A recent investigation by Porter (1970) has shown fibres being inserted into the medial aspect of the meniscus and this feature would seem to be capable of pulling the meniscus in a medial direction.

The lateral pterygoid muscles acting together pull the condyles forwards and downwards and are two of the openers of the mandible. However, they can only pull the condyles downwards and forwards and this movement is also determined by the shape of the articular eminence. When the left muscle contracts, while the other relaxes, the mandible moves to the right. This contraction also helps to pull the mandible bodily to the right and takes part in the production of the Bennett movement.

A significant feature of this muscle is its sole responsibility for protracting the condyles. However, there is no opposing muscle inserted into the posterior aspect of the condyles or menisci in order to retract the condyles and so impart smoothness to the closing movement. This is provided partly by contraction of the posterior fibres of the temporalis and deep fibres of the masseter muscles, both of which are inserted into the body of the ramus, and partly by the relaxation of the lateral pterygoids. This calls for a high degree of co-ordination since the fine adjustment to occlusal positions and articulations (or the avoidance of them) depends on it. Equally, failure to adapt to alterations of occlusion or to an unexpected bolus can cause injury to fibres of this muscle. This has proved a common cause of mandibular joint pain (*see* Chapter 8).

The lateral pterygoid muscles not only play the dominant part in the fast movements of the condyle and meniscus but they seldom have the opportunity fully to stretch and, as it were, rest from their labours. Stretching a muscle is an activity which allows the tension of continuous contraction to ease and is often curative of spasm. In the case of the lateral pterygoids the habitual IP of the mandible sometimes prevents the condyles from retracting fully and it requires a conscious effort to cause the retraction necessary to stretch the muscles. This is a physiotherapeutic function often worthy of prescription (*see* Chapter 13).

The digastric and geniohyoid muscles

These two muscles acting together are depressors of the mandible in a down and backwards direction and provide the chief opening component in the retruded arc movement of the mandible. Along with the stylohyoid and mylohyoid muscles they form the suprahyoid group of muscles.

The *digastric* muscle has two bellies, the posterior belly originating from the mastoid notch and the anterior belly from the digastric fossa of the mandible which is close to the lower border. The two bellies are joined by a tendon which is held close to the horn of the hyoid bone by a loop of strengthened fibres of the deep cervical fascia. The length of this loop varies as will the obtuse angle between the two bellies. This may have some effect on the angle of pull on the mandible. The anterior bellies may be joined together making one thick muscle. In order that the mandible be pulled down and back by this muscle the hyoid bone has to be fixed and this is achieved by the opposing contractions of the stylohyoid and infrahyoid muscles.

The *geniohyoid* muscles run down and backwards from the anterior end of the mylohyoid ridges and are inserted into the upper border of the hyoid bone. The insertion is wider than the origin and the two muscles lying together have a fan shape. Their action is to depress the mandible and it is difficult to imagine their acting without the digastric muscles. When the mandible is fixed in IP their contraction will raise the hyoid bone which occurs during deglutition. These two pairs of muscles can be palpated in contraction when the mandible is pulled down and back and occasionally a knot of spastic muscle can be felt following a disturbance of muscle activity.

MOVEMENTS OF THE MANDIBLE

After visualizing the muscles on the mandible and skull it may be difficult to imagine how it is that such precise and sometimes powerful movements can be carried out when the condyles seem to fit so imprecisely into the glenoid fossae. As Sicher (1964) pointed out, however, the movements of the mandible are directed by the play of the muscles and not by the shape of the bones nor by the ligaments as in many other joints.

There are essentially two movements of the condyles which account for the varied and three-dimensional mandibular movements of the mandible. These are the *rotations* and *translations* of the condyle axis. The opening and closing rotational movements are brought about by the depressor and elevator muscles and the translatory movements by the protractor and retractor muscles. It is repeated, however, that all mandibular movements involve all its muscles, either contracting or relaxing.

Opening and closing

On opening, the mandible rotates around a transverse axis which passes approximately through the centres of the two condyles and this is achieved by the action of the anterior digastric and geniohyoid muscles. At the same time the condyles are protracted by the lateral pterygoids and the two movements continue jointly until the required amount of opening is reached. The extent of the rotatory opening is considerable and in the healthy mouth three fingers can be inserted between the incisor teeth at full opening. As the impulse to close is received the depressors and retractors relax and the elevators begin their contraction. The condyles move back rapidly as the temporalis muscles contract. As closure approaches, the movement is slowed by the reciprocation of lateral pterygoids and temporalis when the rotation of the condyles is completed. The two elevators play the main part in this movement but the adjustment to precise closure or to the avoidance of occlusion in the chewing cycle is left to the two horizontally acting postural muscles. The movements of the meniscus in opening and closing will be described in the next section.

The opening and closing movements of the mandible, whether for mastication, speech, or other activities, all take place within a space limited by the ligaments running between mandible and maxilla and by the shape of the bones themselves. This aspect of jaw movements will be further discussed in Chapter 4 and will be described as the parcel of mandibular movement. Meanwhile, emphasis is given to the feature of muscle activity which permits a wide range of movement through two joints.

Retruded opening and closing

With effort and patience the mandible can be pulled back and made to rotate about an axis through the condyles which is rotational and involves no translation. This may require assistance from the dentist but can usually be practised voluntarily provided the muscles are healthy. The backward pull is achieved by the posterior temporalis fibres and deep belly of the masseter with assistance from the digastrics and geniohyoids. The latter two muscles will then effect opening on the retruded arc and pull the point of the chin down and backwards for a distance of up to 20 mm. Closing on this arc is achieved by the elevator muscles but with posterior fibres of temporalis and deep fibres of masseter exerting a backwards pull. As will be evident throughout the text, this movement on the retruded arc is useful in the diagnosis and treatment of occlusal disturbances because, with healthy muscles, it is reproducible.

Lateral shift (Bennett movement)

When the mandible moves to one side or the other, either in opening or closing, the condyle on the side to which the mandible is moving rotates minimally and moves slightly forwards, downwards and laterally. If, for example, the mandible moves to the right the left condyle moves downwards, forwards and inwards while in contact with the meniscus and eminence. The right condyle is allowed only a small rotatory movement because its lateral pole is limited by the temporomandibular ligament and cannot move backwards for more than 1 mm. (Sicher, 1964). It therefore moves laterally and slightly forwards and downwards due to the combined action of the left lateral and medial pterygoids and to the contact that exists between the condyles, menisci and opposing fossae. Sicher describes this as an evasive movement and the condyle as resting. Certainly, the force causing the movement comes from the left side and the right condyle moves as it can within the limits of its ligaments. If this movement is inhibited or altered by unexpected tooth contacts the pattern of muscle activity may be altered unfavourably. It should be remembered that this is only one component of an opening or closing movement. As will be described in Chapters 4 and 7, all mandibular movements can be analysed as deriving from three centres (axes) of rotation in each condyle region.

Bennett (1908) made his observations on this component of mandibular movement using bent wire and candle-light and they remained in the gloom of insignificance for twenty years. Pantographic tracings of the mandible then revealed that they still existed and have some significance in the analysis of tooth articulations and restorative dentistry. This asymmetrical lateral shift has now been separated into *immediate* and *progressive* components as observed on pantographic tracings (*see* Chapter 7). These tracings are extensions of the movement and take place with the teeth parted but they are reproducible and represent an extreme or border movement limited by ligaments. One wonders what Sir Norman Bennett would have thought of it all.

THE MANDIBULAR LIGAMENTS

Muscles move and ligaments limit. In forming part of the attachment of the mandible to skull the ligaments provide the borders of the circumductory mandibular movements.

The fibrous capsules of the joints (*Fig.* 2) constitute the chief ligaments particularly the outer thickened portions which form the *temporomandibular ligaments*. The capsules are thin fibrous structures attached to the temporal bone at the anterior, medial and lateral boundaries of the articular tubercles and fossae. They are inserted into the necks of the condyles and are continuous with the menisci and with the loose connective tissue behind the menisci. The thick, lateral portions of the capsules forming the temporomandibular ligaments arise from the zygomatic processes of the temporal bones and run down and backwards to narrow insertions at the condylar necks. These ligaments are thus fan-shaped and act to limit various movements of the mandible, particularly the retrusive, when the condyles are, as it were, cornered in their most retruded and superior relationships to the skull. It is in this relationship that the mandible can be made to rotate on its retruded arc. These ligaments also serve to protect the posterior extensions of the menisci which are vascular and innervated and might otherwise be subject to damage by the condyles. There are nerve-endings within the capsules which relay information on positions and movements of the condyles to the central nervous system.

The accessory ligaments are the sphenomandibular and stylomandibular and Sicher refers to them as 'so-called' since neither has any functional part to play in the mandibular articulation. The sphenomandibular ligament runs from the spine of the sphenoid bone and has a fan-like insertion into the lingula, the lower border of the mandibular foramen and up to the lower border of the mandibular neck. The stylomandibular ligament runs from the styloid process and stylohyoid ligament to the region of the angle of the mandible. The majority of its fibres continue into the fascia on the medial surface of the medial pterygoid muscle and would therefore seem to share in the activity of this muscle perhaps by limiting its stretch.

Mention is made of a ligament attaching the malleus ossicle in the ear to the capsules of the mandibular joint. Pinto (1962) established the presence of a 'tiny ligament' connecting the malleus, the capsule of the joint and the meniscus. He described it as being inserted into the neck of the malleus immediately above the anterior process and spreading out cone-shaped, running forward, downward and laterally to be inserted into the medioposterosuperior part of the capsule and meniscus of the joint. Based on this article, Christensen (1969) suggested that as spasm of the lateral pterygoid can interfere with the function of the meniscus it could interfere with the action of the malleus. He suggested that the malleus would be prevented from vibrating normally, resulting in a loss of hearing. This requires confirmation by anatomists and embryologists but it would seem unlikely that the malleus which vibrates in one plane would be inhibited by a tiny ligament which is attached at right-angles to this plane.

The temporomandibular ligaments play a passive part in mandibular movements and are of value when transferring jaw positions and movements to an articulator.

THE MANDIBULAR JOINTS

The joints have been said to permit movement and whereas they do not promote it they guide it from the information of nerve receptors within the capsule and from the shape of the bones comprising the joints. The joint tissues provide for smooth movement of the condyles and discs but they are subject to disease and dysfunction as are other joints. Cine-radiographic films of these joints in function demonstrate the speed with which the condyles move and it is obvious that proprioception and lubrication are properties which the joints possess in good measure. This is not the text for detailed descriptions of the joints but some of their features and significances will be mentioned and discussed.

Since his paper in 1948 Sicher has taught and written about the tissues and functions of the mandibular joint to the benefit of the dental profession and has provided information, guidance and caution on deductions made from clinical observations. Rees (1954) described the structure and function of these joints in a paper which has become a standard source of information and is quoted in many books and articles on this subject. From these sources and others the following relevant features are presented.

Anatomy of the condyles

The elongated shape of the condyles and their angled relationship to each other (*Fig.* 4) make mechanical analogies misleading. The analysis of mandibular movements into centres of rotation is acceptable only if it is assumed the movements are reproducible, made by healthy muscles and limited by taut ligaments. Each condyle presents a transverse ridge in front of its summit with the posterior slope from the summit longer than the anterior one. It is this ridge which may become temporarily jammed against the meniscus when the phenomenon of click occurs. The lateral and medial poles of the condyles present bony tubercles just below the articular surfaces to which the capsules and menisci are attached. The anterior surfaces of the necks of the condyles are roughened indicating the tendinous insertions of the lateral pterygoid muscles.

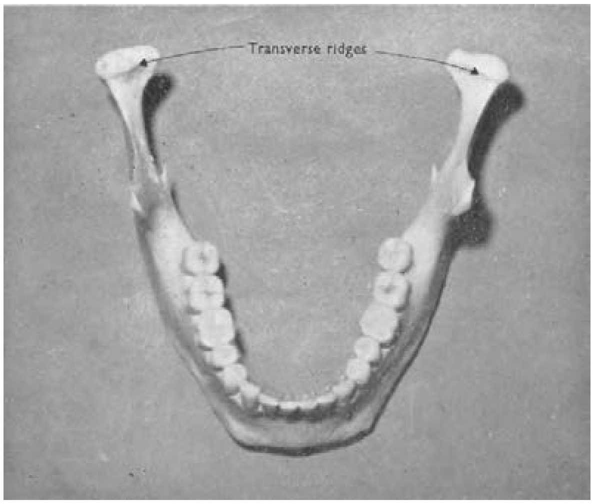


Fig. 4. Mandible. Angled relationship of condyles and transverse ridges.

The glenoid fossae and eminentiae

The hollow fossae (*Fig.* 2*a*) permit a freedom of movement for the condyles but this movement is cushioned by the menisci which fill the spaces and provide continuous contact between the menisci and condyles in all movements. The convex eminentiae are continuous with the fossae and provide a path for the condyles in forward and lateral movements. During these movements the condyles are in unstable bony relationships to the eminentiae and any alteration to the established pattern may result in click or even muscle spasm which is the phenomenon of locking. The shapes of condyles and eminentiae vary between individuals and steep or shallow paths have led to their association with various classifications of malocclusion. This, however, has not received sufficient investigation for proof. Also, a flat eminentia has been claimed to be a cause of condyle dislocations but this, too, is more likely to be attributable to muscle spasm. The translatory condylar movements can be shown to be reproducible by pantographic tracings and while these are made with the teeth parted (Chapter 7) and at a fixed level of jaw separation it would seem to demonstrate that the path of the condyle is determined by the slope of the eminentia.

The interarticular menisci

The division of these fibrous sheets into four ellipsoidal zones (*Fig.* 5*a*, *b*) makes them flexible and allows them to adapt in shape from concave below when the mandible is in intercuspal position to convex below as the condyles glide forwards (*Fig.* 5*c*, *d*, *e*). The *anterior band* is thick but narrow from before backwards: the *intermediate zone* is thin and narrow and provides the flexible

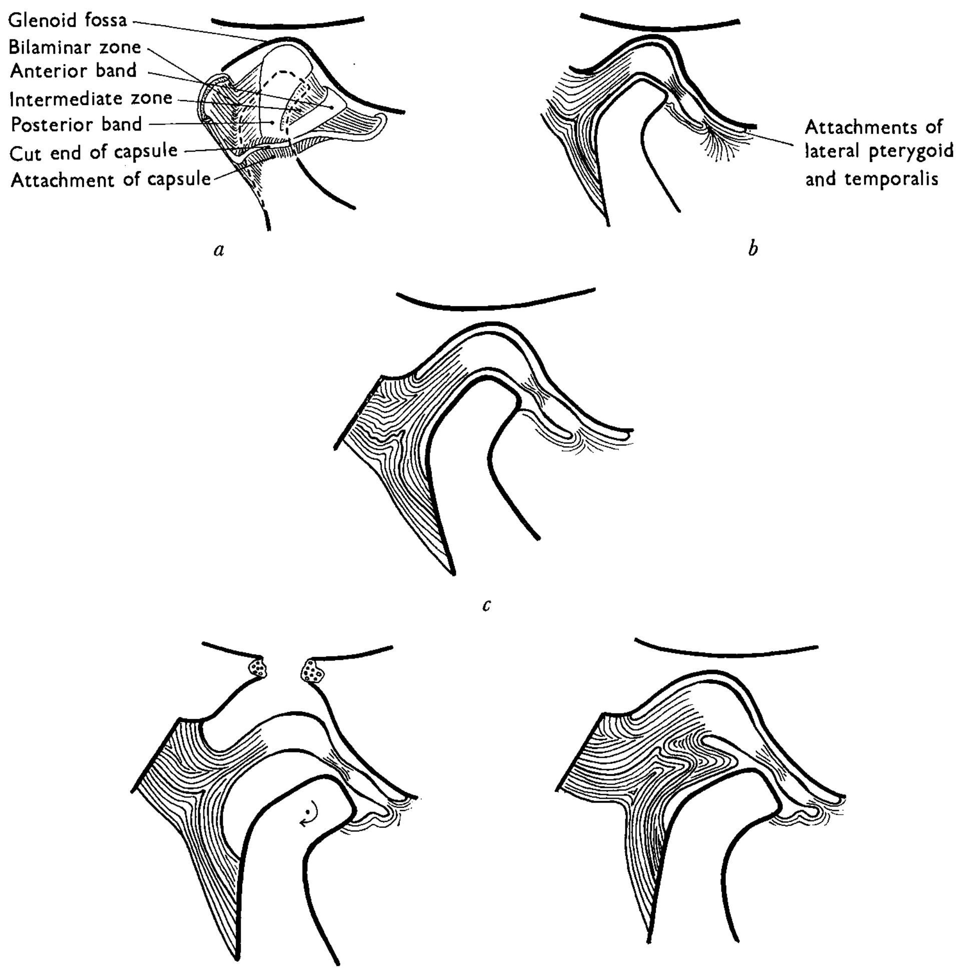


Fig. 5. Mandibular joint. Condyle fossa and meniscus. Opening movement from IP. In living person meniscus remains in contact with fossa and condyle. No air enters the joint. (*After Rees*, 1954.)

element: the *posterior band* is thicker and wider than the anterior band and provides the filler for the condyle–fossa space at IP: the *bilaminar zone* is the distal extension and is attached to the posterior wall of the glenoid fossa and to the squamotympanic suture by its upper stratum and to the neck of the condyle by its lower stratum. The structure of the meniscus is chiefly that of dense fibrous tissue with occasional cells suggestive of cartilage. The upper stratum of the bilaminar zone is composed of loose fibro-elastic tissue and contains blood-vessels and nerves while the lower stratum is mostly fibrous tissue without elastic fibres. This latter differentiation of tissue suggests that the upper stratum is more freely mobile than the lower and moves forward to take the place of the condyle as it moves forwards, while the lower stratum travels with the condyle (*Fig.* 5). The tissues of these zones permit contact between condyle and meniscus without pressure being borne. The menisci are continuous with the capsules and receive muscle insertions anteriorly, laterally and medially.

Muscle insertions

Fibres of the lateral pterygoid merge with the anterior and medial aspects of the meniscus and form a true insertion by tendinous fibres while fibres from the masseter and temporalis muscles, running mostly at right-angles to the main fibres of the muscles, are inserted laterally and anteriorly into the disc. These muscle insertions suggest the possibilities of distracting pulls on the disc during sudden reflex movements and provide further causes for click as the condyle moves forward with the meniscus position altered (*see* p. 144). There are no muscle insertions posteriorly into the disc.

The synovial membrane

This vascular layer of connective tissue lines all structures of the articulation which are not involved in the gliding condylar movements and is found chiefly in the posteriorly placed bilaminar zone. The synovial secretion lubricates the rapid three-dimensional movements of the condyles and discs. The viscosity of this fluid is probably under the control of the autonomic nervous system and therefore is subject to alteration. Any reduction in viscosity of this secretion will lead to frictional resistance within the capsule thus providing a further cause of joint noise (crepitus), inflammatory response and dysfunction. The factual and hypothetical details of this aspect of joint function are explained by Toller (1961).

Movements of the condyles and menisci

The observations of Rees (1954), albeit on dissected cadavers, revealed the possibilities of movement up to a distance of 8 mm. between condyle and meniscus from retruded to full opening. During the forward movement to partial opening the transverse ridge of the condyle moved across the posterior band of the disc. On full opening of the mandible the condyle ridge crossed the anterior band and came to rest in front of it (*Fig.* 5*e*). It was calculated that the total forward condyle movement from retruded to full opening was at least 15 mm. and that consequently the meniscus would move forwards at least 7 mm. on the temporal bone. In other words, the movement of the condyle is greater than that of the meniscus. Another observation made by Rees was that the space vacated by the condyle in its forward movement is occupied by the soft bilaminar zone tissue since there is no air space in the joint cavity. This supports Sicher's (1964) assertion of articulating bones being kept in 'sharp contact' during movement. Finally, the condyle can move in an arc due to its being separated from the temporal bone in retrusion by the thickest part of the meniscus and by the thinnest part when it moves on to the eminentia. It does not have to follow the contours of the eminentia.

The flexibility of the condylar movements and the fact that there are two condyles makes for a three-dimensional space in which any one point of the mandible can move with considerable freedom. It can move from one limit (or border position) to another without going through a central or median position such as the rest position. The presence of teeth, however, provides restrictions to these *circumductory* movements and when this inhibitory effect is associated with parafunctional habits or deflective tooth contacts the muscle activity can itself be disturbed by injury. The joint tissues can suffer through persistent low-grade injury (click and crepitus), through inflammatory or degenerative processes and through severe injury resulting in fracture or effusion into the joint. But in function generally and for the majority of people the mandibular joints permit various and versatile movements throughout the average life span.

The relationship between occlusal function and the movements of the mandibular joints is one of interdependence. The teeth determine the various occlusal positions of the mandible; the joints provide a guide to the movements of the mandible to, from, and between these positions. It could be said that the teeth perform and the joints permit occlusal function and that the comfort and efficiency of this function depend on the neuromuscular control of the movements and the occlusal shapes of the teeth. It is desirable that these shapes conform to the stable patterns of joint and jaw activity and that the joints are not called upon to perform movements to which they cannot adapt.

THE OCCLUSAL SURFACES OF THE TEETH

Neuromuscular activity causes the mandible to move towards the maxilla stimulated by impulses from the masticatory system or the higher centres of the brain. If the objective or result of this movement is tooth contact the shapes of the occlusal surfaces of the upper and lower teeth will determine the position of the mandible during occlusion. Since the occlusion and articulation of the teeth have an effect on the behaviour of the muscles it is necessary to have a knowledge of the shapes (or anatomy) of their occlusal surfaces and to know how they can most efficiently occlude in order to provide occlusal function.

Normal occlusion

Tooth surfaces and relationships will be described as applying to what is generally accepted as normal occlusion. *Fig.* 6 shows the labial and buccal segments in Class I (Angle) relationship to their opposing segments where the key teeth are the first molars. The mesiobuccal cusp of the lower first molar occludes between the upper first molar and second bicuspid. The upper and lower incisors occlude at an oblique angle to each other which is constant within certain limits. This concept of normal has its critics in terms of efficient occlusion and, besides, it is often the exception in contemporary western man. Normal occlusion as a term is of less importance than the need to have an objective for efficient and comfortable occlusal function. A further criticism of the term 'normal occlusion' is that it implies a static relationship between the teeth which seldom exists in function. It is an incident in the swallow as is contact with the ball in a golf swing but as in the golf swing it must be efficient to be effective and preventive of harm. Normal occlusion is therefore a term of reference related to muscle and joint function, to skeletal relationships, and to the effect it produces on the masticatory system.

The incisor teeth

The development of the incisor teeth usually results in occlusion between uppers and lowers at an angle of between 130° and 135° in the skeletal Class I relationship (*Fig.* 7). This angle will vary with the angle between the mandibular plane and one of the fixed planes of the skull, say, the Frankfurt plane

Fig. 6. Skull. Intercuspal position of mandible.

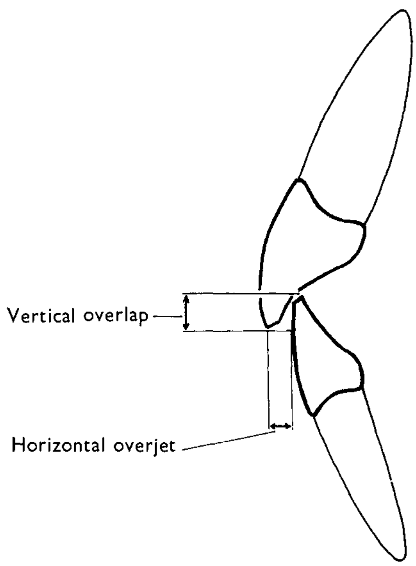


Fig. 7. Vertical overlap and horizontal overjet in incisors.

(*see Fig.* 14*b*, p. 49). The angle is important however, since a pleasing appearance is provided when the angle of the upper incisors to the Frankfurt plane is about 108°. Secondly, it allows a gliding contact between the upper and lower incisors in protrusion. If the angle is greater the buccal teeth will separate on protrusive articulation and if smaller the incisor teeth will separate. The importance of this variable feature will be discussed in Chapter 5.

When the incisor teeth occlude in IP the resultant of force will be forwards tending to displace the upper incisors forwards. This force is balanced by the lip muscles which not only balance the occlusal forces but those of the tongue muscles in function. It should not be forgotten, however, that in intercuspal occlusion the posterior teeth will be sharing the occlusal forces generated. The incisor teeth are thus stabilized in occlusion, in the functions of speech and facial expression and, not least, in the rest position of the mandible.

OVERLAP, OVERJET AND INCISAL GUIDANCE

The incisal edges of the lower incisors contact the lingual surfaces of the uppers on their cingula at intercuspal occlusion. The vertical distance between the incisal edges at this occlusion is called the *vertical overlap*. The horizontal distance between the incisal edges is called the *horizontal overjet* (*Fig.* 7). When the mandible protrudes in articulation the lingual slopes of the upper incisors determine the path which the mandible will follow and the influence on protrusive movement created by the inclination of this slope is called the *incisal guidance*. Together with the variable angles mentioned above these three features of incisor occlusion have some significance when analysing occlusal function and when planning reconstruction or complete dentures. When to these features of incisor relationships is added the variables of lip and tongue muscle activity it is understandable that orthodontists and prosthodontists find occasional difficulties and disappointments in their treatment procedures.

The canine teeth

In addition to their characteristic labial appearance the upper canine teeth have a well marked lingual ridge and cingulum which divide the lingual surface into two slopes. These slopes have significance in occlusion and may provide guidance during articulation with the opposing lower teeth. The distal cusp ridge of the lower canine occludes on the mesial of these two slopes; the mesial cusp ridge of the lower first bicuspid occludes on the distal slope (*see Fig.* 11). The lingual ridge of the upper canine also provides guidance for the articular movements of the buccal and mesial cusp ridge of the lower first bicuspid in protrusion of the mandible and for the cusp of the lower canine in lateral movement to its side. This articular movement has clinical significance in the development of canine guidance in anterior segment articulation (or mutually protected occlusion) (*see* Chapter 5). The lingual ridge and cingulum are not so well marked in the lower canines and this emphasizes their function in the upper which is to divide the occlusion between lower canine and first bicuspid and to provide guidance for their articular movements.

The buccal segments

The posterior or buccal segments will be treated as groups of four teeth although they comprise two different forms of teeth, namely, the bicuspids and molars. Their occlusion and articulation conform to patterns as a group, however, and this justifies their consideration as segments. Drawings of the four upper and four lower posterior teeth can be seen in *Fig.* 8. Each posterior tooth has a varying number of cusps, ridges and grooves and each cusp is at the summit of three ridges and a buccal or lingual surface. There is a mesial and distal cusp ridge descending from each cusp, and a triangular ridge descends

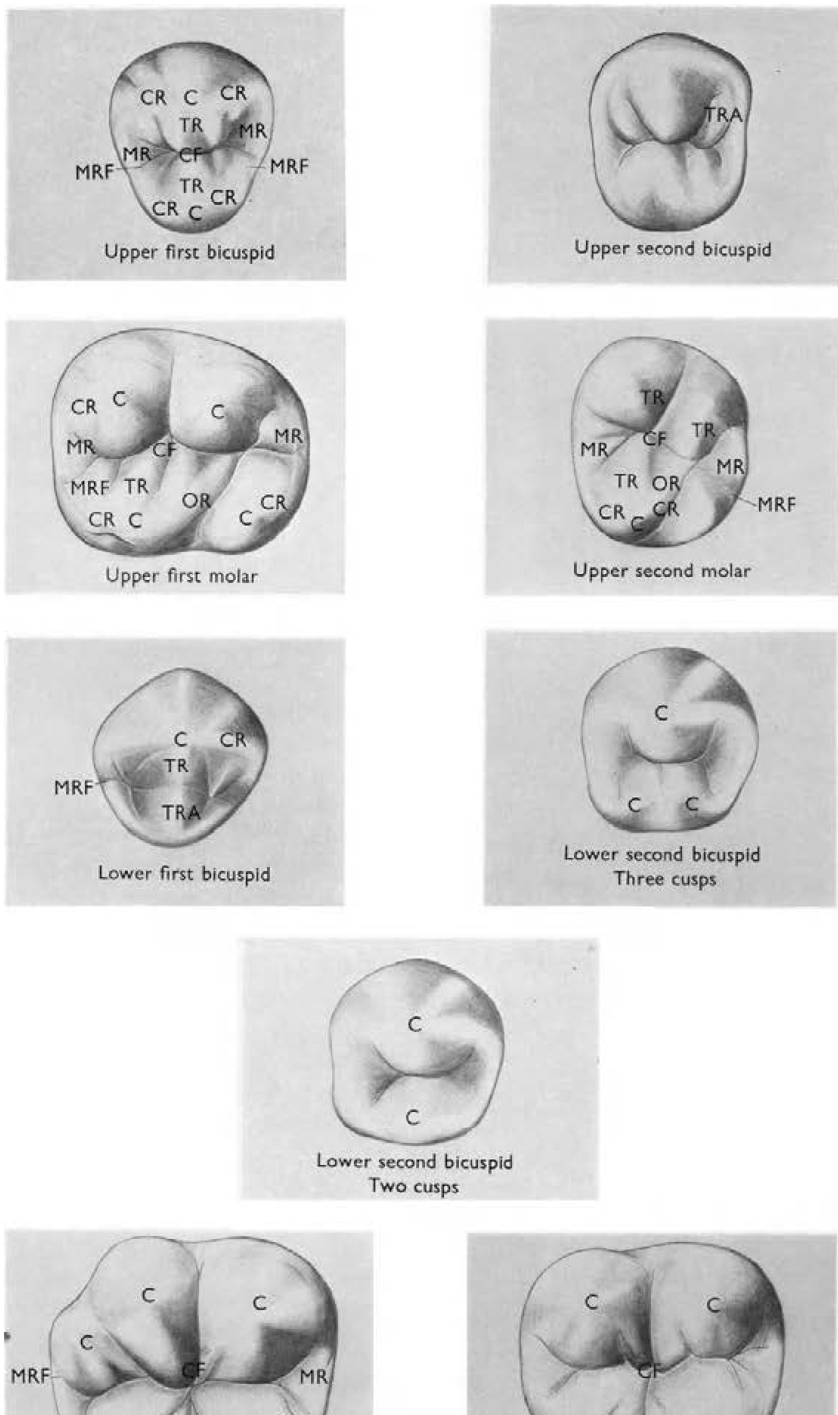


Fig. 8. The posterior teeth. C, Cusp. CR, Cusp ridge. MR, Marginal ridge. TR, Triangular ridge. TRA, Transverse ridge. OR, Oblique ridge. CF, Central fossa. MRF, Marginal ridge fissure.

towards a central fossa and fissure. The buccal and lingual cusp ridges either join adjacent cusp ridges or continue as mesial and distal marginal ridges.

CHARACTERISTICS (*Fig.* 8)

Each bicuspid and molar has its own characteristics and the significance of each is by no means certain. The third molars are not included since they appear in many variable forms. The *upper first bicuspid* has an angular shape while the *second bicuspid* is more rounded; both have well-marked cusps. The *upper first molar* has a dominant mesiolingual cusp which gives a triangular ridge to the central fossa and a supplemental (or oblique) ridge which joins the triangular ridge of the distobuccal cusp across the central fissure. This molar usually has a diminutive extra cusp lingual to the mesiolingual cusp and this distinguishes it from the *second molar* to which it is otherwise similar. The *lower first bicuspid* has a small lingual cusp which does not have any occlusal function and this is sometimes blamed for creating adverse forces on the upper first bicuspid. The ridge running from the lingual cusp to the central fissure is called a 'transverse ridge'. The *lower second bicuspid* has three forms, two of them giving it two lingual cusps. The *lower first molar* has a characteristic pentagonal shape with three buccal cusps while the *second molar* is more rectangular and only occasionally has the third buccal cusp.

Each posterior tooth has central, transverse and supplemental fissures and the central fissure usually has mesial and distal extensions which cross the marginal ridges. Their direction varies but generally they run towards the lingual embrasures. They are thought to provide channels for directing food away from the contact areas and are valuable for this reason when carved on restorations. The lingual and buccal fissures provide this function and the supplemental fissures aid the milling function of the occlusal surfaces.

The triangular and oblique ridges are separated by central fissures, like streams dividing mountain slopes, and they provide the central fossae for opposing cusps and ridges to occlude. The area between the buccal and lingual cusps is known also as the occlusal table.

Supporting and guiding cusps

In order to understand the functions of posterior teeth their cusps are classified into two groups: those which provide the main support for intercuspal occlusion and those which guide the teeth towards intercuspal occlusion. Thus the terms 'supporting' and 'guiding' cusps are used. They were introduced by Kraus and others (1969) in their book on dental anatomy and occlusion which is recommended reading on this subject. They were also used by Beyron (1969) in his observations on optimal occlusion which repays careful study.

SUPPORTING CUSPS

These are the buccal lower and lingual upper cusps and they occlude wholly within the opposing occlusal table and thus support the occlusal vertical dimension of the mandible in its intercuspal position. They are more rounded in shape than the guiding cusps and are more centrally placed. Ideally they occlude on three sides with opposing ridges leaving a space between the cusp itself and the opposing fossa (*Fig.* 9). The contact area between the inner facing ridges is larger than between the outer facing ridge and opposing ridge. Together with a third contact this constitutes a stable tripod contact and should

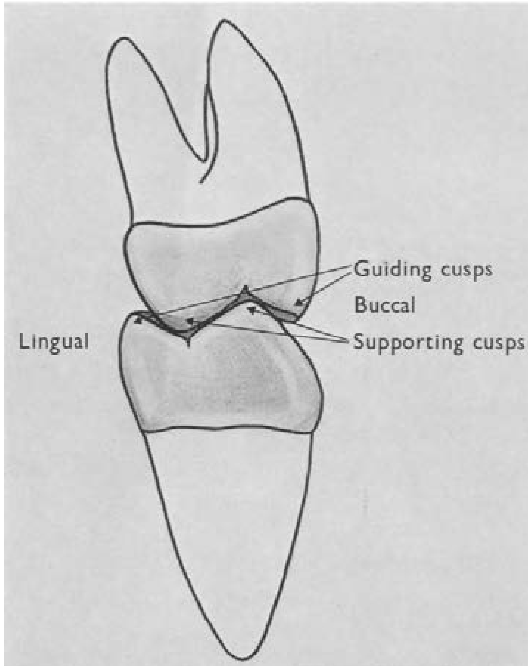


Fig. 9. Supporting and guiding cusps. (*After Kraus, Jordan and Abrams*, 1969.)

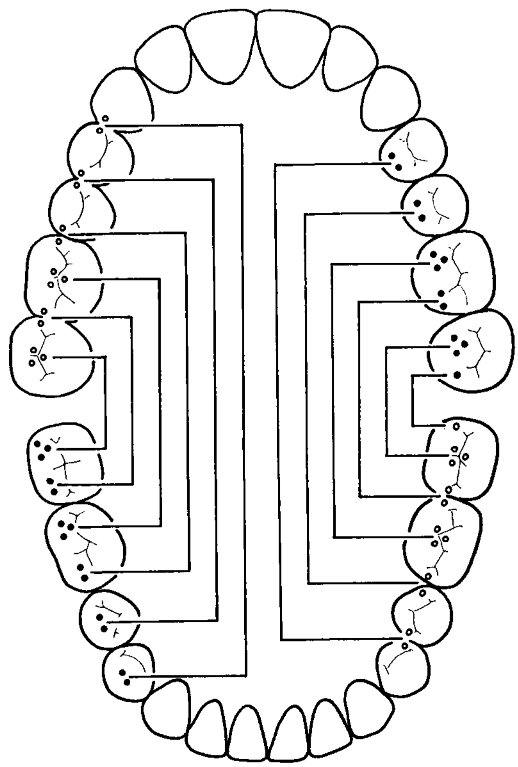


Fig. 10. Tripod contact sites in cusp-ridge IO. Distobuccal cusp ridges of lower first and second molars in opposing fossae. Mesiobuccal cusp ridges of upper first and second molars in opposing fossae. Otherwise, cusp-ridge. ●, Supporting cusp. ○, Contacts.

be a feature of all restorations involving cusp–fossa relationships. The outer facing surface of the supporting cusp is known as its functional outer aspect. One further significant feature is that only two upper and two lower supporting cusps occlude in opposing central fossae. These are the mesiolingual cusps of the upper first and second molars and the distobuccal cusps of the lower first and second molars. The remaining supporting cusps occlude in the opposing marginal ridge areas (*Fig.* 10). Being rounded, however, this does not imply that they are acting as plunger cusps although this is a feature which has to be carefully watched in assessing food stagnation between teeth.

GUIDING CUSPS

These are the lingual lower and buccal upper cusps and they occlude lightly with their inner facing triangular ridges against the functional outer aspects of the opposing supporting cusps in intercuspal occlusion (*Fig.* 9). Thus they occlude outside the opposing occlusal table. The outer aspects of guiding cusps have no opposing tooth contacts. Guiding cusps are sharper and more outwardly placed on the tooth than the supporting cusps and exhibit vertical overlap and horizontal overjet over (or under) their opposing supporting cusps. This feature provides protection against tongue and cheek biting as the mandible closes into intercuspal position. Guiding cusps overlap the opposing embrasure areas and may provide a cause of food stagnation if the marginal ridges are incorrectly restored.

CUSP–RIDGE OCCLUSION

The contacts described and illustrated (*Fig.* 10) constitute cusp-ridge intercuspal occlusion and represent normal occlusion in Class 1 jaw relationship. Deviations are common and may result in unstable cusp relationships with consequent tendencies to deflexions of individual teeth or of the mandible on closure. One clinical application of the relative shapes and positions of supporting and guiding cusps is the expectation of opposing tooth contact when making restorations on teeth in the mouth which involve marginal or cusp ridges. Cusp–ridge occlusion accounts for many broken amalgam ridges. This is common when caries or wear has destroyed a marginal ridge which has remained untreated for a long time. There is a tendency for the opposing tooth to tilt and permit the supporting cusp to occupy the ridge area. There is little space left to restore the ridge to its original shape and attempts to do so often lead to breakages.

During incoming or outgoing lateral movements the guiding cusp ridges make potential contact with the opposing supporting cusp ridges on the side to which the mandible is moving (working contacts). This contact is often prevented, however, by canine contact which separates the posterior teeth. On the opposite side there is a potential contact between the triangular ridges of the opposing supporting cusps (balancing contacts). During the protrusive movements the mesial cusp ridges of the lower supporting cusps make potential contact with the distal cusp ridges of the upper guiding cusps. The inclines of these cusps determine the articular paths followed thereby justifying the term 'guiding cusps'. Again, these contacts are potential because the articular guidance provided by the upper incisors and canines may cause a separation of the posterior teeth, thus demonstrating the phenomenon of *disclusion* (Chapter 5).

Cusp relationships in occlusion and articulation will be discussed further in Chapter 5 when assessing the existence of occlusal forces on the teeth and articular contacts between them.

Wear, caries and change

The occlusal surfaces of the teeth are subject to wear by function and parafunction and loss of surface by caries with consequent changes in the contours of ridges and fossae, of cusps and fissures. Therefore, the occlusal relationships are continually changing and the cycle of adaptation, repair and further change is the often unrecognized story of occlusion. Occasionally, in the hands of skilled operators occlusal contours are adjusted or created in such a way that their relationships are not so subject to wear and change. Therefore, it is helpful to have a clear picture of the teeth as they should be before attempting to restore them.

THE ROOTS OF THE TEETH

Root shape and size, the number of roots per tooth and their direction are generally specific. The size and direction of the roots have a direct relationship with crown size although this can vary. When correct, this feature provides stability for the crowns in function. Surrounding each root is the periodontal membrane which permits movement of the roots within the membrane space in a limited but omnidirectional manner. The function of the roots cannot be considered without their membranes since all forces on them are received by the membranes which act as resilient cushions between the roots and alveolar bone. For some years this membrane has been referred to as a ligament since the principal collagen fibres in it seemed to run from bone to root surface in an apical direction and act as a stay to the apical movement of the root. Recently, it has been suggested that no fibres have been seen to cross the membrane space from bone to tooth and consequently the function of the tissue between root and bone acts more as a membrane than as a ligament. Further, since few forces are directed axially on to a tooth the function of the membrane is to be displaced within its bony socket when a force is applied to the tooth and to recover when the force is removed. Forces in excess of those which can be accepted by this membrane are directed to the alveolar bone which then responds by the phenomenon of resorption. Such forces can also be excessive in an apical direction and cause strangulation of the vessels as they enter the tooth, with potential death of pulp.

The periodontal membranes contain nerve receptors which act proprioceptively to give information about position and movement to the central nervous system. As a result of forces on the teeth stimuli are transmitted from these receptors and this results in reflex activity of the masticatory muscles (Chapter 3).

The size and direction of roots are subject to developmental alterations from those established as normal. These take the form of short and narrow roots relative to crown size and this can predispose to a tendency to tooth movement especially where adjacent teeth have been lost. Also, twisted roots will provide less stability against occlusal forces. It is possible to determine, using study casts and radiographs, the centre of resistance of a tooth against these forces and the closer this is to the apex the less stable the tooth will be. There are four factors which will help in assessing this resistance value: the crown–root ratios of the teeth, the height of alveolar bone, the resultant of force following intercuspal occlusion, and the health of the gingival and periodontal tissues.

Axial stress

It has always been asserted that the most favourable stresses for the supporting tissues of the roots to receive are those in an axial direction. This can seldom be expected in view of the lines of forces suggested by the diagram in *Fig.* 11. The

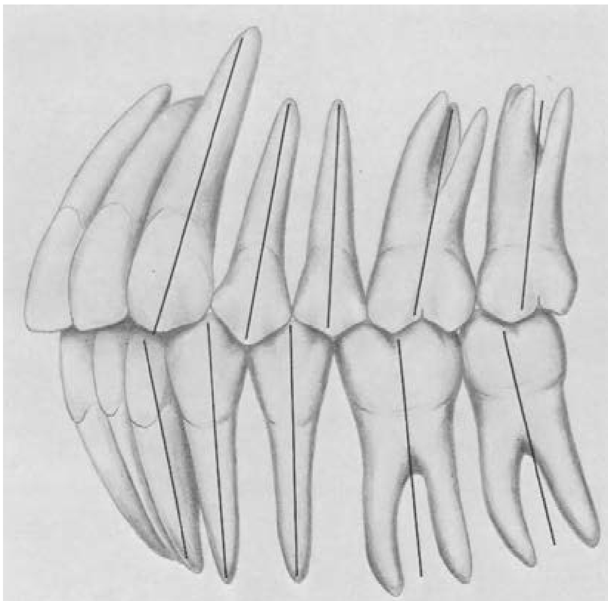


Fig. 11. Intercuspal occlusion. Relationship between upper and lower canine, bicuspid and molar cusp ridges. Incisor relationships. Crown and root inclinations of canines, bicuspids and molars. (*After Kraus, Jordan and Abrams*, 1969.)

second bicuspids come closest to this ideal but all occlusal forces depend on cusp–fossa and cusp–ridge relations and these are subject to variation in both direction and force. There are many teeth in good periodontal health performing adequate function whose roots are receiving anything but axial forces in occlusion or mastication. The variable factors providing stability for such teeth will be discussed in Chapter 5.

Comment

The integration of muscles, joints and teeth to provide comfortable and efficient occlusion is a proposition which depends on the health of these tissues and on healthy responses to the demands made on them. In order to understand the various disturbances which can threaten the function and health of these tissues it is necessary to examine the positions and movements of the mandible in relation to the maxilla and the neuromuscular function which controls them. These features will be the objectives of the next two chapters.

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Chapter 3

Neuromuscular function

THE masticatory system receives its full share of mechanical analogies when attempts are made to describe its functions. These are justified when jaw positions and movements are transferred to a mechanical mandible and maxilla with varying degrees of accuracy. On the laboratory bench, however, the movements depend on hinges and tracks and the power derives from the technician's hand. However necessary it may be to make these transfers for the diagnosis and treatment of occlusal problems it should be realized that in the live system mechanical analogies tend to oversimplify these movements and to be misleading. The limitations of mechanical analogies and transfers are best appreciated by a knowledge of the neuromuscular control of posture and movement.

In this chapter an attempt will be made to describe the neuromuscular function which provides mandibular movement and briefly to apply some of its principles. The chapter will include some notes on muscular function and observations on spasm, fatigue, injury and pain in muscles. All the information comes from standard sources and it is hoped that the selection and pruning will not have excluded any essential facts and that the observations made are no more speculative than most authors agree are still a feature of this subject. It is also hoped that the practitioner and student alike will appreciate that the complex nature of muscle activity is slowly reaching comprehension.

Skeletal muscle has sensory and motor innervation. The sensory (afferent) endings give rise either to sensations of discomfort and pain as when a muscle is fatigued and protection is required to control overactivity or to the transmission of information about the state of contraction (shortening) or relaxation (lengthening) of the muscle-fibres to the central nervous system at both spinal and higher levels. The motor (efferent) nerves receive this information and use it to make adjustments to the discharge of impulses which are transmitted along the motoneurones and result in contraction or relaxation of the muscle-fibres.

Muscle contraction

Skeletal muscle has intrinsic abilities to contract and relax. This is achieved when an impulse is transmitted along the motoneurone and reaches a group of muscle-fibres. At the junction of neurone and muscle-fibres are to be found the motor end-plates which liberate minute amounts of acetylcholine when stimulated by the impulse. This initiates a depolarization which spreads across the muscle and tension is developed. This, in turn, causes the fibres supplied by the neurone to contract.

Innervation ratio

The basic unit of the neuromuscular system is the motor unit which transmits efferent impulses to a varying number of muscle-fibres, by means of the motoneurone (the cell). The ratio of fibres to neurone depends on the movement required: the more refined the movement the lower is the ratio. One motoneurone may supply two or three fibres when adjusting the lens of the eye while many hundreds of fibres are supplied by one motoneurone in the more massive task of raising the back. A smaller but equally significant difference exists between the innervation ratio of the lateral pterygoid muscles which provide the fine adjustments required for the various horizontal mandibular positions and of the masseters which provide the forceful closing movement into a bolus of food against gravity.

Muscle-fibres

Skeletal muscle consists of two types of muscle-fibre. These are the *extrafusal fibres* which are contractile and make up the bulk of the muscle and the *intrafusal fibres* which are minutely contractile and are found in the muscle spindles. Contraction of the extrafusal fibres shortens the muscle. Contraction of the intrafusal fibres in the spindle provides information about the state of the muscle. In this respect the muscle spindle acts as a stretch receptor.

Muscle spindles

These consist of elongated bundles of intrafusal muscle fibres bound together by their own connective tissue sheaths. They extend beyond the poles of the spindle and are attached to the connective tissue structure of the muscle. They are called 'spindles' because they lie near the middle of the length of the whole muscle and may appear as a small swelling (*Fig.* 12). In length the spindles vary between 1 and 4 mm. and in breadth between 10 and 20 μm. There are two types of intrafusal muscle-fibres in the spindles, namely 'nuclear bag' and 'nuclear chain' fibres and the difference lies in the position of the nucleus in the muscle-fibre. Each is provided with a nerve receptor, a primary receptor arising from the nuclear bag fibres and a secondary receptor from the nuclear chain fibres (*Fig.* 12).

Innervation of the muscle spindles

Afferent fibres arise from the primary and secondary receptors and carry impulses to the relevant nuclei in the central nervous system. They are given numerical group numbers Ia and II and are classified according to size. The larger fibres conduct their impulses at higher speeds and possess a lower threshold to electrical stimulation. The motor nerve supply to the intrafusal fibres is by fusimotor-nerve fibres. These are given the alphabetical classification of gamma (γ) fibres or *gamma efferents* to distinguish them from the *alpha* (α) nerve-fibres which supply the extrafusal fibres (*Fig.* 12). A single fusimotor axon may run to intrafusal muscle-fibres in several different spindles all lying within the same muscle. Thus, whereas each extrafusal muscle-fibre or group of fibres receives impulses from only one (alpha) motoneurone, there may be several (gamma) motor axons running to each of the intrafusal muscle-fibres. A single spindle may receive from 7 to 25 motor axons (Roberts, 1966).

Golgi tendon organs

In the tendons which attach the muscle-fibres to the bones are found a complex spray of branching nerve-fibres embedded in the connective tissue of the tendon. These are the Golgi tendon organs and they discharge afferent impulses in response to tension or contraction within the whole muscle. These are the

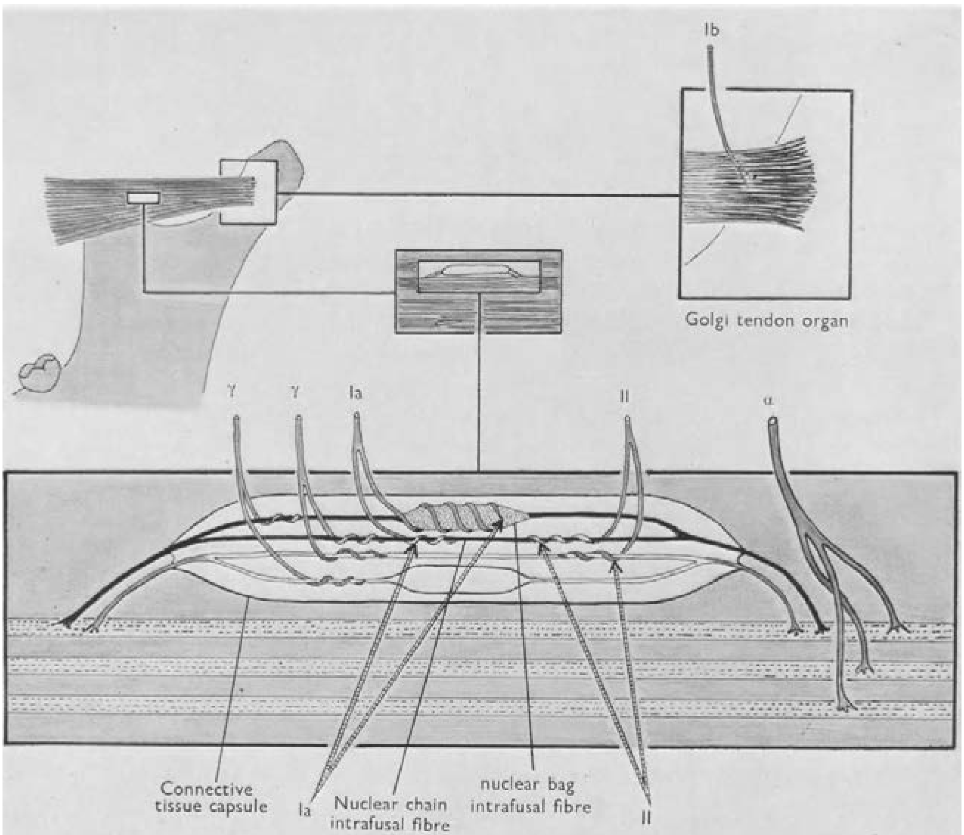

Fig. 12. Muscle spindle and tendon organ. Muscle spindle is much enlarged in breadth (*see* text). I*a*, Primary afferent path to CNS where synapse with α motoneurones. I*b*, Afferent path to CNS from tendon organ. II, Secondary afferent path to CNS (impulses transmitted at lower speed). α, Efferent motoneurones to extrafusal muscle-fibres for contraction of muscle. γ, Slower conducting efferent motoneurones to intrafusal muscle-fibres which alter bias of spindle and cause afferent impulses. Stretch reflex arc. (*Adapted from Bell, Davidson and Emslie-Smith*, p. 828.)

Group Ib afferents and occupy a place between Groups Ia and II afferents from the spindles in terms of conduction velocity and threshold of electrical stimulation (*Fig.* 12).

Spindle action

The forces created by skeletal muscles are the function of the extrafusal fibres while those created by the intrafusal fibres are immeasurably small. The function of intrafusal fibre contraction is to signal information about the state of the muscle as a whole. The interaction between intra- and extrafusal fibres depends on various conditions and the following is an abstract from Bell and others (1972) on this topic.

In a passively extended muscle the spindles are stretched. If the extrafusal fibres contract but the intrafusal fibres remain relaxed, the spindle shortens passively and the sensory discharge declines or stops. If the intrafusal fibres contract in isolation impulses are discharged. If the intrafusal and extrafusal fibres are stimulated simultaneously the spindle discharge varies according to the resistance to shortening experienced by the extrafusal fibres. If the muscle meets little resistance to shortening (isotonic contraction) it brings together the two ends of the spindle and the tension applied to the equatorial zone is slight. There is little afferent discharge. If the extrafusal contraction is resisted (isometric), the intrafusal contraction is concentrated on the equatorial zone and a vigorous discharge from the sensory endings results. Thus if the motor centres send simultaneous impulses to the intra- and extrafusal fibres the response from the spindle endings will indicate how much shortening has occurred in the extrafusal fibres. The spindle discharge of impulses is relayed back to the motoneurones of the extrafusal fibres and, if the muscle meets resistance during contraction, extra contractile force is supplied by spindle activity.

One further aspect of muscle spindles which should be mentioned is their variation in density and this applies to the tendon organs as well. Their greatest densities are found in muscles requiring the most delicate movements. The occurrence of muscle spindles in the lateral pterygoid muscles has been demonstrated by Honée (1966, 1970) who states that the relatively few but highly differentiated spindles in this muscle have the same function as the relatively high number of less complex spindles in the other masticatory muscles.

Control of muscle activity

The significance of the foregoing information on neuromuscular function is that of control. How this is performed is not clear but it has been suggested (Wright, 1961) that the gamma efferent system is permanently active though it does not necessarily set up movement, and that the gamma discharge keeps the alpha cells reflexly in preparation for the reception of impulses arriving from the cortex or for the receipt of afferent impulses from the spindles. It is possible that all but the fastest voluntary movements are controlled by the link between the gamma efferents, the spindle afferents and the alpha motoneurones. This combined output produces the required contraction or inhibition of the muscles with the neuromuscular system keeping, as it were, a check on itself. Thus, impulses initiated in the motor cortex signalling voluntary movement synapse with the gamma motoneurone. They travel to the spindle (*Fig.* 13) and become integrated with the afferent output from the spindle receptors. The combined output passes back to the alpha motoneurone and thence to the extrafusal fibres when the relevant muscle contraction takes place. If the afferent fibres returning from the spindle are cut the muscle fails to contract but the gamma motoneurones continue to fire at an increased rate. Therefore, the spindle afferents exert an inhibitory action on the gamma motoneurones but remain excitatory to the alpha motoneurones. This concept was developed by Eldred and others (1953) and applied to the masticatory system by Newton (1969). When a sudden impulse for contraction is sent out it is thought that the direct alpha motoneurone pathway is used. The resultant abrupt onset of contraction may cause damage to muscle-fibres (pulled muscle) or may institute spasm (aching back).

Another aspect of control concerns the Renshaw recurrent inhibitory loop (*Fig.* 13). If the stretch applied to a muscle is more prolonged or intense than that which typically elicits the tendon-jerk impulses are passed through this loop before emerging in the alpha motoneurone. Impulses in this loop cause a

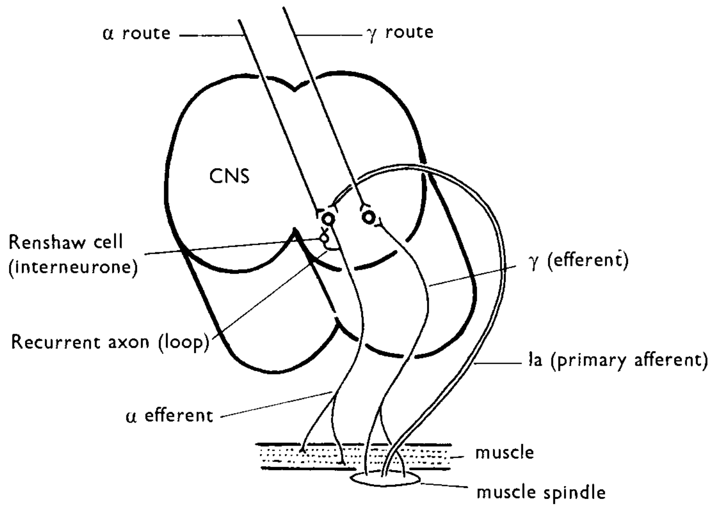

Fig. 13. Muscle spindle and CNS. Ia afferent fibres in synaptic connexions with α motoneurones. γ efferent fibres supply contractile poles of spindle. Muscle contracts either by impulses from higher centres (α route) or by impulses through γ route which activates muscle indirectly via stretch reflex arc. (*Adapted from Bell, Davidson and Emslie-Smith.* p. 916.)

reduction in excitability of the anterior horn cells and this has an inhibitory effect on the reflex movement. This pathway exerts a stabilizing action on the large (alpha) motoneurones (Buller, 1961). Thus, if the force applied to elicit the knee or jaw tendon-jerk is applied slowly and forcefully the reflex response will be inhibited.

It will be appreciated that these observations on neuromuscular function apply to skeletal muscle activity at all levels supplied by the 12 pairs of cranial nerves giving off the upper motoneurones and the 31 pairs of spinal nerves arising from the anterior horn cells and comprising the lower motoneurones. This activity is the result of sensory (afferent) impulses received by the cortex, brain-stem and spinal cord.

The neuromuscular function of the masticatory system is transmitted largely by the trigeminal nerve which contains sensory and motor fibres. The nerve-cells receive afferent impulses from the periodontal membranes of the teeth, from receptors within the capsules of the mandibular joints and from the muscle spindles. They lie within the brain-stem in the mesencephalic nucleus of this nerve. There is a complex distribution of sensory impulses to higher levels in the brain but the reflex control of jaw movements is carried out between the mesencephalic nucleus and the trigeminal motor nucleus according to the principles already stated. Ramfjord and Ash (1972) report that in addition to the type of afferent neurones from the spindles two other types of neurones reach the mesencephalic nucleus: (1) a neurone which conveys impulses from the periodontal membranes of several teeth and adjacent gingival and oral mucosa and (2) a neurone transmitting impulses from the periodontal membrane of a single tooth.

The activities of the tongue are controlled by the hypoglossal nerve whose nucleus receives fibres from the trigeminal, glossopharyngeal and vagus nerve.

There are several features of muscle activity which should be understood and which derive from these principles. These are *reflex action*, *reciprocal innervation*, *muscle tone*, *conscious control*, *stable patterns* and *irrelevant muscle activity*.

Reflex action

This is usually defined as the response resulting from a stimulus which passes as an impulse along an afferent neuron to a posterior nerve-root or its cranial equivalent where it is transmitted to an efferent neurone via the anterior horn cell or motor cranial nucleus to the skeletal muscle. The response is independent of the will and can be facilitatory or inhibitory. The pathway is called a monosynaptic reflex arc. The stretch (myotatic) reflex which causes a muscle to contract when stretched provides an example and is to be found when the chin is suddenly pulled downwards (jaw-jerk). Afferent stimuli may arise from varying sources to provide the same action and these sources include the higher centres of the brain. Impulses reach the same efferent motoneurone through interconnecting facilitatory neurones. These are polysynaptic reflex arcs and, in the masticatory system, include such responses as yawning, laughing and the clenching of the teeth.

Reciprocal innervation

This feature of muscle activity ensures that when a stimulus for muscle activity is received the muscles that are to provide the movement (the protagonists) contract while the muscles which would normally oppose the movement (the antagonists) are inhibited from contraction. Thus smoothness is imparted to the movement. If, during the movement, an interfering stimulus is received (the unexpected encounter with a sharp piece of food during mastication) a reflex opening is initiated by an alpha motoneurone impulse.

Muscle tone

This is the reflex contraction of skeletal muscle concerned with maintaining posture. Muscle tone is probably due to a slow asynchronous discharge of impulses from the anterior horn cells producing a partial tetanus. Tonic muscle gives a steady uniform pull because groups of fibres contract and then relax as other groups contract. Muscles in tonic contraction permit the blood-supply to provide full metabolic requirements and fatigue is prevented indefinitely. By contrast, muscles in full tetanic contraction fatigue rapidly because it is not possible for the circulation to cope with the increased metabolic demands. Muscle tone can be further defined as a maintained resistance to stretch in healthy skeletal muscle subject to passive displacement. In the masticatory system the tone of the muscles ensures that the mandible adopts a posture in relation to the maxilla which it can maintain indefinitely and without fatigue, provided that the health and length of the muscles remain constant. This is the rest position of the mandible and has some clinical significance in assessing and analysing problems of occlusion.

The neurological researches on the control of mandibular posture are reviewed by Wyke (1974) and his observations on this topic are of considerable value to all clinicians and, in particular, to those concerned with the replacement of teeth.

Conscious control

All voluntary muscle action is predominantly under conscious control and is the result of excitatory and inhibitory impulses. This can be replaced by reflex action when an emergency arises. On the other hand, reflex control can be overruled by impulses from the cortex via interconnecting facilitatory neurones using the same muscle patterns. The mandible may be moved from its rest position by thinking to move it. Any learned movement subsequently performed can be altered by conscious control.

Stable patterns of muscle activity

These are organized movements which provide for the functions of useful movements and are said to be endogenously determined. Several are present at birth and include respiration and the ability to suckle. As growth proceeds other endogenous activities become apparent such as those which cause a limb to move or a face to smile. These and other stable movements are then organized at a higher level of brain development to provide such activities as walking and mastication. At a still higher level they become further organized to produce such complex behavior patterns as speech, mating and providing shelter. This is known as the hierarchical concept of behaviour organization and was outlined by Weiss (1950). It emphasizes the stability of endogenous patterns of muscle behaviour. Gesell (1942) expressed this by saying that just as bones and teeth have characteristic forms, so do patterns of behaviour. They account for all movements which provide natural function and make it possible to distinguish someone by his gait, smile or the way he eats. These patterns are organized within the nervous system and are performed without conscious thought. As was suggested in the previous section, they can be altered but when the conscious stimulus to change has been withdrawn the stable patterns return.

In addition to the conscious stimuli which may alter these patterns, disease or disturbance may cause a change. Thus a painful ankle causes a limp and a tooth in supra-contact alters the masticatory movements of the mandible. When the disturbing stimulus is removed the endogenous or established movement will be restored. A missing tooth may restrict mastication to one side and the altered movements will be composed from the existing co-ordinated patterns These are usually performed within the limits of injury and fatigue. However, tolerance to these habitual movements is not unlimited and pathological responses may develop in the affected muscles. The application of these principles of muscle activity to the posture and movements of the mandible was outlined by Ballard (1955) and is recommended for further study.

Adjustment to disturbances is achieved, first at reflex level, and secondly, if the disturbance is maintained, by a more permanent change in muscle patterns. But the gamma system serves to provide the muscles with a controlled feedback system to deal with conflicting alpha and gamma impulses such as may happen when stepping unexpectedly off the pavement. In this context it is referred to as a *servomechanism* and provides optimal muscle function in both normal and abnormal conditions.

Irrelevant muscle activity

This is the term given to muscle contraction which does not participate in the execution of a particular movement. It is commonly experienced during the performance of a task which requires mental as well as physical effort and is manifest as an involuntary increase in muscle activity unconnected with the job in hand. Thus, one can observe or experience pursing of the lips while threading a needle. These activities may be explained in part by the secretions of the hormones adrenaline and noradrenaline in preparation for a task where there is no opportunity to fight or fly. Thus, the public speaker paces the rostrum or makes excessive use of his hands.

The stimuli which produce these tensions are thought to arise from various excitatory and inhibitory foci believed to be a part of the reticular system in the central part of the brain-stem. The reticular system is not a morphological unit but consists of many nuclei of different nervous structures and has the function of modifying motoneurone activity (Bell, Davidson and Emslie-Smith, 1972). In this respect it is thought to exert a correlation between sensory and motor signals from the higher centres. For example, strong stimulation from the reticular system facilitates the contraction of the masseter muscles and inhibits that of the digastrics thus promoting irrelevant closure of the mandible while the hands are extracting a lower molar tooth.

Irrelevant muscle activity may also derive from anxiety states and can occur during sleep. The tossing and turning experienced while trying to sleep are well known although the body is supposedly in its most resting posture. The anxiety which causes or is caused by insomnia provides an explanation for this irrelevant muscle activity and when asleep the movements usually subside. But movements while asleep are equally well known and these include hyperactivity of the masticatory muscles. An introduction to the possible functions of the limbic system may be helpful in understanding these phenomena.

The cortex and the limbic system

Whereas the reticular system was said to modify motoneurone activity it can act as a relay station for transmitting sensory stimuli to the cortex. These stimuli generate a response from the cortex which are either passed back to the reticular system or proceed directly as motor impulses to various parts of the body. The function of the cortex appears to be one of evaluation and decision and has been likened to a computer. It provides the direction of the impulses. This function can, however, be modified by various emotional states which provide the quality of intensity to the impulses. This quality arises from the functions of the limbic system. This system consists of a group of structures in the brain which include the amygdala, the hippocampus and the septum. Stimulation of the amygdala produces the varying responses of fear, panic, aggression and anxiety depending on the intensity of stimulation and the area stimulated. The septum and hippocampus control these emotions but produce anger if stimulated. Stimuli from the limbic system combine with those from the cortex and decide the action which the brain takes in terms of direction and intensity. The parts of the body affected by these stimuli must be prepared for the appropriate level of physical exertion and this is the function of the hypothalamus. Acting through the autonomic nervous system the hypothalamus organizes the physical resources of the body. Both the hypothalamus and the amygdala are thought to have connexions in such activities as physical effort resulting from anxiety (*Nobrium*, 1971).

Much of this information is speculative but, in summary, it can be said that impulses from the higher centres of the brain are the result of interaction between the various centres involved and that sometimes the intensity of impulse exceeds the direction. The result may take the form of irrelevant muscle activity and provide an explanation for the parafunctional movements of the mandible in both the waking and sleeping states. At such times the directive control of the cortex is overruled by the activity of some of its parts.

Summary

Skeletal muscle possesses an intrinsic ability to contract and relax. The provision of the gamma system of motoneurone supply to the muscle spindles controls the alpha motoneurone impulses which cause the muscles to contract. This permits the control of excitatory and inhibitory functions by reciprocal innervation and leads to the co-ordination of groups of muscles to provide effective movement. Sudden contraction of the muscles generally by-passes the gamma system and proceeds directly by the alpha motoneurone route. Conscious impulses to contract muscles overrule the reflex control but the latter is always present to maintain muscle tone and posture. The activities of the limbic system may provide an explanation of the phenomenon of irrelevant muscle activity which is manifest as parafunctional movements in the masticatory system.

MUSCULAR FUNCTION AND DYSFUNCTION

As a postscript to this discussion on neuromuscular function some notes will be given on the metabolism of muscle function followed by descriptions of three muscle disturbances, namely, *fatigue*, *spasm*, and *intramuscular injury*. This will provide a prescript to the discussions on the mandibular dysfunction syndrome to which references will be made throughout the book.

Metabolism of muscle contraction

The metabolic changes which take place when muscle-fibres contract will serve to emphasize the complexity of this function and to indicate the numerous possibilities for dysfunction.

The arrival of a neural impulse at the neuromuscular junction resulting in the release of acetylcholine produces a change in the permeability of the membrane surrounding the muscle-fibres. This permits a flow of potassium ions out of the fibre cells and a flow into the cells of sodium ions. This exchange is accompanied by a depolarization of the membrane and contraction of the fibres follows.

Under the light microscope the sarcolemmae of the muscle-fibres consist of numerous nuclei, mitochondria, undifferentiated cytoplasm (sarcoplasm) and cross-striated material. The electron microscope reveals these cross-striations to consist of sarcomeres which are the smallest contractile units of the muscle-fibre. Each sarcomere consists of a regular arrangement of thick and thin filaments. These filaments are thought to consist of myosin and actin respectively, both of which are proteins essential to the process of contraction. Myosin has enzyme properties and in resting muscle the tendency to form actomyosin is prevented by the presence of adenotriphosphate (ATP). When the muscle is stimulated the ATP is hydrolysed to adenodiphosphate (ADP) and actomyosin is formed. In this reaction phosphoric acid is produced. Shortening is then brought about by the thin filaments sliding between the thick ones. This reaction is also governed by the presence, in the sarcoplasm, of a high concentration of calcium ions which are discharged. When the calcium ions are reduced the chemical interaction between actin and myosin ceases and the muscle relaxes.

Three other reactions are going on at the same time which provide and produce the energy necessary for muscular contraction. Firstly, the glycolytic utilization of glycogen is brought about by the action of the enzymes phosphorylase and phosphofructokinase giving off pyruvic and lactic acids. Secondly, creatininic phosphate is reduced to creatinine and phosphoric acid. Thirdly, there is the supply of oxygen which governs these biochemical reactions and the removal of carbon dioxide which in turn plays its part in the control of respiration necessary for the supply of oxygen.

It will be obvious that an arterial blood-supply and venous return is necessary to supply these biochemical elements and to remove the metabolic by-products. These by-products include the acids already mentioned and the salts subsequently formed; and they are potentially irritant to sensory nerve-endings in the muscles if allowed to remain. There are, therefore, many requirements for effective function and many possibilities for dysfunction including fatigue, spasm and injury.

Fatigue

The detailed processes which produce muscular fatigue are unknown. Bell, Davidson and Emslie-Smith (1972) suggest the loss of muscle spasm may be due to failure at a number of different places including the central synapses, the motor end-plates and the contractile processes, but that the cause is probably in the muscle fibres themselves. Horrobin (1968) states that fatigue is not due to a failure of the neuromuscular transmission and that experimental evidence suggests that it is due to a failure of the blood to supply an essential metabolic element or to remove some waste product or to a combination of both. A lack of oxygen and an accumulation of acid metabolites are probably involved. Also involved is the voluntary response to fatigue by the higher centres which may lead to tiredness or to further effort, both of which can disturb efficient function. There is also a psychological component in fatigue in that it depends largely on motivation. And there is the phenomenon of the hypnotized subject who can maintain postures and tensions for long periods without fatigue. The influences of the higher centres on normal actions and diseased processes is well known, if not fully understood, and may explain why some people succumb to the mandibular dysfunction syndrome and others do not while demonstrating similar clinical features.

Another uncertainty is that fatigue may cause pain. It has been suggested that the metabolites of muscular function are potentially irritant to the sensory nerve-endings within the muscles. The response to such a stimulant may be interpreted as pain which will subside when the muscle recovers. Pain, however, is a separate entity and is not simply due to an excessive stimulation of nerve-endings, thus presenting the diagnostician with his biggest problem. The muscle may also respond by spasm or, if further effort is required by the higher centres, by injury of the muscle-fibres involved.

Spasm

Skeletal muscle spasm is broadly defined as an abnormal involuntary contraction of skeletal muscle. However, Buller (1961) adds to such a definition, 'with a subject so vague in definition, and so little studied in detail, ideas may prove as important at this stage as the few available facts'. Travell (1960) says that when muscles are subject to mechanical, emotional, infectious, metabolic or nutritional noxious stimuli they react in one way—*they develop spasm and shorten.*

The clinician is thus presented with a combination of doubt as to cause and dogma as to effect. This becomes a problem when treating spasm since the cause must be discovered if the effect is to be prevented. There are four levels or zones where excessive excitatory or diminished inhibitory influences may arise. Firstly, there is the muscle spindle where the intrafusal fibres may suddenly shorten causing a prolonged gamma efferent discharge resulting in spasm. Secondly, at the supraspinal level, there is the possibility of an abnormal pattern of descending impulses which might upset the balance of spinal excitation and inhibition. This may result in an abnormal discharge of impulses along the alpha motoneurone and cause spasm. Thirdly, a severe cutaneous stimulus will provide a sudden barrage of impulses which can reach the alpha motoneurones. The phenomenon of spasm following pain provides an example. Finally, there is the metabolic irritant within the muscle which, as has been suggested, can provide the noxious stimulus to the sensory nerves within the muscle and cause spasm.

Muscle spasm has to be differentiated from contracture which may be indistinguishable from spasm but which is caused by an 'artificial' stimulus such as the prick of a needle or the effects of certain drugs such as acetylcholine, noradrenaline and caffeine. Also the condition of spasticity has to be differentiated and this is a pathological response to a lesion of the nervous pathways.

The commonly held view that spasm is antalgic and protective is discounted by Capener (1961) who gives several reasons including that of the pain which it provokes. This can sometimes be so intense as to affect the whole constitutional state of the individual, but when relieved may still leave the cause untreated. A personal view is expressed here that the pain of trigeminal neuralgia could be simulated by a severe spasm of one of the masticatory muscles. According to Ritchie (1961), local intramuscular spasm serves no purpose except to establish the ischaemic background for later fibrous change.

Intramuscular spasm perhaps provides the most significant cause of pain in the mandibular syndrome. Here, groups of fibres can be in spasm without immobilizing the whole muscle and provide a cause of intermittent pain which is relieved by gentle stretching but which recurs if the cause (? cusp interference) is not removed. A further speculation is the possibility that intermittent spasm results in an excessive discharge of calcium ions which, in the connective tissue surrounds of the fibres, could build up calcification of this tissue and cause a more permanent limitation of movement.

Referred pain. Travell (1960) refers to trigger areas in muscles in spasm which are small hypersensitive zones. They have a lowered pain threshold to stimulation by pressure and cause pain some distance from the zone. The areas to which the pain can be referred have been plotted and the muscle in spasm can be named by the site of referred pain.

No discussion on the clinical aspects of spasm would be complete without mention of its incidence during sleep. True spasm is rarely psychogenic (Layzer and Rowland, 1971) and one must look to the vascular changes and maintained postures to explain spasm during sleep. Exercise of untrained muscles is often followed by nocturnal spasm and this can be explained by increased permeability of the blood-vessel walls during sleep and the increased presence of metabolites acting as irritants. Spasm can also be induced by forcible stretching or sudden movements on waking which suggests the presence of irritants ready to be effective. With regard to posture the forced retraction of the toes or feet by tight sheets can have a prolonged stretching effect on the calf muscles with consequent spasm. The mandible can be deflected during sleep and its muscles stretched for long periods by the head posture on the pillow and lead to spasm. This is a common symptom of the mandibular dysfunction syndrome but this posture theory does not provide the only explanation. Mandibular spasm and consequent grinding of the teeth while asleep are so common, especially in children, that a psychogenic cause as from the limbic system must be suspected. Such a cause has been described for irrelevant muscle activity which, if prolonged, could presumably lead to spasm.

In conclusion, systemic causes of spasm are to be found in pregnancy, dehydration, salt depletion, hypothyroidism and uraemia.

Intramuscular injury

In addition to spasm, sudden impulses to contract can result in torn muscle-fibres and consequent replacement by connective (scar) tissue. Christensen and Moesmann (1967) describe muscular hyperfunction as causing a primary mechanical lesion of the interfibrillar connective tissue since it cannot provide the necessary tension without damage. Their histopathological examinations reveal inflammation of the connective tissue with oedema and a fibrinous exudate together with degeneration of the muscle-fibres. The degenerated muscle-fibres are replaced by scar tissue or newly formed fibres. These findings may cause a revision of the 'torn-muscle' diagnosis but the possible effect of producing resistant scar tissue is the same. This will cause a persistent localized stiffness or pain in muscles.

Another intramuscular condition which resists effective movement concerns the elasticity of the interfibrillar connective tissue. Prolonged contraction of muscles as in so-called 'body-building' exercises or in the isometric contraction when the teeth are being clenched (or ground) leads to abnormal contraction of the connective tissue. The elasticity of this tissue is less than that of the muscle-fibres and it tends to resist relaxation of the muscle-fibres. If these movements continue the connective tissue resistance increases due to its relative inelasticity and a 'muscle-bound' condition results. This will account for stiffness and a resistance to refined movements required in many functions including those of mastication. This condition was given the name 'cumulative strain' by McLurg Anderson (1951) and can account for many disturbances of muscle function. These include excessive, irrelevant or unbalanced movements such as the parafunctional habits and unilateral chewing in the masticatory system.

General disorders of muscles

Horrobin (1968) lists five disorders of muscle which should be borne in mind when assessing disturbances of the masticatory muscles.

1. *Motoneurone disorders* in which trauma or disease (as in poliomyelitis) destroys the motoneurones. The muscle-fibres atrophy and the contractile tissues are largely replaced by fat.
2. *Neuromuscular transmission* is blocked by a failure to release acetylcholine. This can occur in rare cases of food poisoning by the botulinum toxin and in myasthenia gravis.
3. *Ionic disorders* such as a low calcium level render the motoneurones abnormally excitable and the irregular contractions of tetany may result.
4. *Myotonia* where muscles become contracted for an abnormal length of time in response to a normal stimulus.
5. *Muscular dystrophies* where the muscle-fibres atrophy without obvious cause.

Summary

A brief account has been given of the metabolic changes which take place when a muscle is stimulated to contract. These involve the presence of myosin and actin in the sarcomeres which are the smallest contractile units of muscle-fibres. The energy necessary for muscular contraction is provided by the utilization of glycogen, the reduction of creatininic phosphate and the supply of oxygen from arterial blood. The by-products of these reactions are potentially irritant to the sensory nerve-endings in muscle if not removed by venous return. Functional disorders of muscle activity consist of fatigue, intramuscular injury, stiffness and spasm. These may result from two main causes: a stimulus causing a rapid change of the established pattern of movement and prolonged isometric contraction. These can result in the conditions known as sprained ankle, housemaid's knee, aching back, tennis elbow, frozen shoulder, crick in the neck and the mandibular dysfunction syndrome.

Comment

The chief requirements of healthy muscles are to respond effectively to impulses and to return smoothly to their starting length or resting posture.

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Chapter 4

Positions and movements

IF the term 'occlusion' in dentistry implies the comprehensive and complex pattern of mandibular movements and contacts between the upper and lower teeth the fact remains that the word itself means 'contact'. Therefore, an understanding of mandibular positions during contact is as important as the movements which lead to them.

It has been asserted that the muscles, joints and shapes of the teeth provide occlusal function. Muscle activity results in various occlusal positions and, in natural function, these are momentary. Apart from sleeping and various resting postures the maintenance of bodily positions cause fatigue. The guardsmen at attention and the immobile young ladies who used to adorn the Windmill Theatre are highly trained for inspection but their efforts cannot be considered as natural, however pleasing. Fear can freeze and practice will sustain the stationary trunk and limbs but in healthy natural function, with the exceptions mentioned, to remain still is to tire.

In this chapter the positions of the mandible at rest and in various occlusal positions will be considered. These occlusal (contact) positions are momentary and generally serve as a stimulus to movement and other positions. Otherwise, as has been suggested, the muscles will tire. The movements described will be those between the occlusal positions and this will include a description of deflective (premature and initial) contacts. The border movements, the Bennett movement and the condyle positions and movements will then be described and discussed in relation to the functions they perform. Articular movements will be described in Chapter 5 under patterns of articulation and masticatory movements in Chapter 6 when considering functions of the masticatory system.

REST POSITION

The rest position of the mandible is the posture which the mandible adopts when the muscles attaching it to the maxilla are in minimal contraction. It can be maintained indefinitely, without fatigue, by the intermittent contraction and relaxation of groups of fibres within the muscles. It represents a reflexly-maintained resistance to stretch of the muscles by the force of gravity acting on the mandible. It assumes that no other stimuli are being received which might cause movement or other posture. The teeth are parted and the distance between them is generally about 3 mm. This position of the mandible is endogenously developed and is determined by the length and direction of the muscles which run between mandible and cranium. It constitutes a stable pattern of minimal activity and the position is constant provided the muscles remain healthy. It is said to be unaffected by the posture of the head or body and is therefore controlled by the higher centres of the brain as well as by the resting length of the muscles. In this posture of the mandible the face is in its *rest vertical dimension* (RVD).

The word *dimension* has been criticized in this context when compared with the word *relation* which is used to describe the horizontal (anteroposterior) position of the mandible, as in retruded (or centric) relation. The term 'rest vertical relation' might, therefore, seem more applicable. However, as the term *vertical dimension* between mandible and maxilla, either at rest or in occlusion, is used to denote a measurable distance between the two bones this term would seem to be justified.

The terms *rest position* and *resting posture* are synonymous and, although the latter is preferred, rest position is the original term and is in more general use. *Endogenous posture* is even better since it implies the innate feature of this position, but *postural position* is an unnecessary tautology. *Rest position* is the term which will be used.

Skeletal relationships at rest position

The horizontal relationship between the dental bases of the resting mandible and the maxilla is of clinical significance when assessing the intercuspal position of the mandible. The dental bases are those regions of the mandible and maxilla which lie below and above the apices of the mandibular and maxillary teeth respectively. They are not subject to change so long as the teeth are present. One method of occlusal analysis (Chapter 9) is to observe the path of closure from rest position to intercuspal position and to assess any interfering tooth contacts.

The vertical relationship between the dental bases of maxilla and mandible at rest provides a reference plane for assessing the correct vertical level of occlusion which should be 3 mm. above the rest vertical level. The clinical application of this principle will be repeated many times. It is of value, therefore, to be able to classify the dental base relationship at rest position in order to assess optimal expectation of tooth relationships.

Tracings made from lateral skull radiographs provide information about the skull, mandible and teeth in relationship to each other. For assessing dental base relationships the angles SNA and SNB allow the classification into skeletal Classes I, II and III to be made (*Fig.* 14*a*). S is the centre of the sella turcica and N is point nasion or the anterior end of the nasofrontal suture. Point A is the deepest midline point on the premaxilla and point B is the deepest midline point on the mandible. The difference between SNA and SNB is 3° in Class I skeletal relationship. It is greater than 3° in Class II and less than 3° in Class III. These are also referred to as *normal*, *postnormal* and *prenormal* relationships. This classification corresponds to Angle's molar relationship classification. The variability of the incisor relationships which corresponds to these skeletal relationships depends on the angle between the Frankfurt or maxillary planes and the mandibular plane (*Fig.* 14*b*) and on the forces exerted by the orofacial muscles labially and the tongue muscles lingually. These variables make the assessment of optimal tooth positions and their occlusion a complex study, as orthodontists will agree, but the skeletal classification at rest position is a useful aid towards the expectation of Angle's molar relationship. This is particularly true in the edentulous mouth when determining tooth positions for complete dentures (*Fig.* 14*c*).

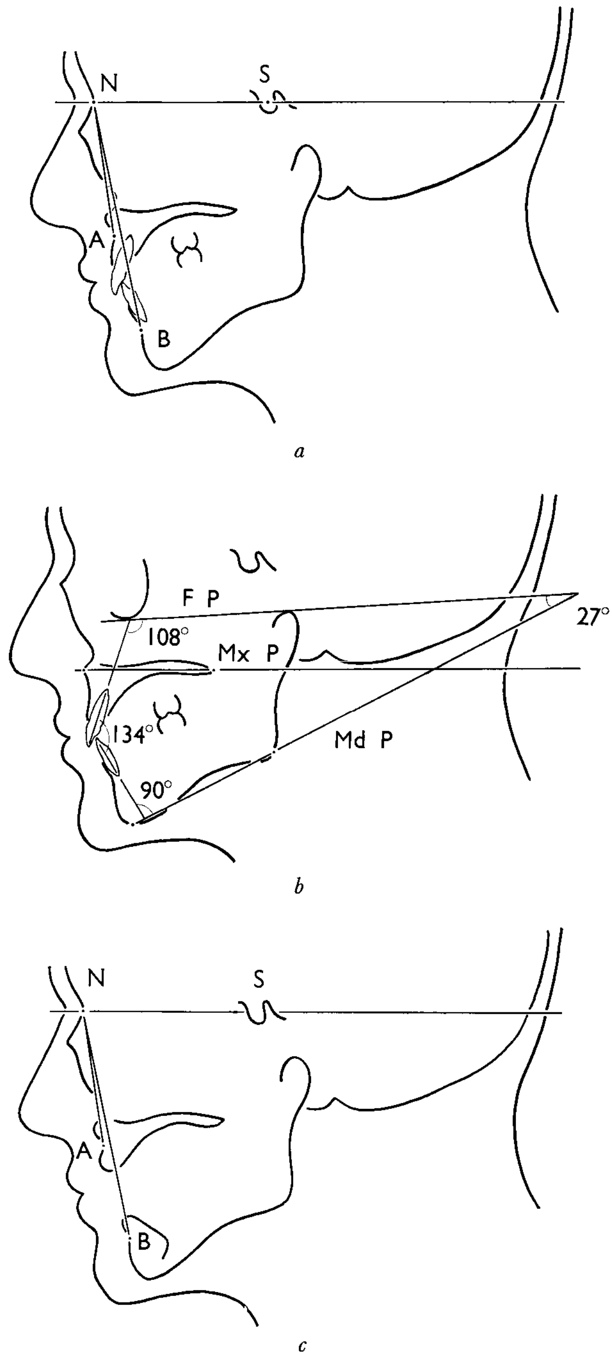


Fig. 14. *a*, Tracing of lateral skull X-ray to illustrate Class I jaw relationship. S, sella turcica, N, Nasion, A, Deepest midline point on premaxilla, B, Deepest midline point on mandible. SNA gives relationship between cranial base and face. SNA and SNB give relationship of maxillary to mandibular base. Normal SNA is 81° and SNB is 78°. *b*, Tracing of lateral skull X-ray to illustrate normal angle between Frankfurt and mandibular planes (27°) and normal angles between the incisors and both the Frankfurt and maxillary planes. These angles produce favourable incisor relationship and a pleasing appearance. *c*, Tracing of lateral endentulous skull X-ray. Mandible at rest position in Class I jaw relationship.

Rest position is a reference plane for assessing intercuspal position and is normally assumed to be the position from which all mandibular movements begin and to which they return after function.

HABITUAL POSTURE

While rest position is endogenously developed and maintained it is subject to reflex adaptation. In patients where there is a Class II dental base relationship and where the incisors do not permit a comfortable seal between the lips the mandible may move anteriorly in order to attain this seal at rest. This is clinically recognized as habitual posture. At the new position of the mandible the muscles are no longer minimally contracted but the posture can be maintained for purposes of mouth comfort and good appearance for varying periods. Lip seal keeps the mouth moist and preserves a closed-mouth appearance, but the habitual effort required to maintain it is no longer minimal and may result in muscle fatigue. Also there is a tendency to shift between the two positions and this can result in changes in the paths of closure such as when saliva is being swallowed. Variations in intercuspal positions may follow and this can lead to premature contacts, especially if there are missing teeth. If the cause of this reflex adoption of habitual posture is removed the endogenous rest position will be resumed.

The clinical significance of habitual posture is that it is often adopted by patients in the belief that they are in the rest position and this can lead to a mistaken diagnosis of premature contacts. Alternatively, some patients like it to be thought that their lip seal is natural although it requires a habitual posture to provide it. Difficulty in making an analysis of occlusion from rest or habitual rest position can be solved by a test which will be described in Chapter 9 when discussing functional analysis.

INTERCUSPAL POSITION

IP is reached by an upwards and slightly forwards movement from rest position which ends with intercuspal occlusion at which moment the mandible is in intercuspal position. The distance travelled by the mandible in this movement is between 2 and 4 mm. and intercuspal occlusion is reached by simultaneous contact between both arches from rest position. This is a physiological requirement for comfort, stability and efficiency in the mouth. At this level the closing muscles are in optimal contraction. Any further movement upwards (as when teeth are lost), or laterally (as when teeth are tipped and cause displacement), or if the movement is cut short by restorations or prostheses can result in discomfort, fatigue or even injury in the muscles. The *occlusal vertical dimension* (OVD) of the face is seen when the mandible is in intercuspal position and the difference in height between rest and occlusal vertical dimension is referred to as the *interocclusal distance* (IOD) or freeway space. Thus RVD – OVD = 3 mm. in the normal or average facial development. Intercuspal position from rest position is reached many times throughout the day as saliva is swallowed from the empty mouth.

IP is also one of the positions reached when the teeth meet in parafunctional contact. Here the occlusion may be prolonged and cause fatigue of the muscles and discomfort in the periodontal tissues.

The movement from rest position is endogenously determined as is the posture from which it began. It is as characteristic of the individual as is the blink of the eyelids or a sudden smile. If an interference prevents any of these natural (endogenous) movements the muscles will often adapt and produce a new movement. But when the cause of interference is removed the natural movement will be restored.

DEFLECTED OCCLUSION

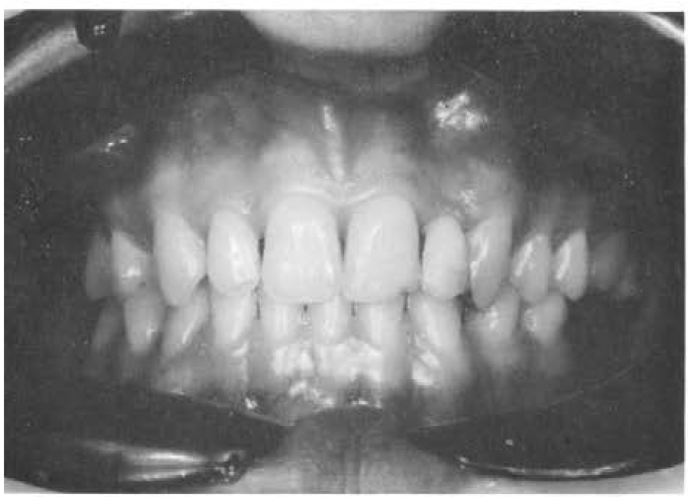
When the position of a tooth and its cuspal relationship with an opposing tooth is altered the mandible may not be able to reach intercuspal position without deflexion or repositioning of the teeth. When the mandible is reflexly deflected the muscles perform a *displacing activity*. The mandible is displaced until a new intercuspal position is achieved implying altered cusp contacts. This represents a series of reflex adaptive movements and the term *habitual intercuspal position* is given to the new occlusal position of the mandible. In the adolescent, when the dentition is developing, displacing activities are continuously taking place as teeth erupt and move into their permanent positions. It is questionable whether any tooth position is permanent in view of the ease with which they can move at any age. Thus it is claimed that all intercuspal positions are habitual. The exception to this is the rare occasion when intercuspal occlusion takes place on the retruded arc when, as was explained in Chapter 1, the term *retruded intercuspal position* is used.

Premature and initial contacts

In order to clarify the confusion that often exists between altering habitual intercuspal positions and repositioning of the teeth the terms *premature* and *initial* contacts were introduced by Thompson twenty-five years ago and were restated by him in the symposium on the Temporomandibular Joint (Thompson, 1964). These constitute momentary positions of the mandible. *Premature contacts* between teeth may occur within the interocclusal distance (freeway space) and the teeth are displaced prior to intercuspal occlusion. There is no alteration in intercuspal position nor in the interocclusal distance. *Initial contact* is the momentary occlusion that takes place at the summit of the IOD following which the mandible is deflected horizontally or vertically until IP is reached. On closing from various open positions the mandible goes directly to its habitual IP. On closing from rest position it will usually encounter the initial contact. This displacing activity is also referred to as a mandibular displacement (*Fig.* 15). As Thompson points out, the distinction between premature and initial contact is more a matter of judgement than of measurement. It is an important distinction, however, when treatment is being planned. Teeth in premature contact may be tender or mobile. Initial contact and displacement may produce muscle pain and restricted movement. Both conditions may require treatment. A vertical extension of mandibular displacement where the IOD is in excess of 4 mm. is referred to as *mandibular overclosure*. A further description of these disturbances will be given in Chapter 8 and treatment described in Chapters 12 and 13. For the present, it is important to be able to recognize rest position (as opposed to habitual posture), to visualize intercuspal position and clinically to diagnose any deflexion in the path of closure.

a

b



c

Fig. 15. Displacing activity of mandible. *a*, Rest position of mandible. *b*, Initial contact between lower and upper left bicuspids. *c*, IP following displacing activity to right side.

Intercuspal occlusion can therefore occur in many positions of the mandible as a result of changing surfaces and positions of the teeth. So long as the maximum number of teeth in opposing arches are in contact intercuspal position is achieved.

LIGAMENTOUS, TOOTH AND MUSCULAR POSITIONS

Brill and others (1959) introduced these terms to define three horizontal mandibular positions in the sagittal plane, in order to clarify functional movements of the mandible as distinct from extreme or artificially induced movements. The *ligamentous* is defined as an extreme position and corresponds to the retruded relation of the mandible. 'It is limited by the lateral ligaments of the joints.' The *tooth position* corresponds to the habitual intercuspal position and can be estimated as a vertical or horizontal component of the mandibular position. The *muscular position* is 'the contact position of the mandible defined by the reflex muscle pattern acting as the mandible closes from rest position'. The authors suggest that the coincidence of tooth and muscular positions constitutes a physiological condition and that, when they do not coincide, a potentially pathological condition results. 'In a very few patients' the three positions coincide, corresponding to retruded intercuspal position.

Criticism of these terms is threefold. Firstly, all positions are reached by muscle activity and confusion may be caused in assessing the difference between the tooth and muscular positions. However, this confusion can be cleared if it is understood that tooth position may follow a premature or initial contact on closure from rest position. Secondly, all border positions (and movements) are ligamentous (presumably meaning limited by ligaments) and are often functional. Thirdly, tooth (occlusal) positions include lateral, protruded and retruded occlusions in addition to intercuspal position. These may be pedantic criticisms and they are offered to emphasize that mandibular positions and movements are under neuromuscular control and are, therefore, continuously subject to adaptation and limitation by the shapes of the teeth and by the joints, including the ligaments. Definitions which are confined to the use of one tissue are therefore limited and could be misleading. The term 'intercuspal' is, admittedly, limited in that it only describes an occlusal position which takes place between cusps. One has to imply that this means the greatest number of cusps and opposing surfaces in contact. But this term and the others used do describe positions and movements. It can be assumed that they are caused by neuromuscular function, limited by ligaments and directed by intercuspal relationships and pathways of the mandibular condyles.

Other occlusal positions

The mandible can voluntarily close into several occlusal positions. There is usually only one such position preferred in each horizontal direction. Thus there is the retruded occlusal position (or retruded contact) on the retruded arc, the left and right lateral, and the protruded occlusal positions. The mandible can hold these positions but usually they are avoided in mastication when the bolus acts as a buffer. Occlusion, if any, is light and acts as a guide to IP. They cannot be called deflective contacts. However, these occlusions can be the cause of premature contacts and deflected mandibular movements. The

5

effects of these contacts will be discussed in the next section and again in Chapter 8.

BORDER MOVEMENTS

Functional movements of the mandible conform to a pattern when the dentition is complete and this applies to speech and other activities as well as to mastication. When teeth are lost or their shapes altered by disease, wear and restorations the patterns of movements will adapt to the changing environment. The neuromuscular function will ensure optimal efficiency and comfort within the limits of muscle, joint and tooth tolerance. Excluding tooth contacts, however, the mandible is capable of a wide range of *circumductory* movements limited by the ligaments of the joints as described in Chapter 2. These movements are more simply called *border* movements and they are reproducible if

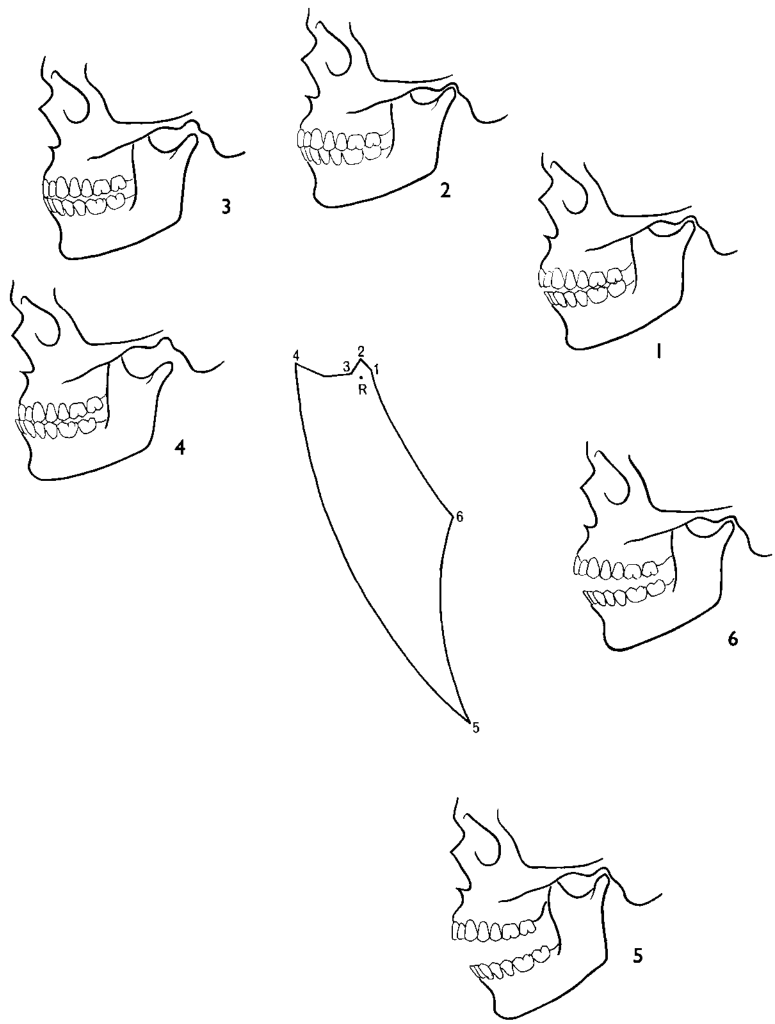


Fig. 16. The median vertical envelope of motion traced by point I. 1, Retruded occlusion. 2, IP. 3, Protruded occlusion. 4, Full protrusion. 5, Full opening. 6, Opening at lower extent of retruded arc.

the muscles are in good health. For the purposes of this study of occlusion border movements also include those limited by the teeth in the vertical upwards and lateral directions.

Border movements are those limited by ligaments and teeth against the maximal effort of the muscles. They form a characteristic reproducible shape and can be demonstrated in vertical and horizontal planes. Where tooth contacts provide the limits, the shape will vary according to the varying number and occlusal surfaces of the teeth. If the mandible is prevented from closing by the insertion of a central bearing screw and plate so that lateral movements are possible without tooth contacts the characteristic Gothic arch tracing can be scribed on the plate. If the complete range of horizontal movements is performed a reproducible diamond shape is achieved.

The median vertical envelope

Fig. 16 shows a series of diagrams of jaw positions during the vertical border movements. In the centre is the plane covered by a point I between the two lower incisors during the movement. Beginning at the retruded occlusal position (1) the mandible moves upwards to intercuspal position (2); thence to the protruded occlusal position (3); and full protrusion or reverse vertical overlap (4). The line 1–4 constitutes the upper limit of the border movement determined by tooth contact. The mandible then swings to full opening (5) with the chin forwards following which the chin is pulled back to begin closure. As the condyles reach their retruded positions in the fossae (6) the closure on the retruded condyle axis begins. The line 1–6 is the retruded arc and is the arc of a circle with the retruded condyle axis as centre. It can measure up to 20 mm. on point I when there are no inhibitions to border movements. Point R represents the rest position which exists 3 mm. below IP (2) but in front of and slightly below the retruded occlusal position (1). The vertical component of all mandibular movements takes place within this envelope and its chief significance is its reproducibility, particularly the retruded arc 1–6. As tooth positions change so will 1–4 change but this can be under the control of the dentist.

The basis for the foregoing observations on the median vertical envelope is Posselt's (1952) studies on the mobility of the mandible.

The horizontal envelope

Fig. 17 shows the mandible from above and the same point I making left and right lateral movements at a precontact level determined by the central bearing screw and plate. The border limits of these movements are shown in the diamond shape I–7–9–8. The lines I–7 and I–8 represent the Gothic arch. The horizontal diamond shape can be repeated at all levels of jaw separation although it will become smaller as the opening increases (*Fig.* 18).

The three-dimensional (or space) parcel

As the mandible moves laterally and protrusively while the teeth are in contact the shape of the border movements will be modified by the occlusal surfaces of the teeth. These movements can be followed in *Fig.* 18 which is a diagram of the completed three-dimensional parcel.

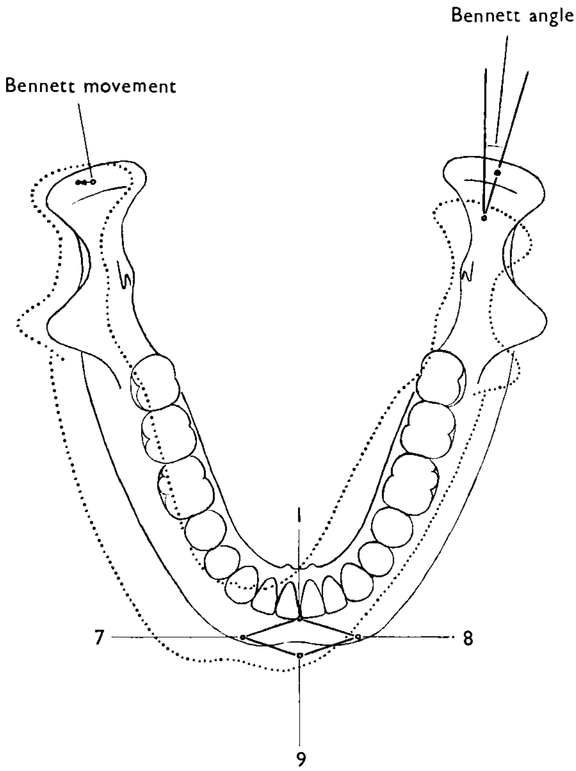


Fig. 17. Horizontal envelope of motion. Point I moves to 7 and to 8 on border movement. Then to 9 at full protrusion. Mandible is shown moving to right demonstrating Bennett angle and Bennett movement.

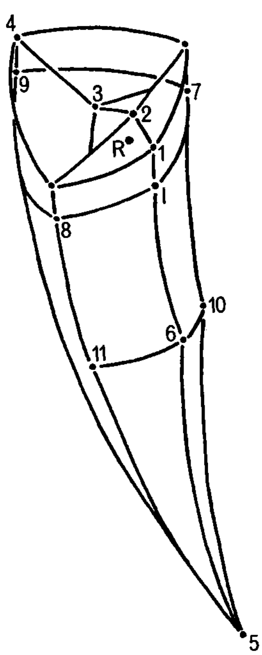


Fig. 18. Space parcel. Combination of median vertical envelope and series of horizontal envelopes. Numbers refer to positions indicated in the text.

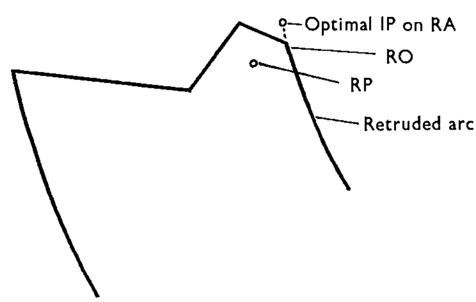


Fig. 19. Optimal IP. Point on retruded arc above RO where mandible is at optimal relationship to rest position for reconstruction procedures and complete dentures.

EXPLANATIONS AND COMMENTS

1 The retruded occlusal position can vary in height with tooth loss and wear but it remains on the retruded arc. The arc does not vary unless the muscles are inhibited in function by injury or fatigue or the joint by derangement or disease. Ideally, it can be argued that intercuspal position should be a little higher on the arc at the horizontal level of the habitual IP (*Fig.* 19). This is the level on the arc at which IP is optimal in reconstruction procedures and in complete dentures (Chapters 10 and 11). Expressed by initials this reads: IP on RA above RP.

2. The path 1–2 (*Figs.* 16, 18) is the upward articular movement to IP from retruded occlusal position and represents a bilateral sliding contact between one or more lower supporting cusps and upper distal cusp ridges (inner surfaces). If this articulation is not bilateral a deflexion to an altered IP takes place and a muscle disability may result.

3. The articular movement to the protruded occlusal position from IP (2–3) represents the incisal guidance and should be a straight line. If it wavers to one side or the other there may be tooth interferences combined with a minor joint derangement.

4. The opening path 4–5 should also be seen as a straight movement, viewed from the front, otherwise a joint derangement may be suspected. It represents rotation and translation of both condyles.

5. The first phase of the closing movement (5–6) represents the condyles moving back along both eminentiae as they rotate and this, too, should be a straight vertical movement until both condyles reach the glenoid fossae when they begin to rotate.

6. The closing (and opening) retruded arc movement (6–1) is fundamental to all studies and analyses of occlusion and its main feature is the reproducibility of the retruded condyle axis.

7. The rest position (R) lies within the parcel of movement. Its significance is the constancy of its vertical and horizontal relationship to the maxilla and its value is as a reference position for the OVD and for the interocclusal distance between OVD and RVD.

8. The Gothic arch movements I–7 and I–8 are flattened arcs since the centre of rotation of both movements are moving (Bennett movement). Similar arcs of movement can take place at 6–10 and 6–11 while the mandible is still on the retruded arc. These paths are usually seen in reverse since the tracing table is usually attached to the mandible and the tracer to the maxilla (*Fig.* 53*c*, p. 117). The significance of these movements is that during lateral articulations (beginning or ending at point 2) the same flattened arcs of movements are followed by each cusp opposing each fossa depending on the articular contacts. Ideally, the mandible should be able to move along these borders during articulation without cusp interferences.

9. All mandibular movements take place within this space and seldom reach a border except perhaps in retruded occlusion which is sometimes used in forceful closure and parafunctional movements. However, if cusp interference prevents movement towards a border position disturbances may result in the musculature. Further, if a joint derangement, such as click, exists border movements may be prevented and, again, the musculature may suffer.

10. The practical application of the border movements is the possibility for transferring the vertical retruded arc and the horizontal (Gothic arch)

movements to an articulator (Chapter 7). This application provides the basis for gnathology and the gnathological articulators. In the diagnosis and treatment of occlusal disturbances the accurate transfer of the border movements to such an articulator is of great assistance since all occlusal positions and articular movements made in the mouth can be seen on the articulator.

A study of the parcel of mandibular movement, therefore, has more than academic interest and reference to it will be made in subsequent chapters.

Bennett movement

There should now be some familiarity with this movement and the emphasis here is on the lateral shift that takes place in lateral masticatory movements in both incoming and outgoing phases where the teeth meet lightly, if at all. Any alteration to cusp height or shape, particularly in guiding cusps, may cause premature contacts and consequent disturbances. In parafunctional grinding movements, too, the Bennett movement dominates the initial outgoing phase from IP and obstructions to this movement can be equally if not more harmful. The Bennett movement is composed of two distinct phases: an immediate translation which takes place before the rotation, and a progressive translation which accompanies the rotation. Tracings of these movements can be seen in the transfer of these movements to a gnathological articulator (*see* Chapter 7).

In a recent study of 30 dental students Preiskel (1972), using ultrasonic measurements, observed that the amount of Bennett shift varies between individuals but that the movements could be repeated in the same individuals. He also observed that there is a graduated increase in the movement when the occlusal vertical dimension was increased. The clinical significance of this component of masticatory movement lies in the need to allow for this movement in making restorations involving the cusps, cusp ridges and triangular ridges.

Border movements are performed voluntarily for the most part but in the healthy system it is possible to use them involuntarily as the needs arise.

CONDYLE POSITIONS AND MOVEMENTS

When considering the positions and movements of the mandibular condyles it is helpful to remember that there are two and that they move as if joined by an axle. This axle is the retruded condyle axis and can be seen to rotate only when the mandible (and its condyles) is fully retruded and uninhibited by stiff, sore or resistant muscles.

Three-dimensional movements

In the Preface it was mentioned that a three-dimensional approach was necessary when trying to understand mandibular movements. In Chapter 2 it was said that all the muscles of mastication are in function (either contracting or relaxing) in all movements of the mandible. A three-dimensional movement is, therefore, inevitable. In applying this principle, the movements of the mandible can be analysed into three centres of rotation in each condyle region (*Fig.* 20). These are the *horizontal-sagittal axis of rotation* (the retruded condyle axis) resulting in the vertical opening and closing of the mandible (*Fig.* 20*a*), the *vertical axis of rotation* resulting in a horizontal arc of movement (*Fig.* 20*b*), and the *horizontal-coronal axis* resulting in a vertical arc of movement in the coronal plane (*Fig.* 20*c*). In visualizing these movements it may be helpful to refer to a diagram (*Fig.* 21) of the three planes mentioned.

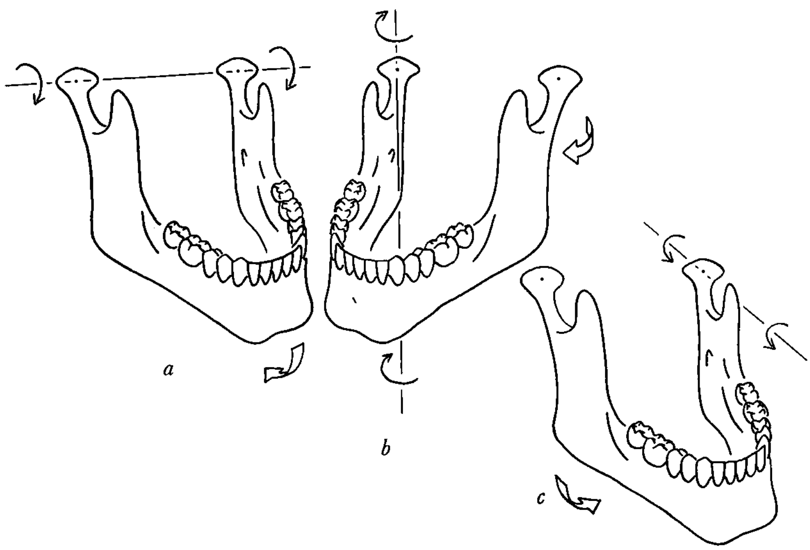


Fig. 20. Mandibular centres of rotation. *a*, Horizontal-sagittal (retruded condyle axis). *b*, Vertical axis with horizontal rotation. *c*, Horizontal-coronal axis. Permits descent of balancing condyle.

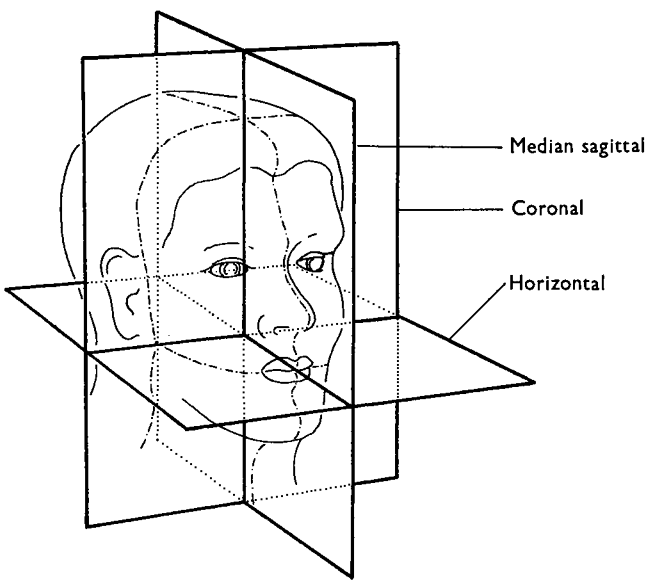


Fig. 21. Planes of the face.

Rotation on the retruded condyle axis will produce a two-dimensional vertical arc of movement. All other movements are three-dimensional and represent movements of the same condyle axis when it is moved away from its retruded relation to the glenoid fossae. Thus the axis (both condyles) protrudes and, as tooth contacts are encountered, it rotates and tilts to accommodate the varying interruptions to a straight protrusive movement. During this movement the condyles maintain a 'sharp contact' with the menisci and the movement itself is reproducible. If the condyle path could be seen it would probably be slightly curved, but the rotations of the axis permit an uneven course for the teeth (and the mandible) to follow. If the movement is lateral the arc of the balancing condyle will follow a steeper path and the axis will rotate while making this movement. At the same time the rotating (working) condyle will follow its Bennett shift. The path followed by each cusp in relation to bolus or opposing tooth can therefore adapt to any encounter. The clinical application of this information is that if the retruded condyle axis and both protrusive and lateral paths of condyle movements can be transferred to an articulator all mandibular movements can be copied (*see also* Chapter 7).

Condyle positions

At rest position and intercuspal position the condyles occupy positions in their respective fossae which show a small change in outline between each position.

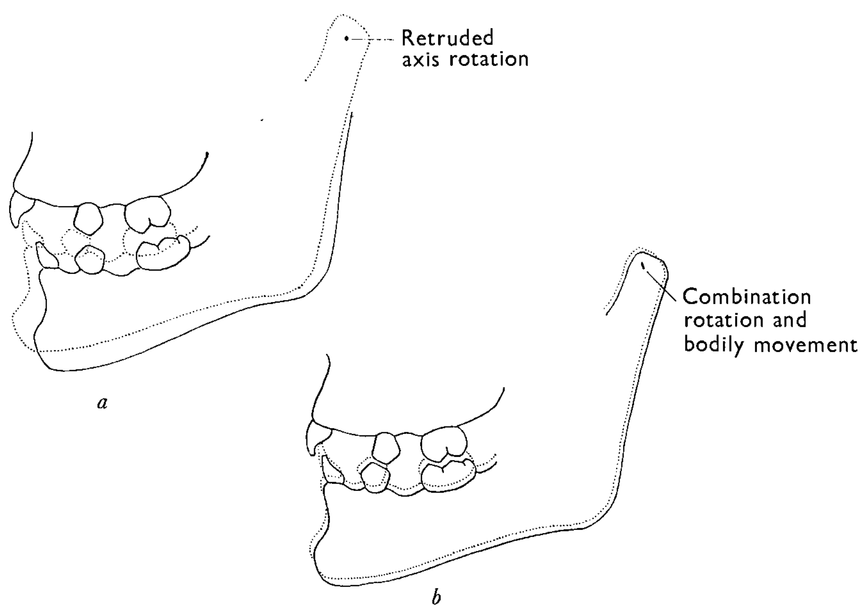
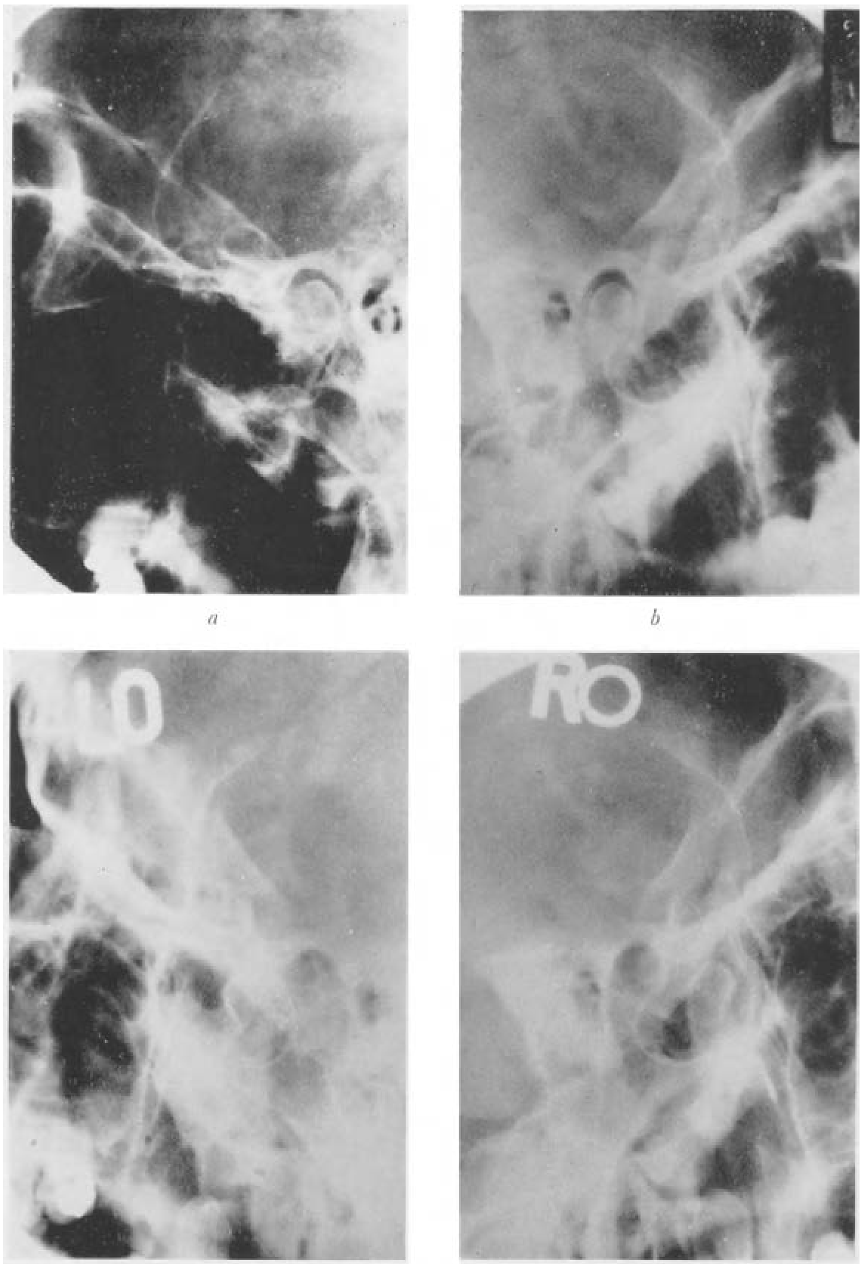


Fig. 22. Condyle positions during closing movements. *a*, Retruded arc to RO. *b*, Rest position to IP.

The movement of the mandible is upwards and forwards for a distance of 2–3 mm. and the condyle axis rotates fractionally and rises bodily upwards. The outline of one condyle traced from an X-ray taken at rest position shows a small change in relationship to the fossa to one traced at IP (*Fig.* 22*b*). Initial contacts and consequent displacements may show varying degrees of change in outline when compared with rest position.

On the retruded axis the condyle outline demonstrates rotation (*Fig.* 22*a*). On protrusion and lateral movements the condyles move downwards and forwards at a measurable angle to the horizontal plane as the mandible makes protrusive and lateral gliding articulation movements. The angle of descent can be measured by inserting a wax wafer between the posterior teeth just prior to protruded occlusion and by transferring this record to casts mounted on an adjustable articulator. The condyle angle can then be adjusted on the articulator when the cast teeth of both arches are seated in the wax record. When the mandible moves laterally to one side the angle of the balancing



a b

c d

Fig. 23. X-rays of condyles open and closed. Normal joint spaces at IP (*a* and *b*) and normal degrees of translation and rotation on opening (*c* and *d*). (*By courtesy of Dr. J. J. Prior, Eastman Dental Hospital.*)

condyle is steeper than the angle of straight protrusion when both condyles move together. The transfer of condyle axis positions and movements to articulators will be described in Chapter 7.

JOINT SPACE

The spaces between the condyles and glenoid fossae at intercuspal and open positions, as seen on X-ray, have a characteristic shape and an example is shown in *Fig.* 23. The space becomes narrowed in old age but can also be reduced in arthritic conditions (*see* Chapter 9). Effusion into the joint cavity will increase this space and in the early stages of rheumatoid arthritis the space is often increased due to the formation of the pannus. These differences in joint space can be seen between two joints in the same individual and this feature can be helpful in diagnosis.

CONDYLE DISPLACEMENT

As was suggested above initial contact and subsequent displacement can result in a change between condyle outline at rest position and at intercuspal position.

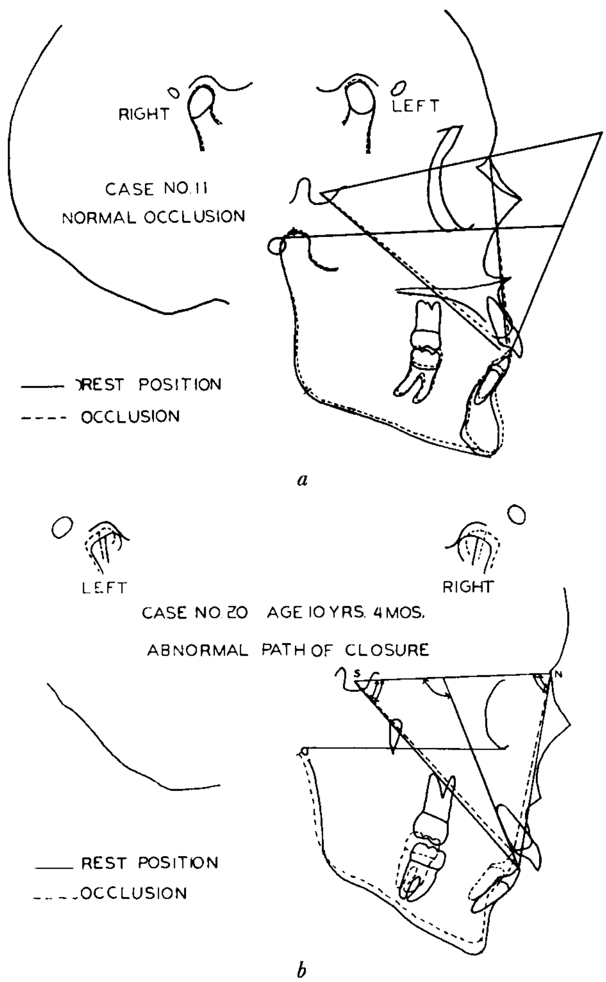


Fig. 24. Tracings of lateral skull X-rays. Rest position superimposed on intercuspal position. Normal (*a*) and abnormal (*b*) paths of closure. (*By courtesy of Dr. J. R. Thompson.*)

X-rays of the condyles at rest position are superimposed over those taken at IP using the fossa outline and auditory canals as references. Differences between the two condyle outlines are indicative of mandibular displacement on closure (*Fig.* 24).

Comment

There are three aspects of this study of positions and movements which deserve emphasis. The first is that occlusal positions are not voluntarily maintained for more than a fleeting contact during function. Intercuspal position is used when swallowing but this, too, is an occlusion momentarily held. On the other hand, all occlusal positions are liable to be used during parafunctional habits and whether these are positions or movements the reflex response to contact is overcome by the muscle forces used.

Secondly, the reflex response to contact is so immediate that whether the contact is with an opposing tooth, food bolus or outside agency an alteration in the path of movement is inevitable. This makes the registration of a mandibular position in relation to the maxilla an operation uncertain of success. The proprioceptive response to any interocclusal substance such as wax is so sensitive that a change of position is likely to alter the resultant record. In addition, the operator's fingers on the patient's mouth are equally certain to cause a reflex adaptive movement. The solution to this neuromuscular problem is to use the reproducible retruded arc on which a forcible closure into the registration substance is less likely to produce a reflex alteration of position or movement.

The third aspect for comment is the existence of reference positions and movements which are necessary for diagnosis, treatment and the transfer of the mouth to an articulator. The rest position is constant enough to be a vertical reference level in relation to intercuspal position. But any attempt to register the relationship between mandible and maxilla at this position will fail for the reasons given in the previous paragraph. The reproducible retruded arc and the retruded occlusal position on it are the only reliable references for transfer. One must look to the borders of mandibular movement for reliable reproduction.

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Chapter 5

Occlusion and articulation

THE purpose in this chapter is to describe the forces which are received by the teeth in function and to relate the instantaneous moments of occlusion to the various patterns of articulation which constitute occlusal function.

THE FORCES ACTING ON THE TEETH

Forces and responses

The forces which act on the teeth and cause them to move within their periodontal tissues vary in magnitude, duration, frequency and direction. The responses by the teeth to the forces depend on such factors as the shape and length of the roots, the characteristics of the fluid content of the periodontal space, the composition and orientation of the periodontal fibres and the extent of alveolar bone (Lewin, 1970a, b). It is, therefore, difficult to assess what is a normal response to a force on a tooth and what is potentially harmful. Lewin (1970a, b) has reviewed the literature on this subject and has devised methods of measuring the omnidirectional displacements of a tooth when subject to forces causing mesial and distal translations, buccal and lingual translations, and rotations about its long axis. An omnidirectional transducer is used and the information which this supplies can be used to specify the displacement of the whole tooth or any point on the tooth. Other references on this topic are Picton (1962a, b), Mühlemann (1967) and Parfitt (1967). Lewin (1970a) divides the displacements which a tooth can make into translatory and rotational components. Each of these components can be subdivided into apical, mesial-distal and buccal-lingual translations and rotations. A tooth can be displaced in one or more of these six basic motions and the result is an omnidirectional movement in response to a force (*Fig.* 25). The extent of this movement will depend on the variable forces caused by occlusion, food bolus or outside agency. It should be remembered that, in intercuspal occlusion, the forces are shared by the remaining teeth in contact. Therefore, the forces produced on individual teeth will be opposed by adjacent tooth contact where this exists.

Omnidirectional and unidirectional responses

These omnidirectional tiltings and rotations of a tooth when subject to a vertical or horizontal force reach a limit when the periodontal receptors cause a reflex stoppage of the force or when an equal opposing force is reached. When the force is removed the tooth will recover its position due to the elastic recovery of the compressed periodontal tissues. Each tooth has a centre of resistance (Fish, 1917) through which the forces pass and this can alter when alveolar bone is lost. Each tooth has adjacent tooth support, the loss of which may alter the elastic response. Each tooth has horizontal muscle support on its buccal and lingual surfaces and the forces created by them can be habitually altered. These three factors may result in a unidirectional movement of a tooth when subject to a force and this will result in repositioning of the tooth. A tooth will continue to move unidirectionally until it reaches a position of stability where

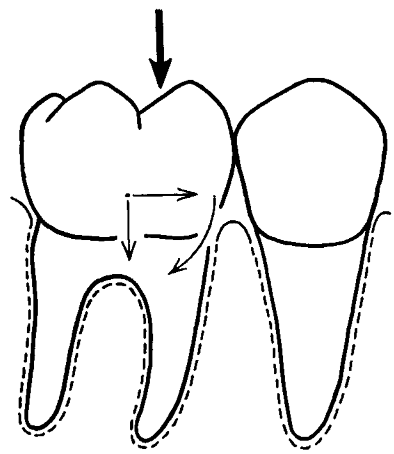


Fig. 25. Omnidirectional movements in response to force on a tooth.

opposing forces are equal to the moving forces. These features of omnidirectional movement and elastic response and of repositioning of teeth are characteristic responses to forces.

The forces which act directly on the teeth are *muscular*, *occlusal* and *extrinsic*. Occlusal and extrinsic forces are generated by muscles but the contact is made by teeth and outside agencies respectively.

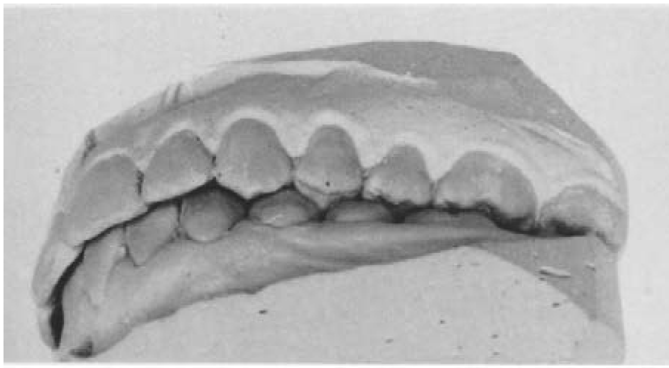
Muscle forces

The muscles of the tongue on one side of the teeth and those of the lips and cheeks on the other (the orofacial muscles) maintain a varying source of horizontal forces on the teeth. The activities of these muscles conform to a stable pattern throughout life and are responsible for the horizontal positions of the teeth as they develop vertically. Overcrowding of teeth may lead to alterations of these positions against the forces of the muscles. Various skeletal and muscular abnormalities may lead to inadequate muscle forces being directed on the teeth. The Class III skeletal relationship and the short upper lip are examples which may lead to an incompetent lip seal and to the tongue producing a forward force on the upper teeth. The forces between the opposing orofacial muscles usually result in a stable horizontal relationship of the teeth. The position which the teeth occupy in this relationship is known as the *neutral zone*. This is a term which does not satisfy the scientists but is helpful to the clinician in assessing possible causes of repositioning of the teeth. It is also helpful when deciding the horizontal positions of denture teeth. Artificial teeth set on one or other side of the neutral zone will be always subject to dislodging horizontal forces.

All activity by the orofacial muscles produces movement of the teeth. Provided it is equally opposed, the movement will be omnidirectional and the teeth will be restored to their original positions. If not they will be repositioned.

Occlusal forces

Intercuspal occlusion takes place between cusp ridges and opposing fossae (formed by triangular ridges) or between cusp ridges and opposing marginal ridge areas. The cusp ridges make a tripod of contact leaving the cusp apex

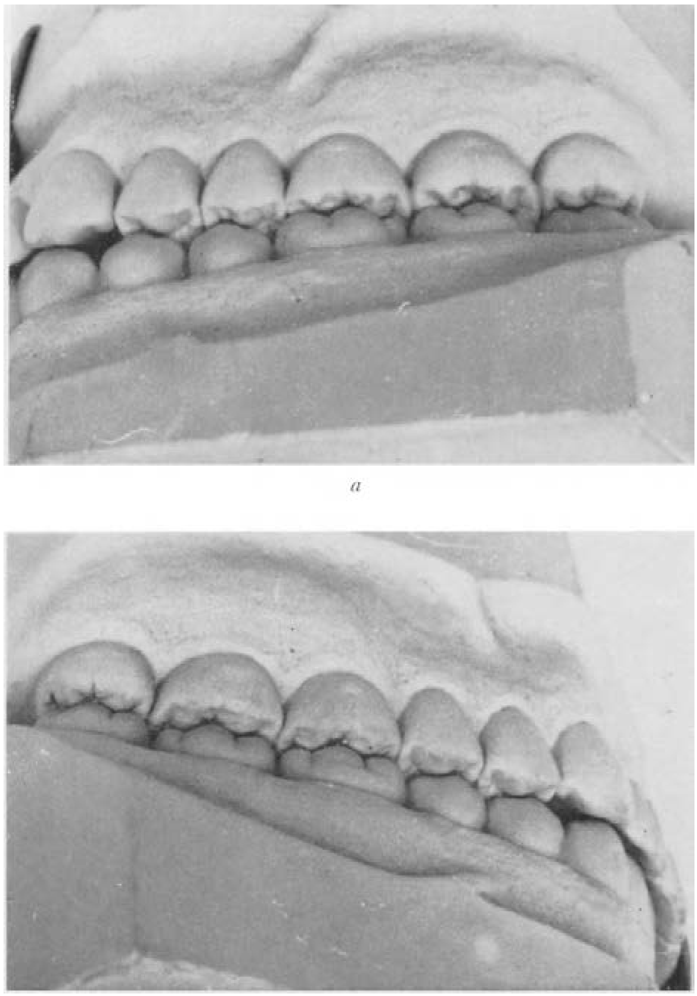


a

b

Fig. 26. Casts of buccal quadrants. *a*, Left. Cusp–ridge IO. *b*, Right. Cusp–fossa IO.

out of occlusion (*see Fig.* 9, p. 28). If the fossa with its ridges can be visualized as a bowl the contacts take place around the rim of the bowl at three points and not at its base. In the case of occlusion with marginal ridges it is the opposing cusp ridges which make contact and not the cusp itself. This feature provides stability of contact and distributes the forces produced on intercuspal occlusion. It also emphasizes the difficulty of seeing occlusal contacts in the mouth and the need to tilt the casts in order to see them (*Fig.* 26). Even on casts it is difficult to see contacts from the lingual aspect without removing the lower lingual cusps. This feature also demonstrates the shortcomings of two-dimensional line drawings of teeth in occlusion. As was pointed out in Chapter 2, only two supporting custs in each buccal segment contact an opposing fossa, the remainder making contact in the opposing ridge areas. In view of the majority of ridge contacts this is referred to as cusp–ridge occlusion and is illustrated in *Fig.* 26*a*. The potential harm which may accrue from this occlusion is the action of the plunger cusp which may develop when proximal restorations are made with ill-defined ridge shapes or when adjacent teeth separate. It can be seen in *Fig.* 26*a* that the lower first bicuspid has slid forwards into an unstable occlusion between the upper bicuspid and canine.



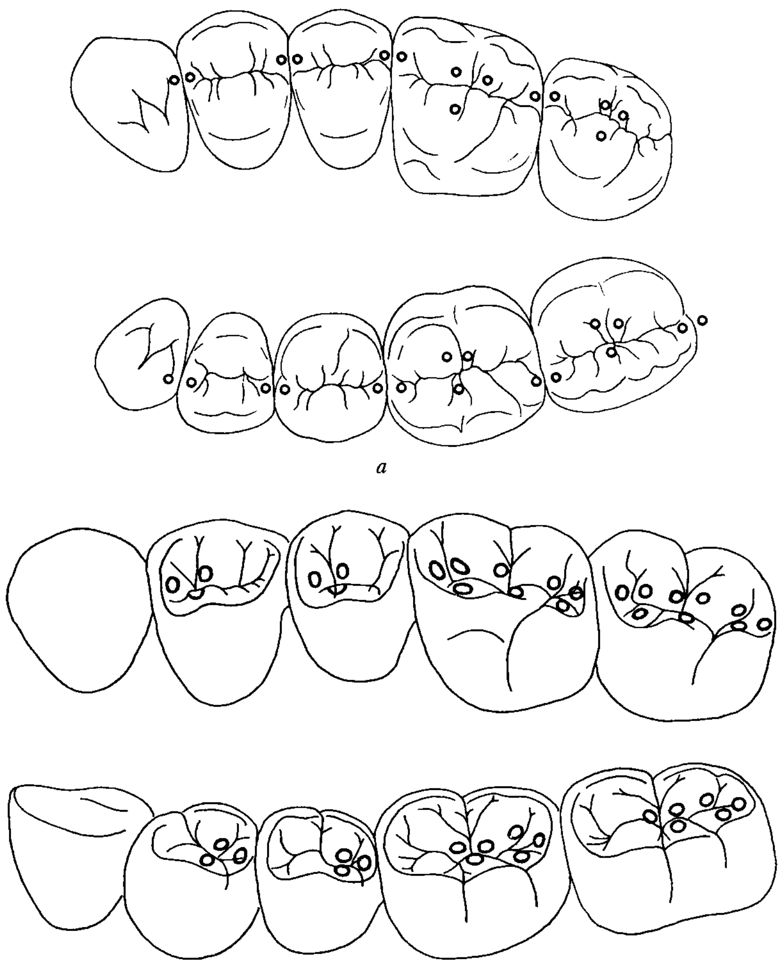
a

b

Fig. 27. Casts of buccal quadrants of reconstructed dentition. *a*, Left. Cusp-fossa IO. *b*, Right. Cusp-fossa IO. (*By courtesy of Dr. P. K. Thomas.*)

This may lead to repositioning of the affected teeth and to interdental problems. The disturbance is not helped by the absence of the lingual (guiding) cusp on the lower bicuspid. When reconstruction procedures are being planned, efforts are made to provide cusp–fossa occlusion, wherever possible, in order to prevent (or cure) this disturbance. *Fig.* 27 illustrates a mouth restored in this way by Thomas (1973). *Fig.* 26 illustrates how it is possible to have cusp–ridge occlusion on one side (*Fig.* 26*a*) and cusp–fossa on the other (*Fig.* 26*b*) in the natural dentition. *Fig.* 28 illustrates the location of the contacts in cusp–ridge and cusp–fossa occlusions.

As has been pointed out, the forces in empty mouth intercuspal occlusion (when swallowing) are shared between all the teeth present. If tripod contact exists between all posterior tooth contacts and if two complete arches are present all teeth will return to their original positions when the teeth part.



a

b

Fig. 28. Sites of contact by supporting cusps. *a*, Cusp–ridge IO. *b*, Cusp–fossa IO. (*After Lundeen*, 1971.)

Parafunctional closures, however, may lead to wear of the interproximal contact areas and a forward drift of all teeth may be the result.

ANTAGONISTIC OCCLUSAL FORCES

These can occur when two teeth in the same segment, either adjacent or separated by other teeth, are receiving occlusal forces in opposing directions. This is illustrated in *Fig.* 29 where the lower second molar is producing a forward force and the lower first bicuspid a backward force in intercuspal occlusion. These opposing forces have the adverse effect on the upper second bicuspid of aiding its extrusion and the possibility of compressing its periodontal tissues. This is a missing tooth problem and is usually associated with a periodontal disturbance of the affected teeth.

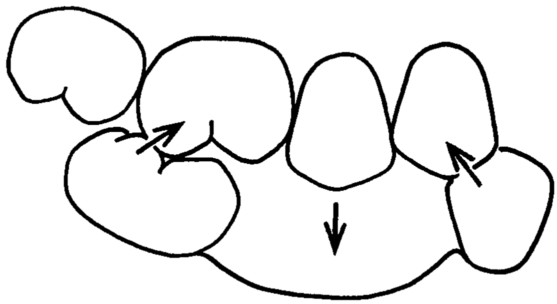


Fig. 29. Antagonistic occlusal forces (*see* text and also *Fig.* 65*b* and *c*, p. 153).

HEALTHY RESPONSES

A healthy response to occlusal forces depends on six factors. These are: stable intercuspal occlusion, stable contact points; healthy periodontal tissues; competent orofacial muscle activity; favourable crown–root ratio and root direction; occlusion of limited magnitude and duration. The direction of the occlusal forces is of less significance than the health and function of the tissues involved.

TWO PHASES OF OCCLUSION

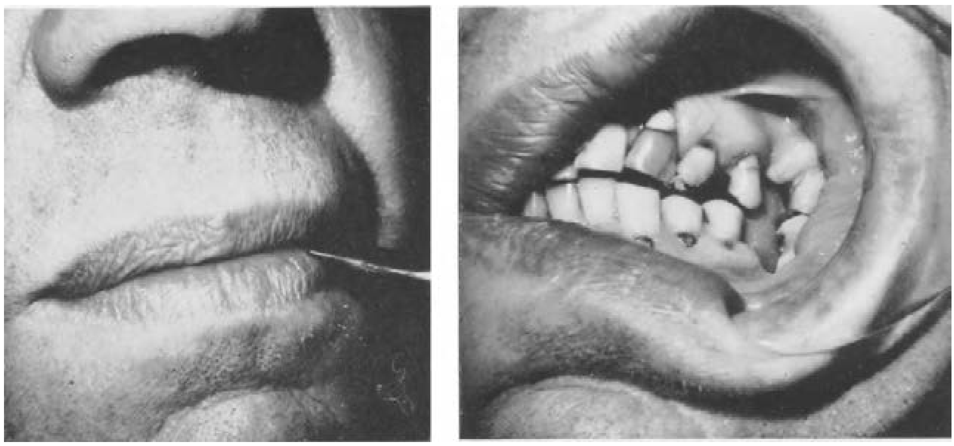
A phenomenon of tooth contact provided by the periodontal membranes is the two phases or levels of occlusion. The first contact between the arches is followed by the omnidirectional movement of each tooth within its membrane. The combination of upper and lower tooth movements results in a difference in level of occlusion which, though not measurable, has some clinical significance. It will include any premature contact and movement of the affected teeth and can confuse the clinician on the occlusion reached between two plaster casts of the teeth. When casts of both arches are placed together the occlusion recorded is that of the first and lightest contact, since there are no periodontal membranes in plaster-of-Paris. This feature may account for errors in transfers of occlusal relationships and in diagnosis and treatment.

OTHER OCCLUSAL FORCES

The contact forces between the teeth mentioned so far have related to those in intercuspal occlusion. However, the principles apply to protruded, retruded and lateral occlusions. These are generally articular forces and take place as guiding contacts during mastication or as parafunctional contacts to and from intercuspal position. In the case of the former, the forces are light and easily reciprocated except perhaps in the unexpected balancing side contact when the muscles suffer more than the teeth; in the case of the latter, the forces are likely to be heavier although they can vary between light sliding and gnashing of the teeth. A sustained force between two canines can be a cause of wear facets as seen in many adolescents. Between two centrals it can be a cause of pulp death in adults (*see* 'Disorders', Chapter 8).

Extrinsic forces

These are the forces caused by biting on pencils, pipes, finger-nails and other outside agencies. These represent parafunctional activities of the muscles but the force on the teeth is created by the object. The cause may be prolonged enough to cause reposition of the affected teeth (*Fig.* 30). The proprioceptive response to an occlusal masticatory force is to part the teeth but this is overruled by the voluntary impulse to contract the muscles and may constitute an irrelevant muscle activity (p. 40).



a *b*

Fig. 30. Effect of holding pipe. *a*, Pipe in habitual position. *b*, Reposition (depression) of affected teeth. Remaining teeth in IO.

If the forces on the teeth could be limited to those exerted by the bolus in mastication and by light closure into intercuspal position while swallowing there would be few disorders of occlusion to diagnose and barely a need to write this book. However, disease and dysfunction lead to disorders of the masticatory system and these include the functions of occlusion and articulation. In addition to the occlusal forces acting on the teeth there are the articular movements and contacts and these have to be considered before making diagnoses and planning treatment.

ARTICULATION

In most people the endogenously determined stable patterns of mandibular movement are efficiently related to the articular contacts between the teeth. The occlusal forces acting either through a layer of food or directly between the teeth are seen as moments of contact making up the pattern of articulation. A stretched analogy might be the series of contacts which the feet and heads of footballers make with the ball before it contacts the back of the net. In the case of occlusal function the goal is the intercuspal position which the mandible reaches when the bolus is finally swallowed. The patterns vary but the objective is the same, and what is natural or normal for one individual has to be seen in relation to the efficiency of his mastication and other oral functions.

The topic of articulation between the teeth was first brought to the attention of dentists by Bonwill (1887) who was 'fully persuaded that of all that constitutes dentistry proper the mechanical forms the basis'. This view still dominates much of restorative and prosthetic dentistry although, in the past thirty years, the physiological basis for the study and functions of the masticatory system has provided a balance to the mechanistic approach. None the less, Bonwill's contribution is a milestone and his influence on other celebrated names in dentistry is undoubted. In particular are those of Gysi (1910) and Schuyler (1935) whose works are still standard on the subject of articulation of the teeth.

Bonwill introduced the term 'articulation' for the teeth as 'a word of action throughout' while occlusion 'answers to the mere act of closing the teeth and lips'. In a stirring phrase from the lectern he cried: 'We must impart action to those otherwise whited sepulchres'. He is perhaps better known for his observation that in the mandible an equilateral triangle exists bounded by the two condyles and the contact point between the lower central incisors. The sides of this triangle measure 4 in. in the average mandible, and this forms the basis for his articulator which will be described in Chapter 7. However, Bonwill's claim that 'nature's triangle' with the double joint permitted 'the largest number of teeth to antagonize at every movement' provided an objective for articulation which is an objective for successful complete dentures today. It was inevitable, perhaps, that he should refer to the occlusal surfaces of the teeth as the grinding surfaces, thus giving emphasis to the habit of parafunction in the empty mouth almost as a desirable objective in the natural as well as in the artificial dentition.

Joint articulation. It should not be forgotten that the term 'articulation' applies to the contact that exists between bones and their respective cartilages and opposing bones. In the masticatory system it applies to the mandibular condyles, as well as to the teeth, and the term 'articulator' derives from this application.

PATTERNS OF ARTICULATION

Before proceeding to a description of articular patterns or schemes attention is drawn to the glossary of terms where balanced and free articulation are defined in addition to articulation itself. It is pointed out that these terms refer to tooth contact in the empty mouth. This infers that articulation between the teeth in the empty mouth is a natural function of the masticatory system but the reverse is true. It was stated in Chapter 1 that occlusion (including articulation) is not necessary for efficient mastication and that the more efficient the occlusion (and articulation) the less the teeth need touch each other. One of the causes of empty mouth (parafunctional) contacts is cusp interferences and when they occur there is a tendency to glide on them. This habit is self-perpetuating and potentially harmful. The analogy of the itch is mentioned to emphasize the point. One is unaware of healthy skin but an itch will induce scratching. The habit can hurt. It is therefore necessary to assess a mouth for the efficiency and comfort of its articular movements in the empty mouth. Mastication introduces the bolus between the teeth and articulation can only be observed with difficulty. It can be assumed, however, that if cusp interferences exist in the empty mouth they are likely to exist similarly in the masticating mouth. This assumption is based on another, namely, that articulation occurs during mastication. Experimental evidence suggests that it does and this will be discussed in Chapter 6.

Patterns of articulation are individual and, when free from interferences, are contacts of which most people are unaware. The need to analyse and classify them arises when interferences arise and cause disturbances and when restorations and replacements have to be made. The classifications may seem to be largely theoretical and not related to natural function but they will serve to provide a yardstick of what is possible, what is desirable and what is potentially harmful. Nairn (1973) has drawn attention to certain fallacies in the assessment of articulation. He disputes the conventional views that a 'deep overbite' (steep incisal guidance) constitutes a 'locked bite' and that protrusive articulation balanced by posterior tooth contacts is necessarily a requirement for either the natural or artificial dentitions. He points out the error, firmly established by many authorities, that working side articular movements result in lower cusps gliding down upper triangular ridges (*see Fig.* 32*c*). In support of this criticism he refers to Gysi (1910, 1913) who stated that in working side occlusion (and, therefore, articulation) 'cusp does not climb cusp'. Nairn's recommendations for providing free articulation in the setting of artificial teeth are threefold. Firstly, even interdigitation of cusps on the working side with an unobstructed articular movement to IP. Secondly, avoidance of premature contacts on the balancing side. Thirdly, protrusive articular balance should not be achieved at the expense of unstable tooth positions with consequent disturbed function or appearance.

Reference will be made later in the chapter to the anatomical features which influence the patterns of articulation and these have to be considered when providing free articulation for complete dentures. It should not be forgotten, however, that the lateral and protrusive movements of the mandible are governed not only by the paths of condyle guidance but also by the rotation of the condyle axis. Therefore, any lateral or protrusive movement can be modified by an opening or closing component. This permits the phenomenon of reflex adaptation to which many references are made throughout the text.

The patterns of articulation which follow will be described as occurring in the empty mouth for the natural dentition. This will be followed by some comments on their application to the artificial dentition where their requirements are more practical. These can be seen by asking the patient to move his mandible from side to side, backwards and forwards, while keeping the teeth together. The paths of movement will generally be those which offer the least resistance to free articulation. The contacts vary between single opposing teeth and groups of teeth and between one or more opposing segments. The patterns will be described, firstly, according to the *movements* made and, secondly, according to the *contacts* observed.

Movements of articulation

There are four articular movements: *retrusive*, *protrusive*, *left* and *right lateral* movements.

RETRUSIVE

This takes place from retruded to intercuspal occlusion and is usually confined at first contact to the cusps and cusp ridges of two opposing molar teeth on each side of the mouth (*see Fig.* 16, p. 54). During the forward and upward movement the cusp ridges of the lower teeth progressively engage the upper triangular ridges until they glide into intercuspal occlusion. When these articular contacts are not bilaterally balanced and the resultant movement is deflected to right or left disturbances may result in the musculature.

Arstad (1956) referred to wear facets on the teeth between intercuspal position and retruded occlusal position and described this as lack of harmony between the two positions which could result in an anterior displacement.

PROTRUSIVE

This takes place from protruded to intercuspal occlusion and, in mouths where Class I jaw and tooth relationships exist, there is usually group contact between upper and lower incisors at the beginning of the movement. This may continue to intercuspal occlusion and be combined with balanced articulation between labial and buccal segments. In Class II mouths this will not be possible if the horizontal overjet does not permit it (division 1) or if the vertical overlap causes disclusion between the buccal segments in protrusion (division 2). This movement is often reversed (from intercuspal to protruded occlusion) during parafunctional articulation.

RIGHT LATERAL

This takes place as the mandible moves in from the right side when contact may begin between the opposing canines. Group contact between the opposing buccal cusp ridges on the right side may then take place as the mandible glides into intercuspal position. When this articulation is accompanied by contact between the opposing lingual cusp ridges on the right side there exists *cross tooth balance* on the working side. When, in addition, there is contact between left lower buccal cusps (their occlusal facing triangular ridges) and their opposing upper lingual cusps (their occlusal facing triangular ridges) there exists *cross arch balance*. This is also known as 'bilateral balanced articulation'. This movement can also take place in reverse, from intercuspal position outwards during parafunctional articulation.

LEFT LATERAL

This is the reverse of the right lateral articular movement.

In the natural dentition these movements are usually confined to one pathway in each of the four directions. In many mouths only one or at most two are used and this restriction is dictated by cusp interferences. These movements can often be recognized by facets of wear on the teeth which are usually an indication of articulation in the empty mouth. Facets of wear can, however, be caused by abrasive foods or by outside agencies. In a lifetime of function and parafunction almost any contact will cause wear if it continues for long enough. And once a facet always a facet.

Contacts during articulation

There are three recognized categories into which articular contacts can be classified: *bilateral balanced*, *unilateral balanced* and *anterior segment* (also referred to as disclusion with canine rise or mutually protected occlusion).

BILATERAL BALANCED ARTICULATION

During lateral movement

Working side. The lower buccal cusp ridges make articular contact with the upper buccal cusp ridges as the lower lingual cusp ridges are making contact with the upper lingual cusp ridges. The upper and lower cusps pass each other with minimal lift or change in the occlusal vertical dimension on the working side during this movement (*Figs.* 31*a* and 32*b*).

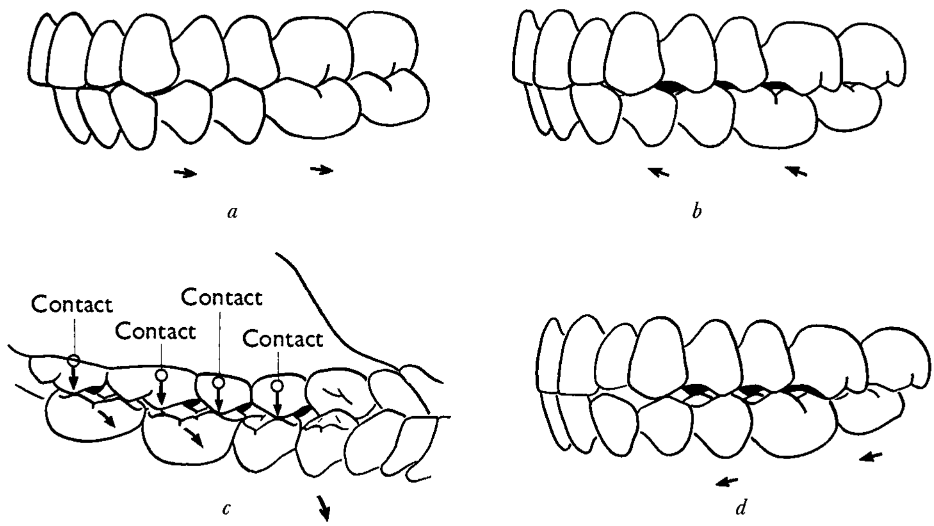


Fig. 31. Bilateral balanced articulation. *a*, Movement to working side. *b*, Movement from balancing side. *c*, Movement from balancing side viewed from lingual. *d*, Movement to protrusion.

Balancing side. The lower buccal cusps and their occlusal facing triangular ridges make articular contact with upper lingual cusps and their occlusal facing triangular ridges. The path of this movement causes a separation between the opposing balancing segments determined jointly by the slopes of the ridges involved and the downwards and inwards path followed by the balancing side condyle (*Figs.* 31*b*, *c* and 32*b*)

Each working and balancing path made by a cusp on the opposing tooth traces a miniature gothic arch (*Fig.* 33). This can sometimes be seen when lateral articular movements are made on a newly packed amalgam or direct wax pattern for an inlay or crown (*see Fig.* 72, p. 171). The apex of this arch does not represent the retruded relation since the mandible is in habitual IP. The apex is, therefore, blunted.

Anterior segment. The lower canine cusp and mesial cusp ridge glides along the distal–lingual surface of the upper canine on the working side and passes between the canine and first bicuspid cusp ridges. The working side lateral and central incisors maintain contact. On the balancing side contact is lost.

During protrusive movement

Anterior segments. The incisal edges of the lower incisors and canines make articular contact with the lingual surfaces of the upper incisors and canines (*Fig.* 31*d*).

Posterior segments. The mesial buccal and lingual cusp ridges of the lower teeth make articular contact with the distal buccal and lingual cusp ridges of the upper teeth (*Fig.* 31*d*).

This is the prosthodontic concept of balanced articulation and has been advocated for the past eighty years as an aid to stability for complete dentures.

UNILATERAL BALANCED ARTICULATION

During lateral movement

Working side. The articular contacts are as for bilateral balanced articulation.

Balancing side. No articular contacts.

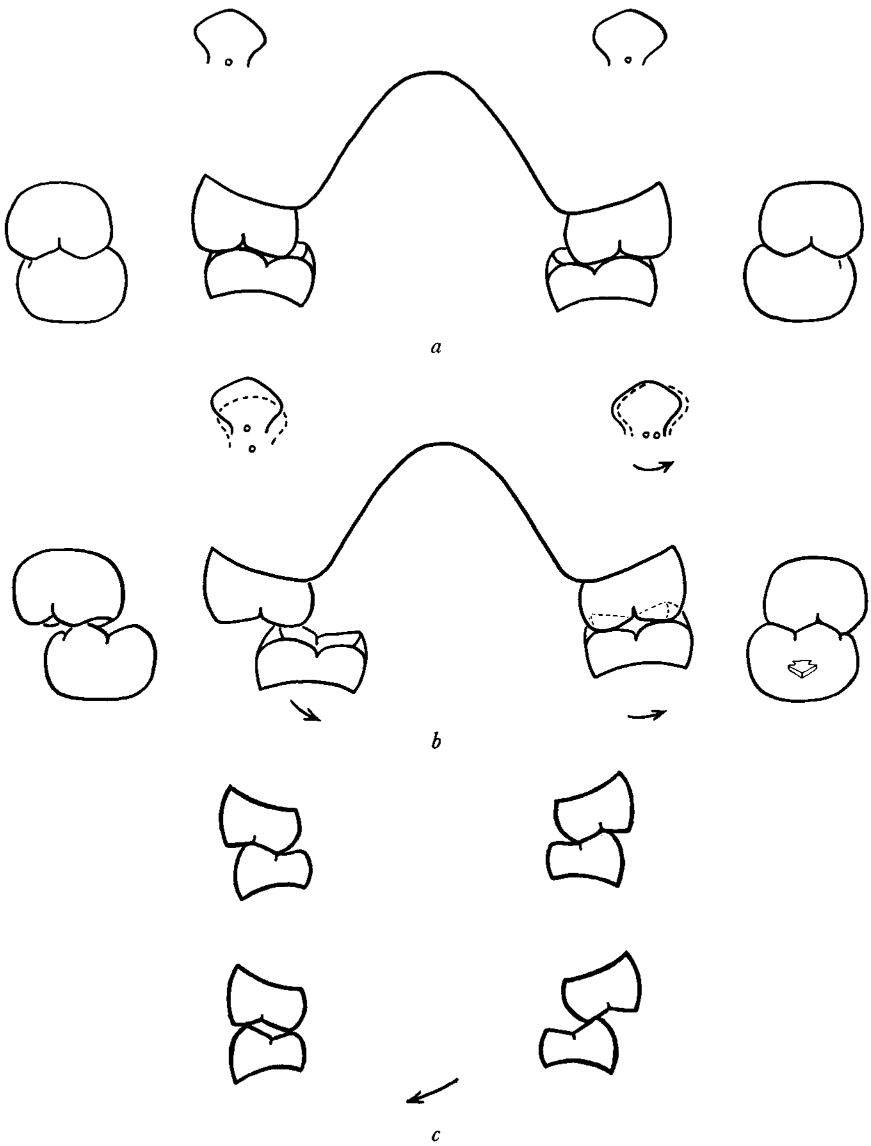


Fig. 32. Diagrams of IO and bilateral balanced articulation viewed from mesial aspect. *a*, Intercuspal occlusion. *b*, Left lateral articular movement. *c*, Erroneous bilateral balance. Cusp does not climb cusp on working side.

During protrusive movement

Anterior segment. As for bilateral balanced articulation.

Posterior segments. No articular contacts.

ANTERIOR SEGMENT ARTICULATION (disclusion with canine rise)

During lateral movements

Working side. The only articular contact is between the canines as the cusp and cusp ridge of the lower glides along the upper distal facing surface or lingual

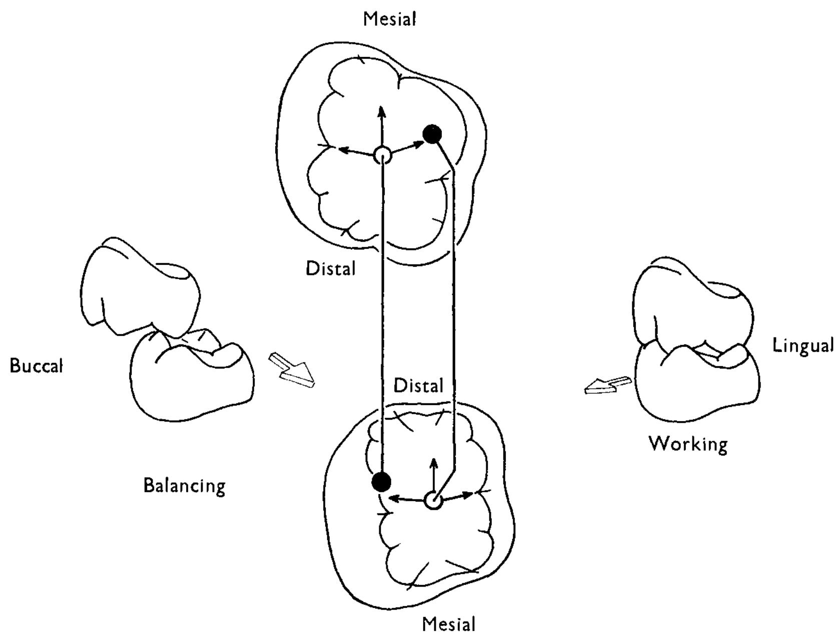


Fig. 33. Paths traced by mesiolingual upper and distobuccal lower cusps in bilateral articular movements.

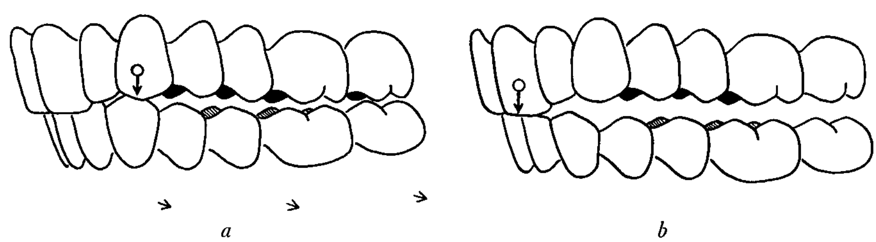


Fig. 34. Anterior segment articulation. *a*, Left lateral articular movement. Contact only between opposing canines. *b*, Protrusive articular movement. Contact only between opposing incisors.

ridge. This articulation separates all the remaining teeth and, as the mandible moves into intercuspal position it acts as a guide (*Fig.* 34*a*).

Balancing side. No articular contacts.

During protusive movement

Anterior segment. Articular contacts are as in bilateral and unilateral balanced articulation (*Fig.* 34*b*).

Posterior segments. There is no articulation.

Anterior segment articulation is also referred to as *mutually protected occlusion* and it exists in many natural dentitions. An example is illustrated in *Fig*. 35. It is the objective in many reconstruction procedures where it is combined with retruded intercuspal occlusion. From this retruded IP all articular movements cause disclusion of the posterior teeth.

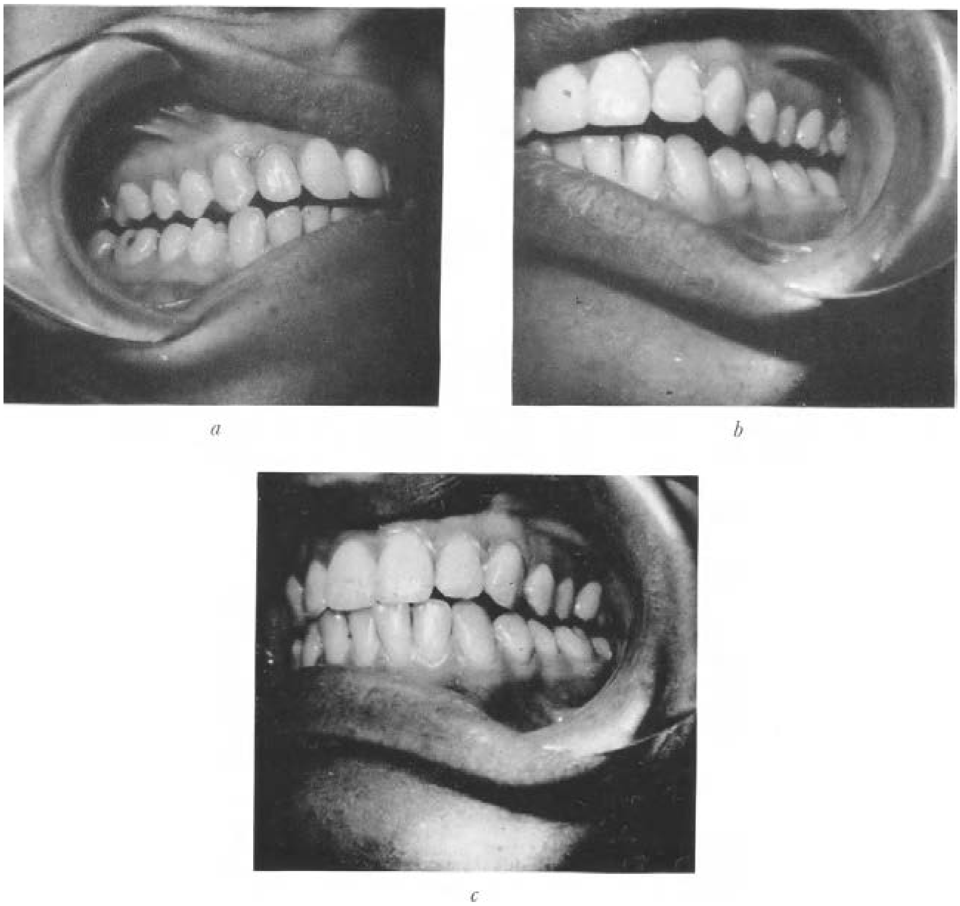


Fig. 35. Anterior segment articulation in natural dentition. *a*, Lateral movement. Working side (canine protected). *b*, Lateral movement. Balancing side (no contact). *c*, Protrusive movement. Incisor contact.

Articulation in the natural dentition

There can be no dogma about what is considered normal articulation in the natural dentition. It exists as it evolves and it changes according to loss and wear of teeth. Variations are numerous and changes are continually taking place. Further, adaptation to these variables and changes is favourable in the majority of mouths, by tooth movement or by jaw movement. This favourable response is not unlimited, however, and the disturbances which may result will be described in Chapter 8.

Two aspects of articulation in the natural dentition are worth restating. Firstly, all articular movements take place within the parcel of motion and in three dimensions. Any cuspal interference which prevents a movement towards the border of the parcel may result in disturbance. Secondly, articular movements are often envisaged as starting from intercuspal position with the mandible moving back, laterally or forwards as previously mentioned. This may occur in empty mouth parafunctional movements, but in mastication these contact movements take place from the open position of the mandible and finish momentarily at intercuspal position prior to beginning the cycle of chewing again. It is not certain whether the paths travelled by the lower cusps along the upper teeth in the closing articular movements are the reverse of those taking place from intercuspal occlusion outwards. When adjustment or reconstruction of the articulation is planned they are regarded as being the same.

Articulation in the artificial dentition

Articulation in the artificial dentition is planned and created by dentist and technician. Artificial articulation has to be developed so as to conform to the four articular movements and a choice of articular contact scheme has to be made from one of the three schemes outlined in the previous section. Having registered a chosen intercuspal position and transferred this to an articulator, a protruded registration is transferred and the articulator is adjusted to copy this position. It is then assumed that the articulator path between the intercuspal and protruded positions will copy those in the mouth (*see* Chapter 7). The dentist has to decide whether to incorporate bilateral or unilateral balanced articulation or disclusion in the reconstructed dentition. The success of articulation in the artificial dentition depends on the accuracy of the transfer of jaw positions and movements to an articulator and on the planning and skill of the dentist and technician in adjusting the occlusal surfaces of the teeth in order to provide the same articulation in the mouth as was developed on the articulator.

The choice of articulation scheme for the artificial dentition depends on whether complete or partial dentures are being made or if the natural dentition is being artificially reconstructed. It will also depend on the pre-existing jaw and tooth relationships if records are available.

For *complete dentures*, one of the chief requirements is stability. This is the property which causes denture bases to resist displacement when subject to vertical and horizontal forces. The forces include those caused by occlusion and articulation. It is therefore desirable, in the empty mouth, that an occlusal force on one segment of a denture should be balanced by a similar force on one or both of the other two segments in order to prevent tilting of the denture base. This requirement applies equally to articular forces while the mandible moves. If an occlusal force causes a denture base to tilt the wearer will tend to persist in applying this force. The base will lose retention, the supporting tissues of the residual ridges will become bruised and the denture will often be discarded. When food is being chewed the confidence and comfort achieved by balanced articulation will help to stabilize the dentures. Further, cross arch balance will still apply. As the bolus is chewed on one side the balancing cusps will come close or will contact on the other. The dictum, 'enter bolus, exit balance' is, therefore, refuted.

The occlusal and articular requirements for complete dentures are therefore: (1) Intercuspal occlusion at a reproducible intercuspal position, and

(2) Balanced occlusions and free articulation achieved by the objective of bilateral balanced articulation where this is possible.

Balanced articulation may have to be modified in mouths where certain malocclusions and abnormal tooth inclinations have pre-existed in the natural dentition. This is particularly true of the Class II, division 2 malocclusion where the vertical overlap has to be copied for reasons of lip competence. Such an overlap will confine articulation to the anterior segment only. The application of these principles will be made in Chapter 11.

For *partial dentures*: articulation requirements for mouths where partial dentures are planned will depend on the existing articulation between the remaining natural teeth. Where there are bounded saddles and the occlusion and articulation have proved satisfactory in function it is advisable to leave well alone. However, where there are free-ending saddles opposing edentulous segments, where cusp interferences can be diagnosed or where over-erupted natural teeth may have a disturbing effect on the prostheses, alterations may be necessary to the existing natural teeth. Bilateral or unilateral balanced occlusion and articulation may be desirable in order to preserve stability of the partial dentures in these cases. It is emphasized, however, that the decision has to be made when planning the denture.

For *reconstruction of the natural dentition* articulation requirements are those which will reduce parafunctional articulation to a minimum. The disclusion (or anterior segment) scheme is the one which is currently believed to give this protection but each case must be planned according to its pre-existing tooth positions and occlusal scheme. In addition, emphasis is laid on the desirability of a reproducible intercuspal position at which intercuspal occlusion is developed with stable contact relationships. These factors will be discussed further in Chapter 10.

Pros and cons of balanced articulation

By way of review some aspects of this topic will be discussed. The three categories of articulation have to be seen as objectives in treatment rather than as diagnosable features of the existing natural dentition. Ideal occlusion and articulation is seen by some as incorporating one or other of these articulation patterns but seldom does one see any of these categories of articulation in an untreated mouth. The most desirable feature of articulation in the natural dentition is freedom from deflective cusp interferences which will reduce to a minimum the adaptive jaw movements which may result from cusp interferences. Bilateral balanced articulation may promote balancing side interferences during mastication or parafunctional grinding; and even cross tooth balance may provide a stimulus for such grinding. As an objective in treatment of the natural dentition, either by occlusal adjustment or by reconstruction, it may be necessary to adopt one or other of the schemes, and for this reason the classification serves a useful purpose.

In complete dentures bilateral balanced articulation has few disadvantages. They will be more stable in the empty mouth where parafunctional grinding is inevitable at the outset of wearing the dentures. This awareness of stability promotes confidence in mastication and reduces tipping forces by cross arch balance. There are two possible disadvantages of bilateral balanced articulation. Firstly, it may tend to encourage lateral and protrusive grinding although this habit may be confined to those people who are subject to irrelevant muscle activity. Secondly, it is difficult to achieve in mouths where an increased vertical incisor overlap is indicated, and it is better to retain the vertical overlap (as for a pre-existing Class II, division 2 dentition) than to sacrifice it in order to achieve articular balance.

Methods of providing balanced articulation will be described in Chapter 10 for the artificial dentition and in Chapter 11 for the natural dentition.

FEATURES WHICH INFLUENCE ARTICULATION

An aspect of articulation which may help in the analysis of occlusal disturbances and in the planning of fixed or removable reconstruction procedures is the five anatomical features of the masticatory system which control the articulation. These are the guidances provided by the condyle movements, by the inclination of the lingual surfaces of the upper incisor and canine teeth, and by the height and shape of the posterior teeth cusps, together with the effect on these guidances of the inclination of the occlusal plane and the shape of the occlusal curve.

Condyle guidance (K) (*Fig.* 36)

This is the inclination of the paths which the condyles follow when making protrusive or lateral protrusive movements. It represents the angle of downward and forward movement of the condyles relative to the axis-orbital plane.

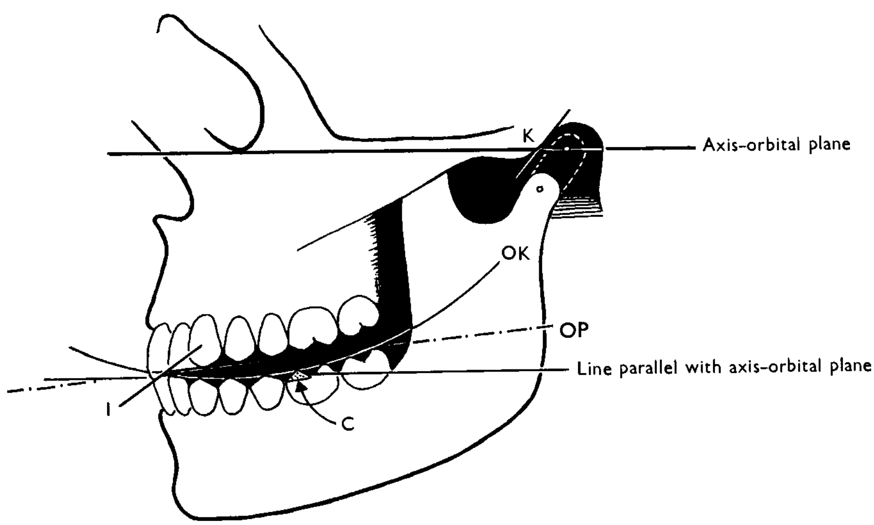


Fig. 36. Articulation features. Protruded occlusion (anterior segment articulation). K, Inclination of condyle path. I, Inclination of labial surfaces of incisor teeth. C, Inclination of posterior cusp ridges. OP, Inclination of occlusal plane. OK, Curvature of occlusal curve. (*Adapted from Posselt* (1962) p. 59.)

The angle of lateral protrusion (of the balancing condyle) is slightly steeper than that made when both condyles move in forward protrusion. The governing factors of these movements are a combination of the directions of muscle pull and the shape of the articular eminence. These guidances are generally estimated as being independent of the effects of tooth contact. During articulation of the teeth, they are interdependent. It should also be remembered that there is a rotation of the condyle axis while these movements are taking place. Attempts to register this guidance are made prior to tooth contact so that it is said to constitute an unalterable factor.

Incisal guidance (I)

This is the angle which the lingual surfaces of the upper incisor teeth make with the axis–orbital plane. It influences the protrusive articular movement and is interdependent with the condylar guidances. The canines exert a similar influence when the lateral protrusive movements are performed. In denture and reconstruction procedures these guidances can be altered.

CHRISTENSEN'S PHENOMENON

When the mandible moves in protrusion without the influence of incisor guidance a separation occurs between the posterior teeth which has a characteristic shape. This is known as Christensen's phenomenon (1905), and is best

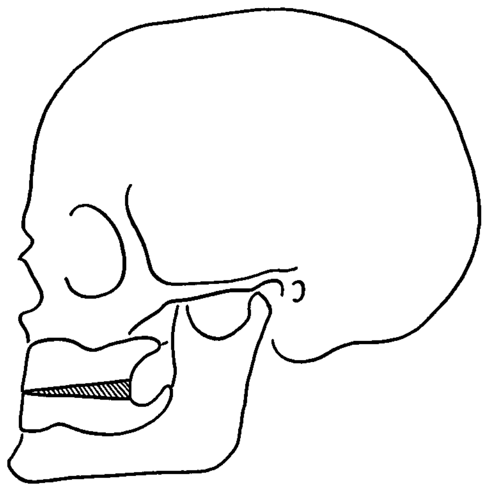


Fig. 37. Christensen's phenomenon. The gap created by condyle descent in protruded contact of occlusal rims.

demonstrated when the upper and lower occlusal planes are replaced by flat occlusal rims as used when making a jaw registration for complete dentures (*Fig.* 37). Compensation for this phenomenon in the provision of balanced articulation may be made by adjustment of all the five features except condyle guidance.

Resultant effect of condyle and incisal guidances. The constancy of the condyle movements is debatable since they are determined by muscles and are therefore subject to adaptation. When freed from tooth contacts, it is likely that they move in reproducible paths and this can be shown to be so in the border movements. It should also be remembered that the condyle is in contact with the meniscus in all movements and the meniscus is in contact with the fossa and articular eminence. Articular tooth contacts guide the movements and the condyles will usually adapt. None the less, it is worth making some theoretical observations on the relationships between the two guidances which have a bearing on setting the teeth for complete dentures. There are four possibilities:

1. When no incisal guidance exists the mandible in protrusion will follow a curved path (with the convexity of the arc facing upwards) as in the Christensen

phenomenon. This will occur with edge-to-edge incisor relationship or with a marked horizontal overjet.

2. When the incisal and condylar guidances are the same the mandible will move on a straight path.

3. When the incisal guidance is greater than that of the condyle the mandible will move on a curved path with the arc facing downwards.

4. When the incisal guidance is less than that of the condyle the mandible will move on a curved path with the arc facing upwards.

The practical significance of these theoretical considerations lies in the effect the curved path will have on the cusp relationships of the posterior teeth while they are in articular contact.

Cusp height and inclinations (C)

These factors are interdependent with the condyle and incisal guidances during protrusive and lateral articular movements. They can be altered in denture and reconstruction procedures, but there are limits to these alterations.

The inclination of the occlusal plane (OP)

This is the inclination of an imaginary plane touching the incisal edges of the lower incisors and/or canines and the distobuccal cusps of the lower second molars. This is also called the plane of orientation and has considerable influence in the setting of lower teeth for complete dentures.

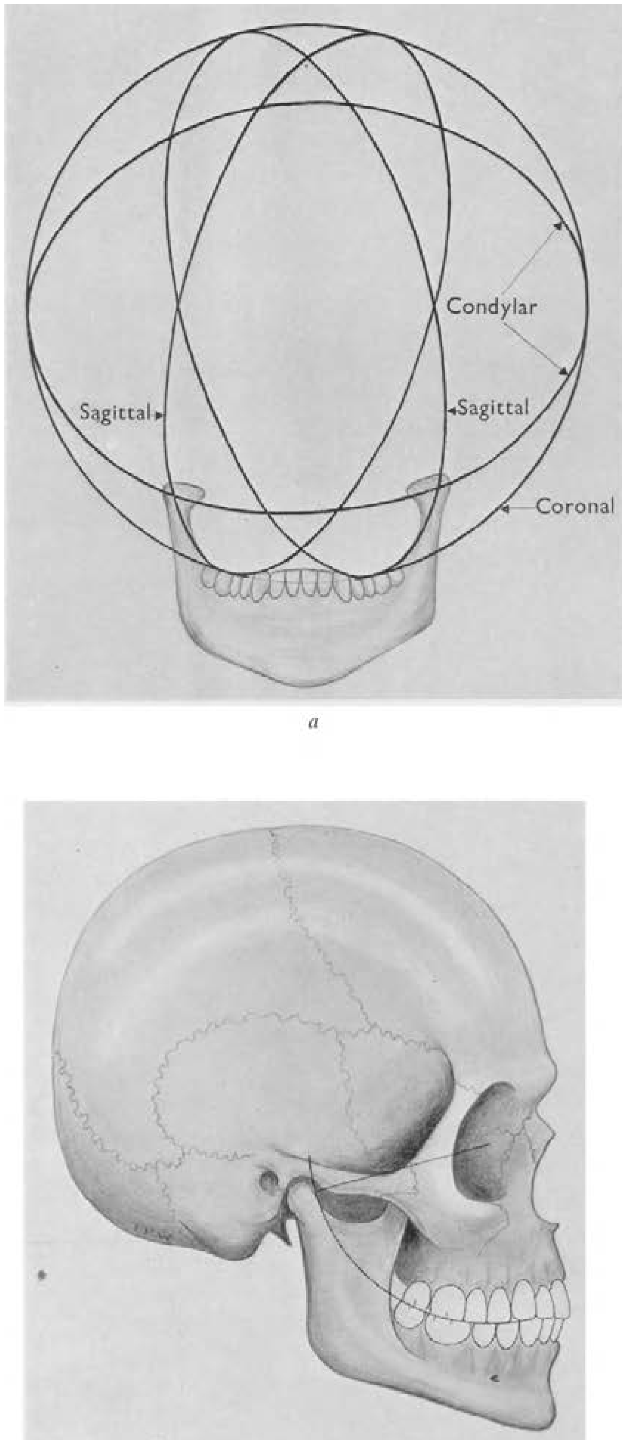
The curvature of the occlusal surfaces (OK)

This is an imaginary curve joining the lower buccal and canine cusps in the sagittal plane. An upper occlusal curve also exists and when the teeth are in intercuspal occlusion the upper curve is below the lower curve. Both are subject to correction in the natural and artificial dentitions.

Interdependence

The interdependence of the five articulation features was first described by Hanau in his curiously named Quint. Thielemann subsequently simplified Hanau's factors by expressing them in the formula for balanced articulation: $(K \times I)/(OP \times C \times OK)$. This formula is of value when setting the teeth for complete dentures and where bilateral balanced articulation is planned. If, for example, the first setting of the teeth results in the separation of the posterior teeth on protrusion balance between the posterior teeth can be achieved by raising the occlusal plane (OP), increasing the cusp heights (C) or deepening the occlusal curve (OK). Since the occlusal plane is determined largely by considerations of the tongue position and the cusp height by the manufacturers of artificial teeth the alteration made is usually that of the occlusal curve. Alternatively, the incisal guidance can be reduced or removed by advancing the incisors but the position and inclination of the incisors is determined by the factors of lip and tongue posture and activity and that of appearance.

Bilateral balance in lateral protrusive movements is also influenced by an imaginary occlusal curve in the coronal and sagittal planes, sometimes referred to as Monson's curve, with the convexity facing upwards (*Fig.* 38). This curve determines the coronal and sagittal inclinations of the posterior teeth. In the lateral movements, it helps to establish the balancing side contacts while the working side lower cusps slide through the upper marginal ridge



a

b

Fig. 38. *a*, Monson's curves. *b*, Monson's sagittal curve with estimated 4-in. radius.

gaps. Thus the balancing path of movement is curved while the working path is more horizontal as determined by the lateral (or Bennett) shift of the working side condyle.

In certain natural dentitions where occlusal wear is excessive this curve becomes reversed and the convexity faces downwards. This may be the effect of wear by a fibrous or sand-containing diet which acts more forcefully on the supporting cusps. Where the consistency of the diet is not a factor in the wear of the teeth, however, the coronal curve generally retains its upwards-facing convexity.

Monson's spherical theory of occlusion

Monson (1932) proposed the theory that the centre of a sphere with a radius of approximately 4 in. is equidistant from the occlusal surfaces of the posterior teeth and from the centres of the condyles. He claimed that the long axes of the posterior teeth form extensions of radii from the centre of this sphere (*Fig.* 38*b*). This is an extension of Bonwill's 'triangle' observations and the theory was applied by Wadsworth (1925), Mann and Pankey (1960) and others in order to find the occlusal curve of the posterior teeth in complete dentures and reconstruction procedures. Reference to the methods used in applying this theory will be made in Chapter 10. The application of this mechanistic approach has proved successful in many hands but the principle should be used warily in practice. The variations in bone and tooth size and in the relationships which exist between maxillary and mandibular bones make it unrealistic to expect that all occlusal curves will perform natural function if set on an arc of a circle whose radius is the distance between one condyle and the median contact point of the lower incisors. But the principle should not be discarded for this reason alone. In practice errors will be reduced if the other factors in the analysis of form, relationships and function are borne in mind.

Further references

The relationships between the angles of condylar movements and those of the teeth (both anterior and posterior) have been a preoccupation of mathematically minded dentists for nearly a century. Bonwill's triangle has already been mentioned and Balkwill (1886) has left his mark in this field by describing the angle between the occlusal plane and Bonwill's triangle. This angle was said to have an effect on the setting of artificial teeth and Balkwill's observations have been repeated (and criticized) by Kohler (1929), Hart (1939) and Bergström (1950). A mathematical study on the variations of Balkwill's angle and how these variations might influence cusp angles was made by Christensen (1960). This study refers to the Christensen (1958) angle which is that between the two flat occlusal planes in Christensen's phenomenon. There would seem to be an interdependence between this angle and the difference between the condyle guidance and Balkwill's angle. Christensen (1959) also concluded that cusp angles in complete dentures should be inversely proportional to the height of Bonwill's triangle. Such studies are not, perhaps, for the average student but they provide information which has been deduced from observations of human mandibles and their articulator copies. They should not be discounted because they are difficult to understand. Bergström's (1950) monograph on the reproduction of dental articulation is a classic of its kind and is required reading for those seriously interested in articulators. Weinberg (1959) made a study of the 'guidance system' of the mandible and its influence on the occlusal plane and cusp angles in the protrusive movement. He was careful to point out that only the mesiodistal cusp inclines were observed and suggested that the protrusive movement could be copied on an articulator provided certain shortcomings of transfer methods were corrected.

Comment

These anatomical features and their geometrical applications are developmental in origin and only the incisal guidance can be altered (by the orthodontist) without removing or reshaping the tooth surfaces. In the stable adult dentition these features may seem to have a limiting effect on the articulation, and when replacements by artificial teeth have to be made, care should be taken before making any alteration to them. Sometimes the enemy of good is better. Stability of replacements depends partly on mechanical balance during articular movements but also on an accurate copy of the natural predecessors so that the orofacial musculature can maintain its endogenous activity without interferences from altered incisal guidances, cusp heights and the levels and curves of the occlusal plane.

Comfort and efficiency in the occlusion and articulation of natural teeth is the rule rather than the exception. Most people are unaware of their chewing ability, of the position where their teeth meet or if they meet. When changes come and losses have to be made good it is not always easy to restore the natural positions and shapes of the teeth and their functions with the means and materials available. Levels of occlusion, occlusal shapes and inclinations of the teeth do require accurate replacement, however, if patterns of articulation are to be retained. The empirical attempts at replacement, often made with the best intentions and in the most difficult of circumstances, do not always succeed in this objective and disturbances can result. It is therefore desirable to have a knowledge of these patterns so that in each patient good occlusal function can be maintained or restored.

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Chapter 6

Functions of the masticatory system

FUNCTIONS of the masticatory system which involve the occlusion and articulation of the teeth are those of incision, mastication and swallowing. The teeth are also involved in the functions of respiration, the provision of a lip seal, speech and facial expression although not necessarily in contact. Since these functions can affect or be affected by the occlusal and articular relationships it is worth while considering the movements which produce them and what happens when they are altered.

General

Most voluntary actions become involuntary with continued use but are subject to alteration by a response to stimuli either reflexly or cerebrally. The muscles providing the actions conform to an endogenously determined pattern initiated and sustained by both cerebral and reflex stimuli. The function of walking is generally considered as an involuntary action and the gait can be as characteristic of an individual as his features. If a stone gets into the shoe a reflex protective limp is the immediate response to this noxious stimulus. If an unexpected drop in the ground is encountered two adaptive possibilities may result: a stumble or a fall may occur and both can cause injury to muscle-fibres almost anywhere from the neck to the ankle. Alternatively, a bending of the knee, quickly performed, may restore normal gait and movement without harm, as the skilled footballer or skier knows. The gait can also be altered by a voluntary decision to do so, either, say, to slow down, turn or even to affect a limp.

The involuntary gait is produced by the co-ordinated contraction and reciprocal relaxation of groups of muscles in a manner which produces the movement as efficiently and economically as possible. The minimum of effort is expended and the activity can be maintained almost indefinitely depending on the health of the walker, of his individual muscles, and of the tissues covering his feet, either natural or artificial. This analogy can be applied to the masticatory system whose functions will now be discussed.

INCISION

The incision of food is performed by a combination of rotary opening and protrusive movements of the mandible and the closing movement on the bolus is reflexly controlled by the consistency of the food and the relationship of the upper and lower incisor teeth. A smooth movement is the objective and contact between the teeth is either light and gliding or is avoided. If the incisor tooth positions and relationships are stable in relation to each other and to the orofacial muscles the function of incision becomes involuntary, efficient and economical of effort. If the positions and relationships of the incisor teeth are not stable and premature contacts on incision take place reflex adaptive movements will occur to avoid the uncomfortable contacts. Either these will succeed and the muscles may tire or the teeth will be traumatized. If these teeth are lost the closing incisive movements will be inhibited and will have to be re-established when artificial teeth are replaced. The movement patterns of the mandible and the relationships of the teeth are therefore interdependent. Incisive parafunctional movements are common and these cause wear on the teeth or injury to the apical periodontal tissues. They may also cause fatigue in the muscles.

MASTICATION

The act of chewing food prepares it for swallowing and involves the activities of the lips, cheeks and tongue, the mandibular joints, the palate, the secretions of the salivary glands, and the teeth with their supporting tissues. Co-ordinating these activities is the neuromuscular function which receives the stimuli of the bolus and responds by moving the mandible so that the teeth shred the food. Mastication is, and probably always has been, an enjoyment for the majority of people. It involves the five senses in turn. There is the call to food, the smell and the sight of it. There is the first touch and the taste of it. Then begins the neuromuscular activity which provides the complex, sensual and generally efficient function of preparing the food for digestion. The saliva having soaked the bolus, the tongue, lips and cheeks load the food on to the posterior segments of the teeth. The bolus is often divided into two portions allowing bilateral chewing. During this function stimuli from the bolus are being continuously received by the periodontal receptors and the reflex responses determine the amount and force of further mastication required. The value of two complete arches for the dentition in occlusion is not in doubt and in mastication this property provides the added advantage of containing the food bolus within the arches. Missing teeth can make mastication difficult by allowing food to pass through the arches into the vestibular regions where it has to be retrieved by the tongue. Also a more convenient platform for shredding has to be found. This entails further muscle activity which can lead to fatigue, to altered and to impaired function.

There are three main variables in mastication which makes it difficult to determine what constitutes normal mastication. These are, firstly, the amount of mastication carried out per individual; secondly, the preference, if any, for one side or the other; and, thirdly, the contact, if any, between the teeth.

The amount of mastication

This can be observed by counting the number of jaw closures or, say, by watching a mark on the chin. The patient himself may be able to provide an answer and, if carefully phrased, information from groups of people can provide helpful data for this aspect of mastication, especially if related to numbers of teeth and efficiency of occlusions and articulations.

Side preferred

The side on which chewing is preferred or if both sides are used can also be useful information to have when considering the cause of mandibular joint or facial pain. This variable is affected by the number and symmetry of the teeth present. However, Posselt (1961) made a study of side preference in mastication in people with complete natural dentitions and found that only 10 per cent chewed on both sides simultaneously and 12 per cent restricted themselves to one side. The remainder chewed alternatively left and right. There was no suggestion of any association with being right or left handed in the side preferred. Hildebrand's (1931) original work on this subject still provides a standard of investigation.

Studies by Hedegard and others (1968, 1969, 1971) on the position of the bolus and duration of the masticatory cycle, using cine-radiography, are a helpful contribution to the understanding of this function.

Loss of teeth will affect the pattern of chewing and the side preferred but it does not follow that the side with the greater number of opposing teeth is the side preferred. This can be explained by a well-established conditioned pattern of chewing being preferred to a greater number of opposing teeth. If mastication is unilateral it is sometimes reported that contact seems to take place on the side not being used (the balancing side); if this contact is a sudden lateral occlusion as opposed to a sliding articulation the point of occlusion will act as a fulcrum around which the mandible will momentarily rotate and the muscle adaptation required may be such as to cause torn fibres and pain. This can also happen when a hard piece of food in unexpectedly encountered on the side being used for chewing (the working side). These sudden tilts of the mandible in the coronal plane are potentially harmful. Simultaneous bilateral mastication performed without haste remains the more desirable method of function as a preventive against disturbance of the system.

Tooth contact

During mastication tooth contact remains a controversial variable. Studies on this subject using transmitting devices from teeth are a study in themselves and a bibliography can be found at the end of this chapter. They appear to establish that contacts do take place during mastication in both lateral and protrusive chewing movements as well as in intercuspal position. This may contradict the information from patients questioned on this aspect of masticatory function who are often unaware of the contacts. Further, it is doubtful if the presence of ingenious devices, however miniature, represents a mouth in natural function. It would seem desirable that contemporary diet be masticated by cusps and ridges passing close to fossae and fissures without their touching. Thus the food is shredded, not ground, and subsequently reduced to pulp by the addition of saliva. When ready for swallowing the bolus is almost liquid and can often be swallowed without occlusion of the teeth. It is more usual, however, for intercuspal occlusion to take place prior to the swallow. Perhaps the sanest comment on this topic was made by Beyron (1964) who pointed out that even a thin layer of food between the teeth acts indirectly as a grinding contact.

Tooth contacts during mastication are acknowledged from patients, however, on working and balancing sides and usually take place following recent extractions when adjacent teeth have become repositioned. Their cusps then present targets for initial or premature contacts in function as well as in parafunction. Further causes of contact in mastication are the over-contoured restoration (supra-contact) and the over-erupted tooth, particularly the unopposed third molar. Contoured restorations may provide good intercuspal occlusion in the empty mouth but may offer initial contacts in lateral or protrusive mastication due to failure to allow for these movements on the articulator.

These contacts in habitual function are difficult to identify since closing contacts in the empty mouth are not necessarily those which occur when food is present and it is in the empty mouth that the clinician has to make his observations and diagnosis. Removal of premature and initial contacts in the empty mouth movements, however, have often served to improve comfort and efficiency in function. Emphasis is placed on the need for accuracy in procedures concerned with grinding the teeth and these will be discussed in Chapter 12.

The more efficient the occlusion and articulation between the teeth, the less they need touch in mastication. The analogy of the robin picking up seed from a stone path may illustrate this precept. Although the action is impressively fast there is no apparent contact between beak and path as the seed is grasped. We are not robins, it is true, and we do not peck our meals from stone paths but the incidence in robins of beak wear, neck pain and joint disturbances is low and the example is good.

Incoming and outgoing articular movements

When the mandible moves during mastication the lower teeth move from the various open positions into intercuspal position and thence to the opening movements. Contact may take place as intercuspal occlusion is approached and this articulation acts as a guide. Articulation may occur as the mandible moves away from intercuspal position but probably for no more than 2 mm. before and after IP. On the other hand, parafunctional grinding habits may begin at IP and move outwards. These movements are similar to those made at the command of the dentist while investigating the articulation of the teeth. But they are not natural movements nor functions and this may explain the difficulty which many patients experience in performing lateral articular movements on request.

Condyle and cusp guidances

In spite of the limitations placed on condyle movements by the shape of the articular eminence and the close contact which the condyle maintains with the meniscus during all its movements, it would seem that the cusp inclinations direct the masticatory movements and the condyles adapt to them. It is easier for the condyles to alter their paths of movement than for the teeth to become repositioned. This is not to assert that the various angles of condyle movements have no significance. On the contrary, these movements have optimal directions and curves and the more accurately the articular relations between the teeth conform to these directions and curves the more harmonious will be the functions of the system. These guidances are inter-related and whereas the dictum, 'teeth direct and muscles adapt', is justifiable the primary response in all systems is adaptation.

Adaptation

This phenomenon of muscle activity is well known and when applied to mastication it refers to the reflex activity which takes place when changes in the consistency of the bolus are encountered and when occlusal contacts occur during mastication. The stretch reflex is produced when closure of the mandible encounters an unexpectedly hard object in the food and, less obviously, a premature contact is avoided in mastication. Neuromuscular adaptation also includes the responses made to missing posterior teeth. Mastication requirements are fulfilled by the tongue, lips and cheeks and by the postural masticatory muscles to provide chewing by the incisor teeth. Adaptation is a term which can also be applied to responses to injury, ageing and disease. Thus all tissues in the masticatory system demonstrate adaptation. In addition to those mentioned, there are the responses of the pulp and cementum to loss of the occlusal surfaces by attritional wear, the responses of the periodontal tissues to toxins and to drift of the teeth, and the responses of the dento-alveolar tissues as a whole to the functionless tooth.

Adaptation and disorder

In the majority of adaptive movements or tissue changes the responses are well tolerated but there are occasions when a pathological response is induced. For example, pain can be experienced in abraded dentine, periodontal breakdown can lead to inflammatory responses, altered muscle activity can result in injured or fatigued muscles, and hyperactivity of muscles can result in grinding habits on interfering cusps. These unfavourable responses can all take place during mastication or in the empty mouth.

Associated muscular activities

The muscular activities of the system during mastication include those of maintaining posture of the head in relation to the shoulders and back and of the mandible in relation to the clavicle and sternum. In normal circumstances the head is kept relatively stationary during mastication but encounters with resistant food or uncomfortable occlusal contacts can lead to movements of the head which involve the neck, shoulder and even back muscles in adaptive movements. If these movements are sudden, especially if the back is unsupported disturbances in any of the muscles from the sacrum to the sternum can be the result. Consequently it is always advisable to suggest that the back be adequately supported while eating, the shoulders relaxed and the head maintained in comfortable posture. This supported posture is a good preventive measure against the sudden changes of muscle activity required from time to time during mastication.

DEGLUTITION

The term 'deglutition' covers the four stages of swallowing from the preparation of the bolus within the mouth, the passage of the bolus from the mouth to the pharynx, through the pharynx, and its subsequent descent through the pharyngeal sphincter into the oesophagus. This function is initiated voluntarily, by the bolus being placed on the tongue while the tip of the tongue is supported by the lingual surfaces of the incisor teeth and anterior surface of the hard palate. The second stage is also under voluntary control and consists of closure of the teeth into intercuspal occlusion followed by contraction of the muscles at the tip of the tongue. Thirdly, the stability instituted by this contraction and by the mandible in intercuspal position allows the subsequent wave of muscle contractions in the tongue to take place reflexly and this forces the bolus into the pharynx. Finally, the subsequent movements and passage of the bolus into the oesophagus all take place reflexly and the phenomenon of peristalsis is set in motion. This continues until the food reaches the stomach.

The teeth in swallowing

The part played by the teeth is that of stabilizing the mandible in stage two and it is possible for the tongue to take over this function and to provide the dual function of holding the bolus and stabilizing the mandible. Here, the tongue is stabilized against the upper teeth or sides of the hard palate. This has been referred to as *infantile* (or *visceral*) swallowing and takes place before the teeth erupt and also when the mouth becomes edentulous and dentures are not worn. *Somatic* swallowing is the term given to a tooth-stabilized swallow.

Infantile swallowing takes place in dentulous mouths where it is uncomfortable to bring the teeth together either for reasons of carious or sensitively abraded teeth or where initial contacts are markedly deflective. It is also used when swallowing liquids. This type of swallowing is also associated with an incompetent lip seal where the tongue is thrust forwards to contact the lips or tips of the incisor teeth in order to make the seal necessary for a closed mouth during deglutition. The adaptive movement required repeatedly by the mandible for this function can lead to discomfort in the postural muscles around the mandibular joints.

It is often claimed that the occlusion attempted for the act of swallowing is on the retruded axis and if intercuspal occlusion is not possible on this axis retruded contact is followed by a forward slide into the habitual intercuspal position. If this forward slide has a lateral component the disharmony of activity produced in the lateral pterygoid muscles can produce pain in one or other of these muscles. The 'retrusion facets' on the posterior teeth observed by Arstad (1956) and to be seen in many dentitions could be caused by this slide between retruded and habitual occlusion during the swallow. It is likely that retruded occlusion is attempted when an effort is required to stabilize the mandible either when the food has been incompletely chewed prior to swallowing or when there is not enough to swallow. It is suggested that retruded intercuspal occlusion is the natural objective in the swallow but that alterations in cusp–fossa or cusp–ridge relationships in the contemporary developing dentition rarely make it possible. Consequently, the mandible slides forwards or laterally until intercuspal occlusion is reached. It is true that when intercuspal occlusion occurs on the retruded axis it is both efficient and reproducible. It is also true that an element of effort is necessary to produce it. It may be that it is this effort which discourages parafunctional closure in this position. The observations of Reynolds (1970) on 50 caries-free complete dentitions indicated that facets of wear occurred least in mouths which demonstrated retruded intercuspal occlusion. He coupled this feature with disclusion by the incisors and canines in the lateral and protrusive articular movements.

It is only during the act of swallowing that teeth come together in functional intercuspal occlusion: all other intercuspal closures are parafunctional. It is therefore a function of considerable significance and the mandibular position at which it is achieved should be observed carefully in all analyses of masticatory function and re-established with care when prostheses are being made.

RESPIRATION

Together with the heart-beat and the circulation of the blood the function of respiration is the first muscular activity that takes place after birth. The circulatory musculature has been active in embryo although provided by a different kind of muscle. It cannot be brought under voluntary control. On the other hand, respiration can be voluntarily controlled and intercuspal occlusion may take place when difficulty in nasal breathing is encountered. This constitutes a parafunctional activity and may result in fatigue. During natural respiration the mandible is in rest position and the lips are together. Any obstruction to nasal breathing which results in mouth breathing does not necessarily alter the rest position. Competent lips can part without altering this position. Alternatively, incompetent lip posture does not necessarily imply oral breathing. Nasal breathing is generally adopted, if the airway is clear, irrespective of lip seal. An obvious exception to this is the oral breathing required during strenuous activity. If a race has to be won or an opponent downed a justifiable parafunction may be indulged. The association of pain around the joint with these activities is not uncommon.

Obstructions to nasal respiration will call for modifications to masticatory movements since breathing has to be performed through the mouth. The maintenance of a lip seal will be difficult if not impossible and the swallow may have to be infantile.

LIP SEAL

As has been said, the adoption of a lip seal is a physiological requirement for the comfort of a moist mouth. If this cannot be adopted because of tooth positions and relationships and it becomes necessary to posture the mandible forwards in order to achieve the seal, an intermittent change of posture is the result. The change is between the mandible at rest position and at the habitual position required to achieve lip seal, that is, between the physiological needs for minimal activity and a comfortable interior to the mouth. This change can involve the postural muscles (the lateral pterygoids and temporales) in sudden changes of pattern which can cause pain. Articular contacts can take place in these changes of posture and cause deflective movements which, because they are sudden and unexpected, can add to the potentially harmful responses in the muscles mentioned.

SPEECH

The closest speaking space

One of the recognized method of assessing the correct positions and relationships of the incisor teeth is by noting how closely they come together in speech. In Class I jaw relationship cases with stable incisor relations the tips of the upper and lower incisor teeth should approximate as closely as possible without touching when s sounds are spoken. This is known as the 'closest speaking space' and was introduced by Silverman (1953) as a method for assessing the vertical dimension in the construction of complete dentures. In his book on *Occlusion* (1962) Silverman noted the variations in closest speaking space in the natural dentitions of 208 patients and this space varied between 0 and 10 mm.

measured in the incisor regions. There was therefore no average space between individuals and the space varied in the same individual depending on the sounds used. It is, however, a valuable piece of information to have as a permanent record of the natural dentition and which should be duplicated in the artificial dentition if this becomes necessary. The closest-speaking space is a measurement of the vertical dimension of the face (*Fig.* 39).

Fig. 39. Closest-speaking space.

The clinical application of the closest-speaking space is twofold. Firstly, in functional analysis of occlusal contacts: the patient is asked to read a passage which includes s, j, sh, ch sounds. These sounds bring the teeth closely together both anteriorly (s) and posteriorly (j, sh, ch). For example, 'The church by the Mississippi was judged to be the simplest on show' is read and the patient is asked if there were any tooth contacts while speaking. If so it is likely that premature contacts are present or, in the case of denture wearers, that the occlusal vertical dimension has been increased. Secondly, in the assessment of appearance: the patient is asked to speak while watching himself in a mirror. Here it is preferable to have a large standing mirror at which both patient and dentist can look, standing side by side.

Speech tests are also of value in assessing the correct positions and alignment of the incisor teeth in relation to the lips and tongue. The f and v sounds produce contact between lower lip and upper teeth and the t and th sounds are produced by the contact between the tip of the tongue and the lingual surfaces of the upper incisor teeth and anterior part of the hard palate. Two such sentences are given for these tests: 'The first victim was found visibly fainting' and 'The tip of the tongue, the lips, the teeth tell the sounds'. Careful listening is required to assess whether there is an excess of air escaping or perhaps a blockage to the production of the sounds. In the natural dentition any malalignment of teeth will have produced muscle adaptation so as to make the sounds approximate those of the local dialect. In the artificial dentition these sounds can produce a useful guide for the alignment of the incisor teeth and the shape of the palate when there are no pre-extraction records.

FACIAL EXPRESSION

The significance of the teeth in facial expression needs no emphasis. From the gnashing of teeth in youthful rage to the endentulous hollow of senility there is a lifetime of communication and expression. There are few better boosts to the morale than porcelain crowns for middle-aged incisors, and few sights more calculated to deflate it than the mirror's evidence of discoloration and disease.

Faulty occlusal relationships particularly in the incisor segments can affect facial expression. A loose or rotated tooth can cause interferences which will inhibit or alter the activities of the lip muscles playing their many parts in the function of communication. Other involvements of the occlusion in the manifestations of facial expressions are largely parafunctional but may require diagnosis and treatment. Let the dentist be advised to miss no opportunity of warning his patients of the potential harm to their teeth of contact between them other than when swallowing.

CRITERIA FOR OCCLUSION

By way of revision lists of criteria for good occlusion and occlusal function will be given. The adjective *good* is preferred to *normal* and *ideal* which tend to emphasize the more static and structural relationships between the teeth.

The adjectives *normal*, *ideal* or even *natural* are not easy to define when applied to occlusion. Posselt (1962) emphasized the difficulty by separating *normal* from *no longer normal* since such changes as wear, loosening and loss of teeth are continuously taking place. He suggested that the word *ideal* could be used to represent the specific, perhaps theoretical, requirements of optimal occlusal function. Ramfjord and Ash (1968) have elaborated on this theme in their book on *Occlusion* and have listed some requirements for ideal occlusion as a clinical objective for those patients who have a low tolerance to minor imperfections in occlusal contacts.

Thus, good occlusal function implies a range of acceptable contacts between the teeth during function, the absence of any disorders in the tissues of the masticatory system, and an adaptability to alterations as they occur. When this adaptability fails and disorders result it becomes necessary to recognize the disturbances causing the disorders and to correct them. A clinical objective of an occlusion designed to prevent all possible disturbances is then desirable and sometimes necessary. These criteria are based on the assumption of Class I jaw and tooth relationships but they apply equally to those dentitions where Classes II(1) and (2) and III exist. Some further requirements will then be added for those mouths where a low degree of tolerance to developing changes and disturbances exists.

Criteria for good occlusion

1. Two complete arches of teeth with secure contact points and occlusal surface contours adequate for function required.
2. Root shape and alignment adequate to resist occlusal forces.
3. Rest position stable with adequate lip seal.
4. An interocclusal distance of 2–4 mm. between rest position and intercuspal position.
5. Simultaneous and bilateral occlusion between all teeth of upper and lower arches at intercuspal position. No deflective contacts.

6. Simultaneous and bilateral occlusion on the retruded arc between one or more opposing posterior teeth.
7. Cusp–fossa and cusp–ridge occlusion having tripod contacts where possible.
8. Return of each tooth to its original position on removal of the occlusal force.
9. Articulation between retruded and intercuspal positions free from any interferences causing lateral deflexion.
10. Stable vertical overlap and horizontal overjet.
11. Empty mouth articular movements free from deflective contacts.

Criteria for good occlusal function

1. Simultaneous bilateral mastication.
2. Light contact in intercuspal position while swallowing.
3. Incoming and outgoing chewing movements free from working or balancing side deflective contacts.
4. No adaptive chin or lip movements on swallowing.
5. No clenching or grinding (parafunctional) movements.
6. No joint noises in mastication or wide opening.
7. No deviation of mandible on wide opening.
8. No tooth contacts in speech or facial expression.
9. Pleasing appearance.

Further criteria for ideal occlusion

The adjective *ideal* is used reluctantly and 'optimal' is equally unacceptable since improvement on nature has nature to deal with. Alterations to natural function require acceptable adaptation. However, for mouths with a low tolerance to disturbances the following three criteria are suggested:

1. Intercuspal occlusion should take place on the retruded axis at a vertical level 2–4 mm. above that of rest position.
2. All incoming articular movements to or outgoing movements from the retruded intercuspal occlusion should free all posterior tooth occlusion and should take place between the canines in lateral movements and between the incisors as a group in protrusive movements. This criterion implies that there are no sliding contacts between retruded and habitual occlusion. Thus, there is no habital intercuspal occlusion; there is only retruded intercuspal occlusion.
3. All supporting cusps should occlude in opposing central fossae and each supporting cusp should have tripod contact with the opposing fossa. This criterion implies that there is no occlusion between cusps and opposing marginal ridges.

This is the concept of disclusion or mutually protected occlusion (*see* Chapter 5) and is currently believed to be the most protective for the function of the dentition. In order to produce it in the natural dentition some degree of reconstruction or carefully planned occlusal adjustment is generally required. It seldom exists in the natural untreated dentition although when it does, according to Reynolds (1970), much benefit accrues.

Considerable debate continues over the belief that this constitutes the ideal occlusal function. There are those who uphold the value of bilateral or unilateral balance in articular movements and of preserving a habitual intercuspal occlusion anterior to retruded intercuspal occlusion with free gliding movements between the two occlusions. This is the so-called *long centric* compromise for occlusal function which serves to satisfy the ambivalently minded but it promotes parafunctional movements in this long centric zone.

Comment

The majority of mouths examined in the course of dental practice show signs of occlusal disturbances but comparatively few require more than minor adjustments to improve and maintain good occlusal function. None the less it is desirable to have these criteria in mind so that treatment can be provided when disturbances result in disorders of the masticatory system.

Before proceeding to a description of disturbances and disorders the possibilities of copying the positions and movements of the mandible will be described and discussed in a chapter on articulators which follows.

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Experimental tooth contacts in mastication

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Chapter 7

Articulators

IN the previous chapters emphasis has been given to the need to understand the tissues and functions of the masticatory system and it may seem unphysiological to attempt the transfer of such a system, of any live system, to a mechanical device devoid of muscles, blood-supply, or a correlating nervous function. However, the curiosity to see the teeth during function and the difficulty of seeing them (because the lips are usually closed) has prompted dentists to transfer casts of the teeth to a hinge representing the mandibular joints. Hinges with teeth on them have been reported from early Egyptian remains, although these were probably the prostheses themselves rather than casts copied from natural teeth. Certainly, hinged dentures date back to antiquity and, as Woodforde (1968) puts it in his story of false teeth, 'for hundreds of years after the collapse of the Roman Empire all kinds of dental skills deteriorated in Europe'. This suggests an inviting field of study for dentists with a training in archaeology. The dark ages of dentistry are reported largely from the fair-ground and the apothecary's shop and it was not until the nineteenth century, when dentistry began to emerge as a profession with an academic as well as a cultural background, that reports of men like Bonwill (1887), Walker (1896) and Gysi (1910) began to show the possibilities of the jaws being mechanically copied. The story of articulators has yet to be compiled and written and no doubt there will be surprises for contemporary dentists when man's ingenuity in the antique past is revealed.

For the purposes of this text a review of the principles and practice of articulators in use today will be given, with emphasis on what can be achieved in general rather than a description of particular instruments.

Definition and classification

The articulator is an instrument on which casts of the teeth can be mounted in order to copy positions and movements of the upper and lower arches of teeth in relationship to each other. This definition implies the need to copy the positions and movements of the mandibular condyles and, since the mandible moves in three dimensions, their axes of rotation. Classification is made difficult by many variations of design. The majority have a single or double joint (hinge), one exception being the Stansbery tripod (*see Fig.* 49, p. 111). The single-joint instrument is popularly known as the plane-line articulator, but what is a plane-line? They are no more than plain hinges (though many are their uses). Many double-joint articulators serve only the purpose of a plain hinge because the axis of the joint in relation to the teeth is different from this relationship in the mouth. Some of these instruments have 'mean-value condyle paths' built into their joints purporting to copy condyle movements. These can be harmfully inaccurate when not related to the natural condyle axis. It is proposed, therefore, to call these instruments, perhaps ungenerously, plain hinges.

Articulators have been classified as one-, two- and three-dimensional according to the movements able to be copied. Another classification ignores the plain hinges and divides articulators into semi-adjustable (which half ?) and fully adjustable (with its own neuromuscular system ?) instruments. Pedantry aside, classification is difficult and perhaps unnecessary. For the purposes of description, in this text, these instruments will be classified as plain-hinge, adjustable and gnathological articulators.

PLAIN-HINGE ARTICULATORS

This is an instrument whose hinge bears no measured or transferred relationship to the retruded axis of the mandible. It may have a single or double

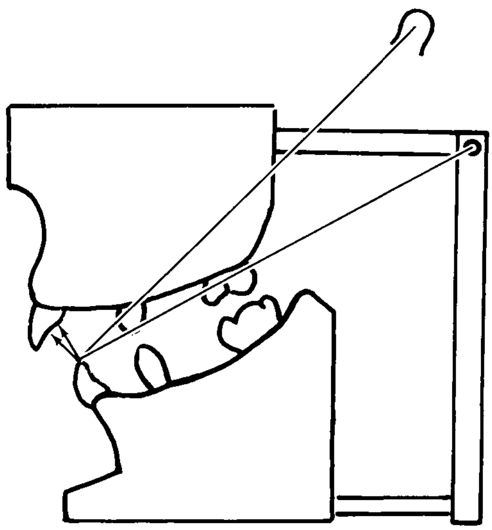


Fig. 40. Diagram. Plain-hinge articulator. Difference in arcs of closure is shown between the centres of rotation of the articulator and the retruded condyle axis.

hinge and casts mounted on it will open and close on an arc which does not copy the mandibular opening or closing arc. If the casts are mounted at intercuspal position the position itself can be copied and repeated but not the arc of closure to it. Thus, a precontact registration for mounting the casts will result in a different occlusal position than the intercuspal position in the mouth (*Fig.* 40).

Examples of plain-hinge articulators are shown in *Fig.* 41. In some with a double hinge it may be possible to use a facebow transfer but the space between the upper and lower members seldom permits it. The mean-value condyle paths will allow lateral movements of the upper member but they will not be an accurate copy of those movements in the mouth since they are not related to the retruded condyle axis. Dentures made with balanced articulation on such an articulator will require adaptive movements by the patient and effort will be necessary in order to produce them. They will not be the border movements which are usually employed in making lateral movements. In the protrusive movement it will be an unlikely piece of luck if the condyle path is copied. Deflective cusp interferences will therefore be inevitable in these movements.

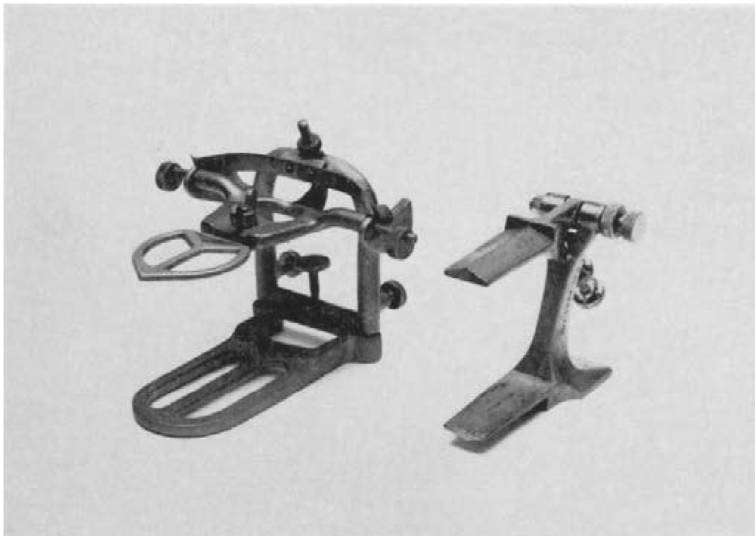


Fig. 41. Plain-hinge articulators. Instrument on left has double hinge and mean value condyle path.

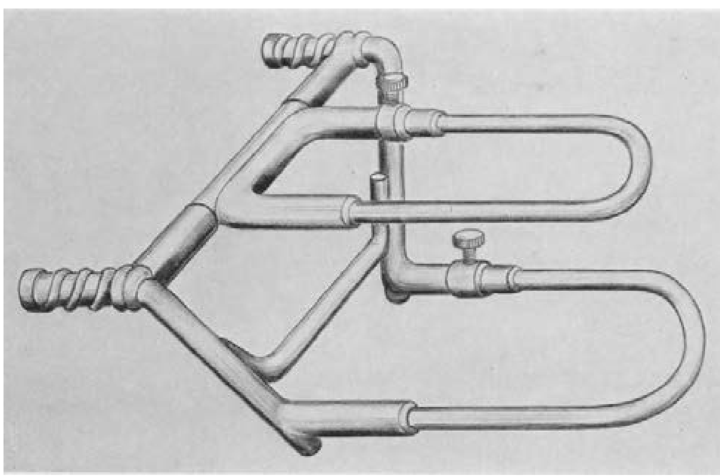


Fig. 42. Bonwill's articulator.

Bonwill's brass wire 'anatomical' articulator (*Fig.* 42) deserves special mention in view of the emphasis in complete dentures which Bonwill gave to balanced articulation between the teeth. The hinge on the upper member is plain enough and the movements allowed by the springs at either end of the upper member permit protrusive and a small amount of lateral movements. The hinge and condyle assemblies do not permit any copy of mandibular movements but a start had been made and the instrument should be acknowledged for its place in dental history.

ADJUSTABLE ARTICULATORS

The adjustable articulator employs the facebow to transfer the arbitrary or actual retruded axis of the mandible to the articulator and possesses condyle mechanisms which can be adjusted to copy condyle positions transferred by interocclusal, protruded and lateral records from the mouth.

Actual and arbitrary retruded axis

The actual retruded condyle axis exists when the condyles are pulled as far backwards and upwards as they will go. On this axis the mandible can rotate and describe an arc for a distance of up to 20 mm. measured in the lower incisor region. This can be located and marked on both sides of the face and constitutes the *actual retruded axis*. It is generally found in front of the tragus of the ear on each side and its position varies between one individual and another. It is thought to remain constant in the same individual provided the muscles remain free from disturbances which might cause stiffness or inhibited movements.

The *arbitrary retruded axis* is assessed as running between points marked on both sides of the face, each one 12–13 mm. in front of the tragus and on a line between it and the external canthus of the eye (*Fig.* 43*a*). These were called the 'condyle centres' by Hanau fifty years ago and come close to the actual retruded axis. The actual axis is generally a few millimetres distal to the arbitrary axis but this may not be significant in denture work when the difference in radius is small and unlikely to affect the direction of the closing arc, especially if the precontact record is made close to intercuspal occlusion. The transfer of this axis is carried out by a facebow.

The facebow

The facebow is an adjustable calliper for recording the distance between the arbitrary retruded axis of the mandible and the upper teeth. The simple facebow in use today has changed little in design since Snow first introduced it in 1899. The adjustable condyle rods of the facebow are placed against the condyle centres while the 'bite-fork', carrying softened wax or compound held against the upper teeth, is secured to the bow (*Fig.* 43*b*). The cast of the upper teeth is then seated on the imprints of the upper teeth on the bite-fork and transferred to the articulator where it is secured by plaster to the upper member (*Fig.* 43*c*). The upper teeth can then be said to rotate on the same arc of movement as the lower teeth rotate in the mouth so long as the mandible remains on its retruded axis. Subsequently, a cast of the lower teeth is related to the upper teeth and attached with plaster to the lower member of the articulator. The upper cast teeth can then move towards the lower teeth on the same arc as the lower teeth move towards each other in the mouth. Therefore, it does not matter which member moves. The orbital indicator is attached to the bow and rests on the infra-orbital ridge and so orientates the record to the Frankfurt plane. This, too, is transferred to the horizontal plane of the articulator (*Fig.* 43*c*).

a

b

c

Fig. 43. Arbitrary retruded axis transfer. *a*, Right side marked. Same on left. *b*, Facebow registration. Patient held. *c*, Facebow record transferred to articulator with upper cast mounted.

The use of the term 'bite-fork' in the facebow assembly is unfortunate since it implies that the facebow has a part to play in the registration of the bite (jaw relationship). This is a common misconception and is often emphasized by the practice of allowing the patient to hold the bite-fork in place with his lower teeth. In addition to causing the misconception this can unseat the bite-fork without the operator seeing it. It is always preferable for the patient or assistant to do the holding (*Fig.* 44*c*). Let it be repeated that the facebow record transfers the arbitrary axis of the condyle centres.

The kinematic facebow

This facebow has adjustable side-arms which can be moved horizontally and vertically. The condyle rods are replaced by rigid wire pointers which are adjusted to touch the retruded axis marks on the face. This facebow is used to transfer the actual retruded axis following its location by the axis locator.

Retruded axis location

The kinematic facebow can be used as an axis locator and the bite-fork is replaced by a clutch which is temporarily cemented to the lower teeth. A rod extending from this clutch is attached to the cross-piece of the locator by a universal joint screw. With the locator secured to the mandible and the side-arms and pointers adjusted to the arbitrary axis areas, the operator moves the mandible up and down while guiding it gently backwards until it can be felt to be rotating on its retruded axis. This is performed one side at a time (*Fig.* 44*a*) or bilaterally (*Fig.* 44*b*). This requires practice and experience and the muscles have to be free from stiffness or discomfort. Once achieved, the sensation of 'give and rotation' is unmistakable. The condyle pointers are then adjusted until they rotate and a piece of graph paper fixed to the face (by petroleum jelly or topical anaesthetic) will help to ensure the rotation. The graph paper is then removed and the condyle points moved in to touch the face on each side and marks made. Preferably they are tattooed—hence the topical anaesthetic—for permanent reference.

The locator with clutch is then removed and used as a kinematic facebow. The clutch is exchanged for a bite-fork which is held against the upper teeth preferably by the assistant (*Fig.* 44*c*). The side-arms and condyle pointers are adjusted lightly to touch the axis marks and the pointers fixed so that they can be withdrawn for removal (so as not to scratch the face) but can be accurately replaced on the side-arms. In this way the intercondylar distance between the axis marks can be retained and transferred to the articulator.

Intercondylar distance

In most adjustable articulators the intercondylar distance is fixed and corresponds to the figure of 6·5 on the condyle rod scales of the Hanau and Dentatus facebows. These articulators can be supplied with extendable condyle rods and the Whipmix articulator has adjustable condyle assemblies. These features can be adjusted to meet the condyle pointers of the kinematic facebow and so permit the actual intercondylar distance to be transferred (*Fig.* 44*d*).

The reason why the kinematic facebow intercondylar distance should not be altered lies in the asymmetry of the mandibular condyles and is best explained by a diagram. In *Fig.* 45 it can be seen that if the condyle pointers on the face-bow are extended inwards (in order to fit a fixed articulator axis) the orientation of axis to teeth will differ between mouth and articulator. This may be

a

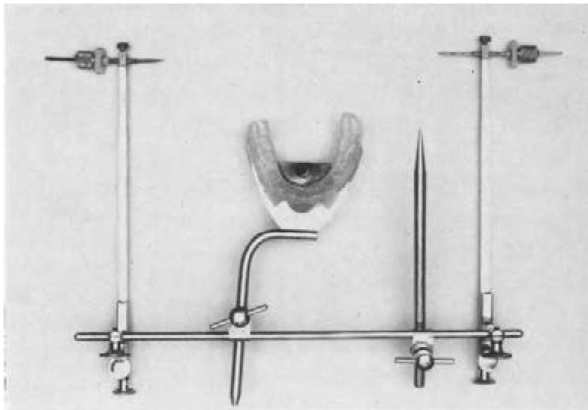
b

c

a small enough difference but it will alter (1) the paths of vertical motion relative to the retruded axis when the teeth close together, and (2) the starting point of the lateral border movements.

Accuracy of the facebow transfer

The need for these degrees of accuracy is a continuing source of debate since the distance between the arbitrary and actual retruded condyle axis is a few millimetres at most. This will cause little alteration to the retruded arc unless



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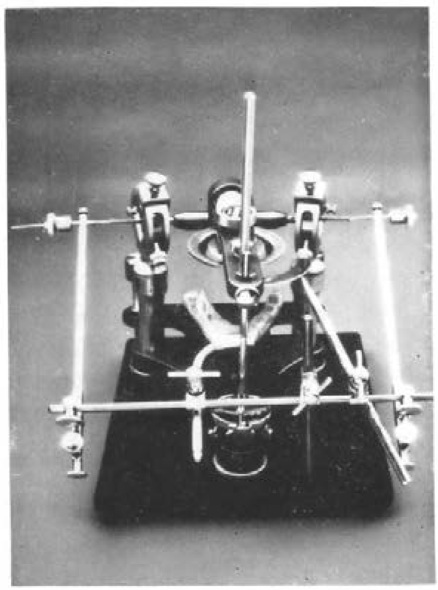


e

Fig. 44. Actual retruded (terminal hinge) axis transfer. *a*, Axis location, one side at a time. *b*, Axis location, both sides at once (home-made locator). *c*, Facebow registration. Assistant held. *d*, Axis locator has been used for facebow record. *e*, Facebow record on articulator, ready for mounting upper cast. Orbital indicator touching axis–orbital plane of articulator. Extendable condyle rods meet condyle pointers on facebow (unaltered).

great accuracy is required as when planning occlusal adjustment procedures (Chapter 10) and when reconstruction procedures are being formed on a gnathological articulator. The same principle applies to the transfer of the intercondylar distance; the resultant articulator movements will differ little from those in the mouth but the difference may be between a deflected path of mandibular closure and one without interferences. Also, accuracy in these transfer procedures helps to promote an accurate state of mind and this will affect all work done for the patient.

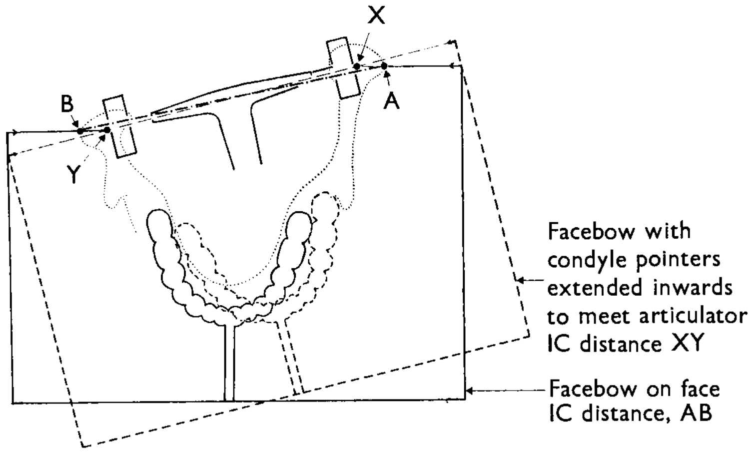


Fig. 45. Intercondylar distance on face (A–B, – · – ·) altered to meet intercondylar distance on articulator (X–Y, – – –). Result is altered orientation of cast to axis on articulator.

In general it is worth repeated emphasis that the facebow transfers a reproducible closing movement to the articulator while the plain-hinge instruments transfer only a position.

Transfer of occlusal position

The decision to transfer the existing intercuspal position or the retruded occlusal position will depend on the objective in using the articulator. If the former, no interocclusal record may be necessary: if the latter a precontact record on the retruded arc will be necessary. A precontact record on any but the retruded axis will be within the parcel of motion and subject to alteration by proprioceptive responses. It will not prove a reliable transfer record. If dentures are being made and bases with occlusal rims are to be transferred a precontact wax wafer is generally used. These procedures will be described in Chapters 9–13.

The *Gothic arch tracing* for transferring the retruded relation of the mandible is usually attributed to Gysi who used it in the construction of complete dentures. This registration is made at a precontact level and the upper and lower bases and occlusal rims are secured together while the stylus rests at the apex of the arch. A tiny hole is often drilled at this point to engage and fix the stylus. This may have the effect of acting as a fulcrum for the mandible which may rotate about this fulcrum while the plaster is setting and give an inaccurate record. Payne (1969) made a study of the Gothic arch tracings of 5 edentulous patients and found this record to be 'a reliable guide to the position of habitual closure' but that 'it is not the maximum possible retruded position'. This is an ingeniously devised study worth repeating. In a mouth with healthy muscles the Gothic arch is the keystone point in pantographic transfers yet it remains controversial.

Condyle adjustments

The objective in using an adjustable articulator is to transfer positional records of precontact protruded and lateral relationships between mandible and maxilla to casts of the teeth already mounted on the articulator. The adjustable condyle mechanism on the articulator is then used to adjust the seating of the plaster teeth into the tooth imprints on the records. The casts are thus placed in the same relation on the articulator as the teeth were in the mouth when the positional records were made. The adjustable mechanism records the angle of descent of the condyles relative to the horizontal plane of the articulator, and this corresponds to the angle of descent of the patient's condyles where the records were made relative to the Frankfurt plane. If the orbital indicator of the facebow has been used to relate the facebow to the Frankfurt plane the angle on the condyle mechanism should be the same as the one transferred from the patient's condyles. If this indicator has not been used the angle will be the same but the figure on the mechanism will be different since all condyle angles on the articulator are relative to its horizontal plane.

Generally, the protruded record is the only one used and if this is made with the mandible in the midline the angle of descent will tend to be the same on both sides and this figure is also used for the lateral movements on the articulator. When lateral records are used, the angle is usually steeper than the protrusive angle. The angle between the protrusive path and the path of the balancing condyle in lateral movement is known as the Fischer angle and varies between 3° and 10°. If lateral records have not been made, it is advisable to increase the condyle guidance by 5° over the protrusive guidance when articulation adjustments are being made for complete dentures. This angle can be readily seen when pantographic tracings of the lateral border movements are being made (*see Fig.* 54, p. 120).

Bennett angle. In order that the inward condyle path followed during the balancing lateral movement be copied on the condylar mechanism the condylar posts are rotated inwards. This angle which the path of the balancing condyle makes with the median plane is called the Bennett angle and varies between 5° and 30°. As this inward (and downward) movement also has an outward component it is an angle which must be difficult to calculate. None the less, Hanau had a formula for it which reads $B = \frac{1}{8}H + 12$ where H is the protrusive angle. This is learned and immediately forgotten by most students after graduation. Gysi is believed to have adjudged it basically wrong and set up geometrical constructions to prove it. In the adjustable articulator this angle is usually set at 15° and if greater accuracy is required, as when reconstruction procedures are being carried out, a pantographic tracing transferred to a gnathological articulator will provide it.

Paths of movement on the articulator

It is assumed that the paths of movement of the condyles on the articulator between the recorded protruded and intercuspal positions are the same as those in the patient. This accuracy cannot be assumed since the articulator condyle paths are straight lines whereas in the joints they tend to be curved. Some adjustable articulators have curved condyle paths but these too can be inaccurate assumptions. Where lateral paths are concerned, the adjustable articulator has no accurate copy of the lateral (Bennett) shift movements. In the Hanau and Dentatus instruments a straight lateral shift is possible after the condyle axis has moved forwards (*Fig.* 46). In the mouth this begins immediately the movement from intercuspal position begins and conversely as the mandible moves into intercuspal position from a lateral incoming movement. This component of lateral movement may be critical in avoiding deflective cusp contacts and where the quality of the work demands such accuracy a gnathological articulator is recommended.

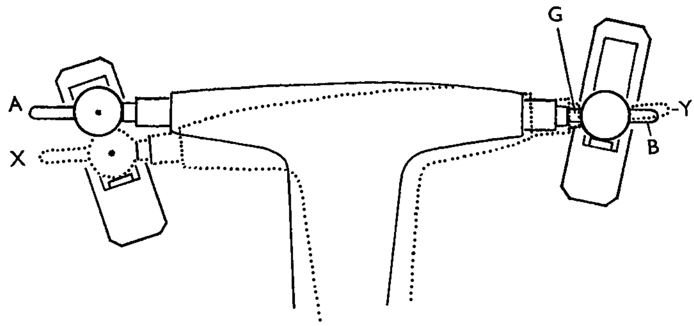


Fig. 46. Lateral shift permitted on Hanau (Dentatus) type articulator, *see* gap G. If shoulder of axle is kept in contact with condyle sphere on balancing side the condyle axis will shift laterally on balancing movement. AB to XY. It is an arbitrary movement and no lateral shift is possible at IP.

Arcon and condylar mechanisms

These are terms given by Bergström (1950) to the condyle mechanisms of adjustable articulators to distinguish between those which have the condyle elements on the upper or lower member of the articulator. The *arcon* articulator has the condyle on the lower member, as in the mandible, and the *condylar* articulator has the condyle on the upper member. Examples of both are shown in *Fig.* 52, p. 114.

The application of this principle to adjustable articulators lies in the accuracy of transfer of the protrusive positional record. The distance between the condyles and the lower teeth in protruded relation will be the same in the mouth as on the arcon articulator. On the condylar articulator where the condyles move backwards in protrusion the distance between the condyles and lower teeth will be twice the distance which the condyle travels. This will usually be 12 instead of 6 mm. Since, in the condylar articulator, the condyle moves upwards as well as backwards, the angle between the line forming the condyle and upper incisor teeth and the horizontal plane will be steeper than the angle made by the line joining the same two points in the arcon articulator (*Fig.* 47). This may not be a significant difference but the arcon articulator will produce a more accurate copy of the protruded relation between the teeth.

Incisal guidance pin and table

These are features of adjustable articulators which essentially provide a stop for closure of the upper member. The pin or rod has a screwstop attachment to the upper member and rests on an adjustable table on the lower member. By altering the level of attachment of the pin to the upper member the vertical dimension of occlusion can be raised or lowered.

The table can be adjustable in level around the pin stop position so that any movement of the pin away from the retruded position of the upper member can be raised at varying angles. Most incisal guidance tables can be adjusted in both anteroposterior and lateral directions. This corresponds to a lift of the articulator upper teeth (or to a drop of the patient's lower teeth) as they move away from intercuspal position. The table then becomes an incisal guidance plane and can be adjusted to correspond to the guidance provided by the patient's incisor and canine teeth by moving the angles of the table until the

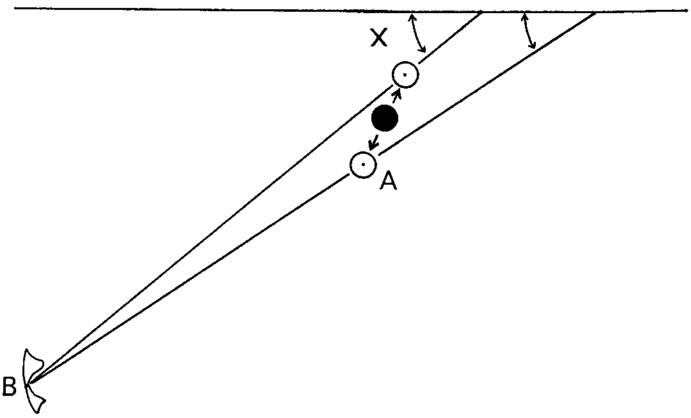


Fig. 47. Difference between angles of condyle descent between arcon (A–B) and condylar (X–B) mechanisms.

pin does not lift from it in protrusion (*see Fig.* 52*a*, p. 114). In setting denture teeth or reconstructing natural ones the incisal guidance can be decided by the dentist to correspond to the requirements of condyle guidance (which cannot be altered) and to fit the articulation plan for cusp height, occlusal curve and plane. It will have no influence where the horizontal overlap is such as to exclude incisor tooth contact. It is a guiding factor for articulator contacts of the incisor and canine teeth. A steep incisal guidance (as in Class II, division 2 cases) will provide immediate separation of the posterior teeth on protrusive articulation. A flat guidance will allow posterior tooth articulation on protrusion. To have any influence, however, the pin must remain on the table during articular movements and the angle is decided by the dentist.

Advantages and disadvantages

Adjustable facebow articulators, therefore, provide four aids to copying mandibular movements on the laboratory bench:

1. Transfer of retruded path of closure.
2. Transfer of angles of condyle descent in protruded and lateral precontact relations of mandible to maxilla.
3. Approximate lateral shifts.
4. Adjustable incisal guidance table.

In addition, greater accuracy can be achieved by those instruments having an arcon condyle mechanism and adjustable intercondylar distance.

There are three shortcomings of these articulators:

1. The arbitrary facebow is an approximation of the actual retruded axis.
2. The precontact records are therefore made within the borders of the parcel of motion and are therefore not reproducible.

3. The paths between the positional records are straight-line approximations of the actual condyle movements.

These shortcomings are not intended to detract from the considerable advantages of adjustable articulators over plain hinges which cannot, by definition, be called articulators.

Adjustable articulators, ancient and modern

It is not the intention in this text to make a comprehensive survey of these instruments. The intention is to examine the principles in articulators rather than in describing the details of each. Posselt (1962) made a simple and well-illustrated survey in his book and wisely referred to articulators as diagnostic aids. Brandrup-Wognsen (1952) related the principles of movements and positions to several articulators and both texts are required reading in this subject.

Bonwill's articulator has already been mentioned and, although not adjustable in the present definition, to him must go the credit for the first in the field of modern prosthetic dentistry. Snow (1900) gets the credit for the first facebow articulator and Christensen (1901) was the first to use intra-oral records for adjusting the condyle guidance and both these instruments had their condyle paths on the upper member and thus were arcon articulators. Gysi's many designs of articulator are a study in itself. His Simplex can be seen in many schools and his Trubyte is reckoned to be too complex for undergraduate students. The Trubyte has a centrally placed mechanism for adjusting to the Bennett movement and this was the prototype for many of the gnathological articulators (*Fig.* 48).

Two adjustable articulators which have no condyle axis are the Stansbery tripod (1932) (*Fig.* 49) and Monson's articulator (1918). The tripod has three guide paths on the lower member and arms which rest on them on the upper member. The guide paths are adjusted from intra-oral plaster records which have to be registered at a predetermined vertical position. Monson designed his articulator to conform with his theory of spherical occlusion in which the lower posterior teeth conform to the arc of a sphere whose radius is 4 in. and whose centre is in the region of the glabella. This provides an axis for protrusive and lateral movements but no relationship is allowed with the retruded condyle axis either arbitrary or actual.

The Hagman balancer* (*Fig.* 50) provides a method based on Monson's theory of assessing the arc determined by the curve of the lower teeth. Segments of spheres of 2-, 3- or 4-in. radii are attached to the upper member of the balancer and the lower cast is placed against successive spheres until the most approximate one is found. The upper cast is mounted to the lower. The relevant radius can then be measured by dividers from a depression on the positioning screw (on the upper member) to the arc of occlusion. Where restorations are being made on natural teeth or complete dentures are being constructed, dividers with a selected radius are used to determine the arc of occlusion. The principle on which the articulator moves is that the occlusal planes of the teeth determine the movements and not the mechanical guides of the articulator. Freedom of movement is permitted on the balancer's only joint and this is performed by holding the upper model and moving the lower.

* 1947, Hagman Balancer Co., Minneapolis, Minn.

Wadsworth's articulator (1918) (*Fig.* 51*a*) employed the arc of a circle to determine the occlusal curve and this principle had its origins with Bonwill and Monson. Dividers were used to determine a radius between the condyle and the 'median incisal angle'. Using this radius and with the condyle and median incisal angle respectively as centres arcs were described on a 'centering plate' attached to the upper member. Then, with the intersection of these two arcs

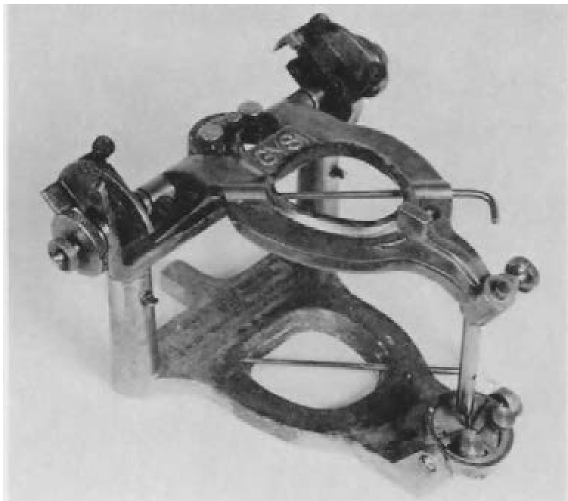


Fig. 48. Gysi Trubyte articulator. (*Photograph supplied by Mr. R. I. Nairn.*)

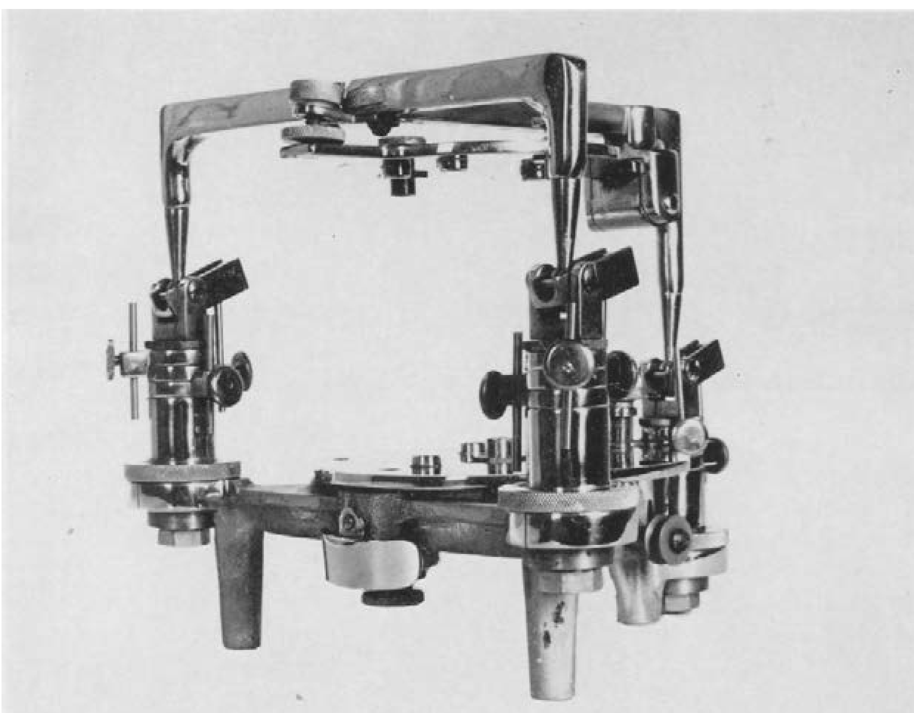


Fig. 49. Stansbery tripod. (*Photograph supplied by Professor W. A. Lawson.*)

as centre, the dividers were used to scribe an arc on the occlusal rims (*Fig.* 51*e*). This arc was then used as a guide for setting the upper posterior teeth. Two other features of the Wadsworth assembly were the use of a T piece attached to the facebow for orientating the upper cast accurately to the patient's face and condylar posts which had screw mechanisms for easy adjustment of the intercondylar distance. This adjustable articulator and others could well be revived today without any loss of accuracy.

Fig. 50. Hagman balancer. (*Photograph supplied by Professor W. A. Lawson.*)

Of the more modern instruments, Hanau's Model H has been and is the model for the simple adjustable articulators. On it the Dentatus was modelled and both have moved forwards with refinements. The Hanau SMX and Dentatus ARL (*Fig.* 52*a*) both have extendable condyle axis rods for adjusting to the intercondylar distance of a kinematic facebow. Dentatus employs a gauge block and lockscrew for restoring any lost accuracy of the instrument in use. The latest Dentatus model (ARO) has a device for resetting the lower model and ring by a universal screw device without having to resort to replastering.

Brandrup-Wognsen (1952) acknowledged Wadsworth as his model and his articulator includes the same method for adjusting the intercondylar distance. Fine adjustment screws in the incisal guidance and condyle assemblies make it possible to adjust the upper member to various interocclusal records and compare them. Also a locknut in the condylar post makes it possible to determine the Bennett angle by adjustment to a lateral record.

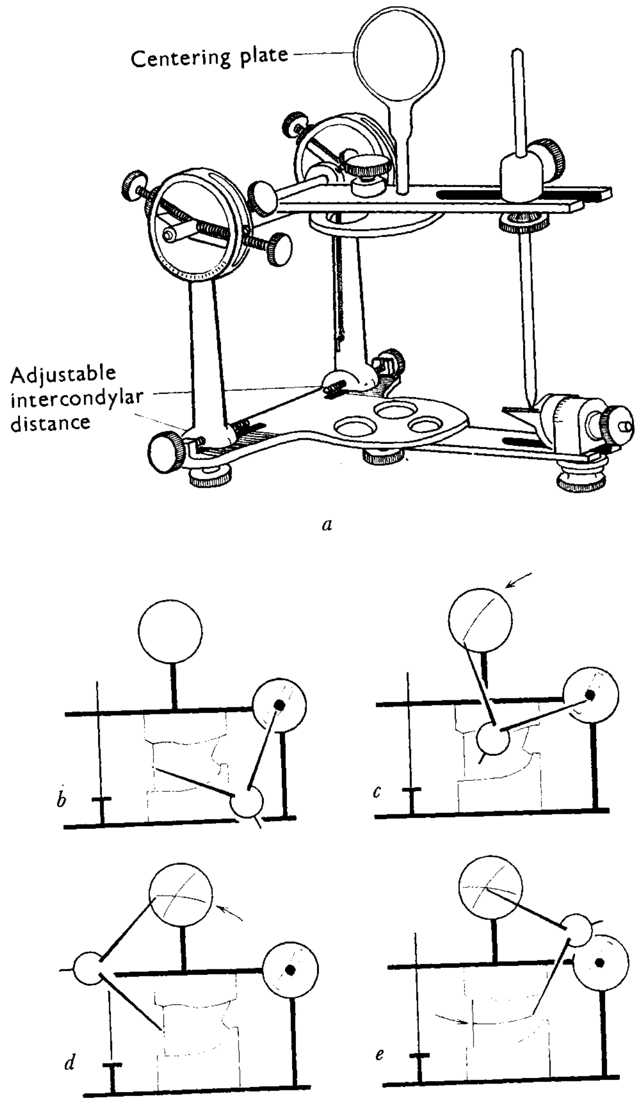


Fig. 51. Diagram. Wadsworth articulator. *a*, Articulator with centering plate on upper member and adjustable intercondylar distance. *b*, Dividers measuring condyle-median incisal distance. *c*, Scribing first arc. *d*, Scribing second arc. *e*, Occlusal plane scribed on occlusal rims.

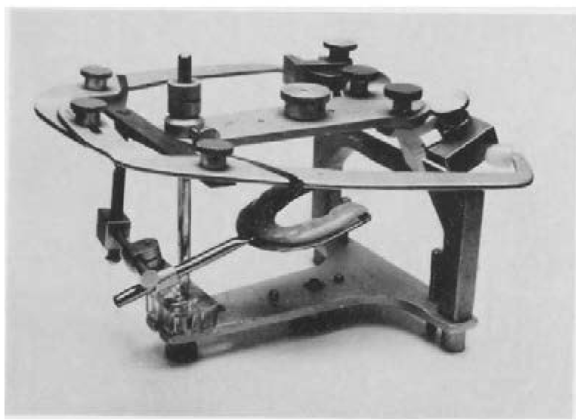
Bergström's articulator with the simplest design possesses the arcon principle, curved condylar paths and possibilities for the Bennett movement. His monograph on the reproduction of the articulation has become a standard work. Illustrations of Bandrup-Wognsen's and Bergström's articulators can be found in Posselt's book (pp. 107, 108).

Finally, comes the latest development from Stuart at the request of many dentists to provide a simple version of his gnathological instruments. The

Whipmix is an arcon articulator with possibilities for Bennett movement and adjustable condyle elements. It is easily handled and possesses a new style facebow which is inserted into the ears (*Fig.* 52*b*).

No doubt articulators will continue to occupy the minds of inventive and mechanically talented dentists and new designs will continue to appear. Two features for future articulators require invention: firstly, a clutch mechanism

a



b

Fig. 52. *a*, Dentatus ARL. Condylar mechanism. Adjustable incisal table. *b*, Whipmix. Arcon mechanism. Facebow in place.

for securing casts to the upper and lower members with the lower clutch reliably and readily readjustable and, secondly, a mechanism for readily recognizing which of several interocclusal retruded records is the most retruded, without resorting to the split-cast (Lauritzen) or opposing-pin (Brewer) methods, both of which are reliable but time consuming. To be able to dispense with plaster would be a great asset both from the point of view of time and the expansion of plaster.

GNATHOLOGICAL ARTICULATORS

The objective of the gnathological articulator is to provide a copy of the reproducible border movements of the condyles and mandible, namely, the arc of opening and closure on the retruded axis and the horizontal envelope at one level. These border movements are not always producible, let alone reproducible, because of muscle disability (pain or stiffness) on one or both sides. Assuming border movements unrestricted by disability, however, it is possible to make an accurate retruded axis registration and tracings of the horizontal envelope of motion in three planes, on each side of the face, by styli on prepared writing tables. These are transferred to the articulator which can be adjusted to follow the tracings.

It may be said that to reduce human neuromuscular movements to a series of curves and rotations is asking too much of man's ingenuity, that jaw movements are too refined and delicate to be copied and that, copying nature is a presumption too bold to attempt. But it is justifiable to assume that the movements, however delicate, have rotational and translatory components, and that if they are reproducible an attempt can be made to copy them.

Hypotheses of mandibular movements

The hypothesis of reproducible border movements of the unrestricted mandible has already been made. These are the vertical and horizontal envelopes of motion. In order to observe and transfer these movements to a gnathological articulator a further hypothesis is made, namely, to suppose that the movements are made by the imaginary retruded axis running between imaginary points on the lateral surfaces of each condyle. *Fig.* 20*a* (p. 59) shows this axis as an axle and it has to be imagined that it is this axle which is rotating, translating and tilting during all mandibular movements and during the border movements in particular. These border movements are assumed to have five centres of rotation:

1. A coronal horizontal centre of rotation around the retruded condyle axis producing a vertical arc of movement (*Fig.* 20*a*).
2. Two vertical centres of rotation (one in each condyle) producing horizontal arcs of movement (*Fig.* 20*b*).
3. Two sagittal horizontal centres of rotation (one in each condyle) producing vertical arcs of movement in the coronal planes (*Fig.* 20*c*).

When the condyle axis is fully retruded its centre of rotation remains stationary and the arc of movement described by a point between the lower incisors can measure up to 20 mm. All other border movements of the axis involve the five centres of rotation with the condyle axis moving in three dimensions. For example, in the retruded lateral movement to the left the condyle axis rotates, the left vertical axis rotates and translates permitting the right condyle to move inwards, and the left horizontal sagittal axis rotates permitting the right condyle to move downwards. A final assumption is that if the left and right border movements (the horizontal envelope) and the retruded axis can be transferred to an articulator all mandibular movements can be copied on it.

Transfer of mandibular border movements

In order to test these hypotheses and assumptions, and to be able to transfer border movements to an instrument which will copy them, several gnathological articulators have been devised. Essentially they consists of four adjustable parts:

1. A condylar axis with an adjustable intercondylar distance. This is not an axle but two independent hinges with the condyles attached to the lower member.

2, 3. Left and right adjustable condyle assemblies which can be adjusted to copy the vertical and sagittal rotations.

4. A guide mechanism between the upper and lower members which will permit the lateral shift movements to be copied.

These parts are adjusted to copy records transferred from the mouth. An incisal guidance pin and table are also included. These permit the height of the upper member to be altered and the horizontal tilt of the table to be adjusted laterally and anteroposteriorly. These adjustments are made, arbitrarily, by the operator.

Advantages of transferring movements

The value of being able to accurately transfer jaw movements are twofold: Firstly, movements made in the mouth can be seen on the laboratory bench and a diagnosis made of occlusal disturbances. Secondly, restorations can be planned and carried out to conform to existing jaw movements.

Movements transferred

The border jaw movements which can be transferred from mouth to articulator are:

1. The arc of opening and closing made when the condyle axis is retruded.
2. The lateral arcs of movements made by the condyle axis at one level of jaw separation.

Records of these movements are transferred to a gnathological articulator which can then be adjusted to copy them.

Retruded axis transfer

The transfer of the retruded opening and closing arc is achieved by registering the retruded condyle axis, marking its extensions on both sides of the face, and by transferring this axis to an articulator which can be adjusted to receive and copy it. This procedure was described in the previous section.

The correct performance of this operation is essential to the accuracy required for gnathological transfers. If the axis transfer is not retruded not only will the axis of closure on the instrument be incorrect but the pantographic tracings which follow will be incorrectly transferred. Instruction and practice in the feel of the mandible when it is fully retruded are therefore essential. Only when the condyle axis is retruded will the condyle pointers rotate and this provides the confirmation of retruded axis rotation. By keeping the mandible in this position and extending the pointers to touch the side of the face the retruded axis centre of rotation can be marked and subsequently tattooed on both sides of the face.

TATTOOING

It is desirable to mark the axis points permanently on the face since the axis transfer is often not made until the pantographic tracings have been completed and ink marks tend to rub off. Also, if restorations are being planned, facebow transfers may be required at various stages and it would be an unnecessary expenditure of time to make a retruded axis registration each time a transfer was required. The permanent marking is made with a skin-coloured tattoo, using a hypodermic needle or a special form of applicator consisting of three tiny needles welded together which carry the tattoo powder between the three points. The tattooed marks are visible only to the dentist and can last for a number of years.

The transfer of the retruded axis to the articulator is made when the pantograph of the horizontal border movements is being transferred.

Registration of the horizontal border movements

This is carried out by a pantograph which is a device for registering the left and right border movements of the mandible. This is performed on three planes

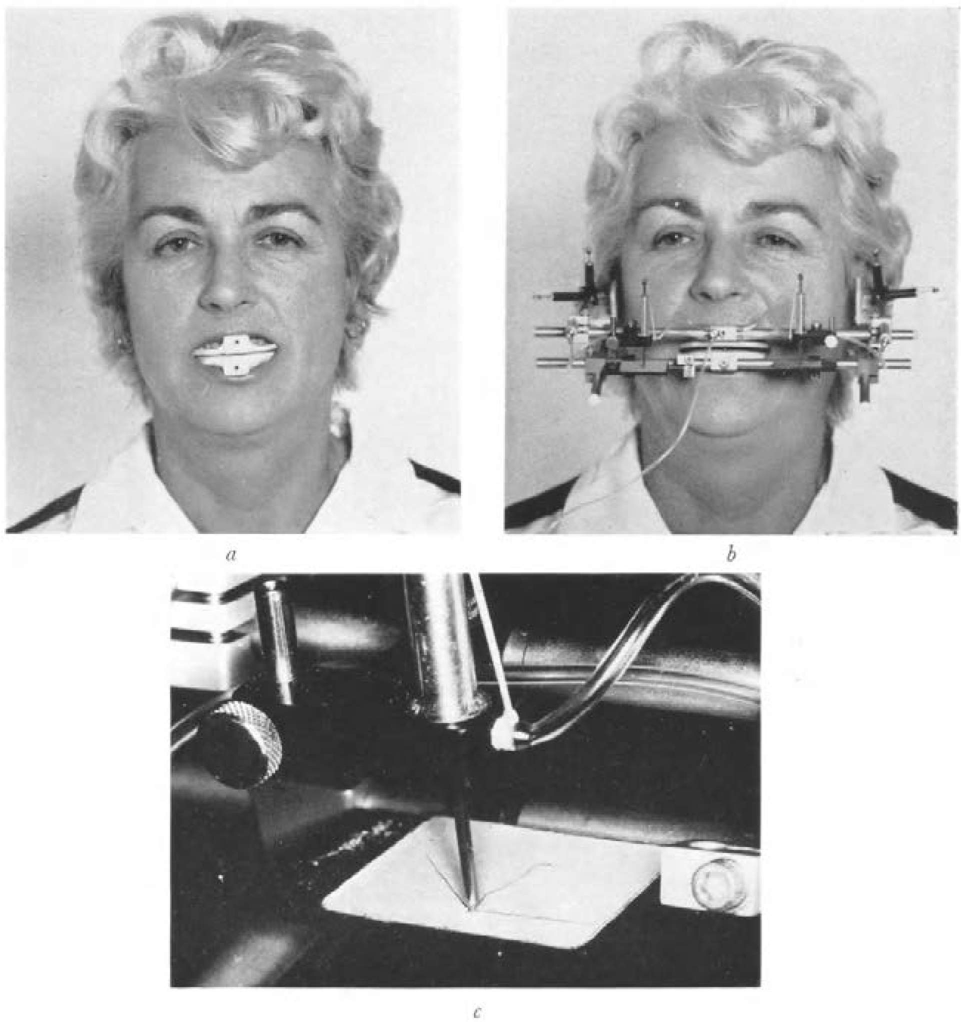
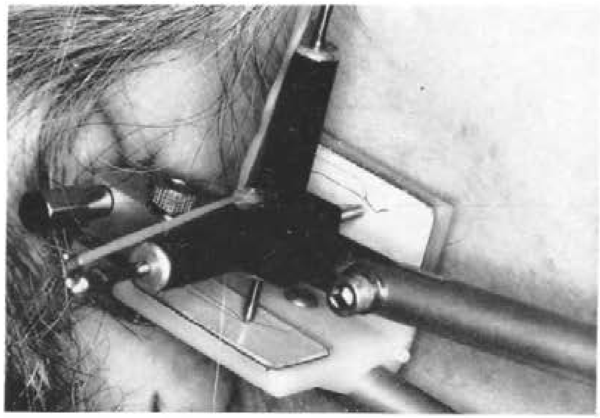


Fig. 53. Pantograph series, *a*, Clutches in place. *b*, Pantograph. *c*, Anterior tracing.

on each side of the midline while the teeth are separated by a central bearing screw. It also registers the protrusive movement which is not a border movement but begins and ends at a border position. The pantograph consists of an upper and lower frame each consisting of three bars bolted together. The side-arms of the lower frame can be adjusted so that the condyle pointers touch the tattooed axis marks. The lower frame is, in fact, the axis locator to which are added six writing tables; three on each side, in different planes. The upper



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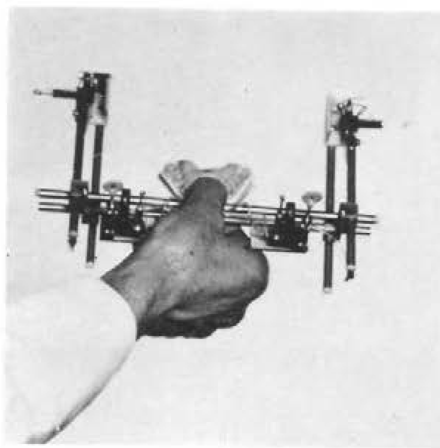

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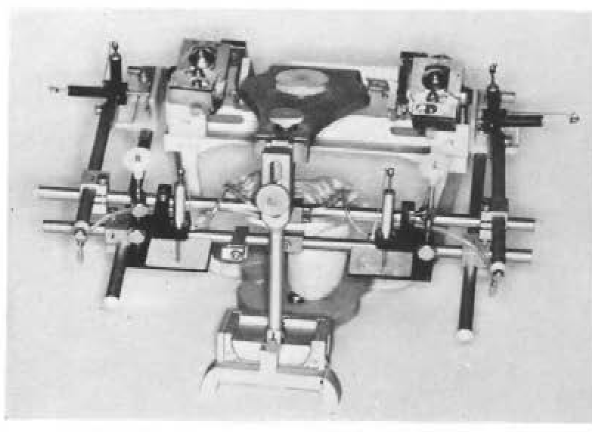

f

Fig. 53. (*Continued*) *d*, Horizontal and vertical tracings. *Note*: Pointer on vertical tracing has slipped. It should not be transferred until seated on retruded position. *e*, Pantograph removed. *f*, Pantograph transferred. Reference pointer missing.

frame carries six styli each at right-angles to each opposing table. The frames are attached to the upper and lower teeth respectively by means of clutches either seated securely or temporarily cemented. They are separated by a central bearing screw adjusted to the closest distance between the teeth but permitting unrestricted lateral movements between the clutches (*Fig.* 53). In some pantographs the vertical and horizontal side-tables are on the upper frame with the styli on the lower. The differences lies in having to read the tracings made on them in reverse of those made on anterior horizontal tables.

The attachment of the frames to the teeth and the assembly of the styli at right-angles to the tables (to provide unrestricted movement of the styli) require careful instruction and practice. The instruction of the patient to provide the border movements also requires practice but when correctly performed the tracings made by the movements will be reproducible. Guichet makes these instructions to the patient a strict ritual which can produce a pantographic tracing in 11 minutes. It should be repeated that these movements will be reproducible only if the muscles are free from inhibitory spasm, stiffness or pain.

The tracings represent movements made by the lower incisor midline, and right and left extensions of the condyle axis.

Analysis of the tracings

RETRUDED POSITION (*Fig.* 54)

This is the dot at the apex of the Gothic arch on the two anterior tables and in the middle of the vertical and horizontal tracings. Two successive check applications of the styli are made after the mandible has moved forwards and back before the lateral and protrusive tracings are made.

LEFT LATERAL TRACINGS (*Fig.* 54*a*)

These are made from retruded position outwards to the left with the styli in contact. The mandible is then returned to the retruded position with the styli withdrawn. The movement is repeated with the styli again in contact in order to check its reproducibility.

The two anterior tables (T1 and T4) have moved to the left so that the tracings are made towards the right and represent the arc of movement when the left condyle LC makes a vertical rotation. The arc is flattened because LC has itself moved to the left.

The two left tables (T2 and T3 working side) have rotated and moved backwards slightly. The tracing on T2 will show an immediate side shift (inwards, because the table has moved outwards) and then a more sloping progressive side-shift. On T3 (the vertically placed table) the tracing shows the extension of the rotation of LC.

The two right tables (T5 and T6 balancing side) will have moved forwards, downwards and inwards following the path of the right-side balancing condyle. It will describe an arc involving the vertical and sagittal horizontal centres of rotation at LC and a slight rotation of the condyle axis itself if the mandible descends in this movement. The extent of this descent will depend on whether the guidance path of the central bearing screw inclines downwards or is horizontal, in which case the condyle axis will not rotate. The tracing on T5 shows the immediate and progressive side shifts in the horizontal plane and on T6 it shows the path of the descending condyle in the vertical plane.

RIGHT LATERAL TRACINGS

These will be the reverse of the left tracings and can be seen in the completed tracings (*Fig.* 54*b*).

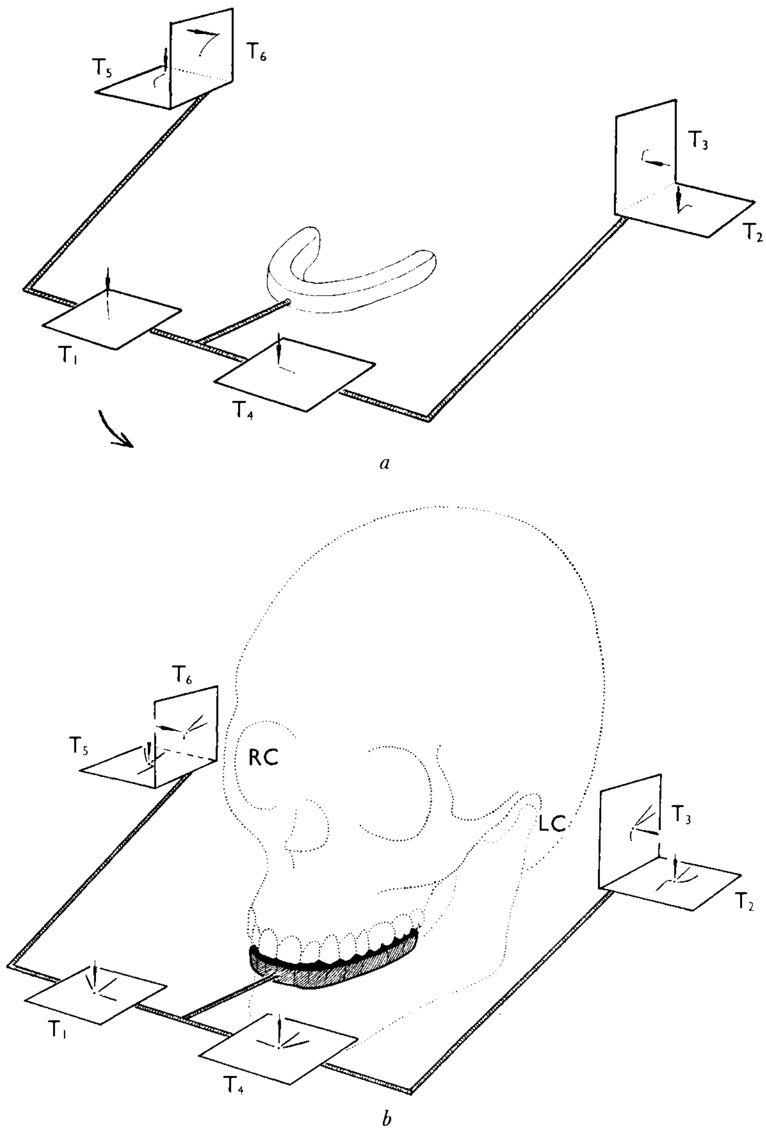

Fig. 54. Diagram. Pantograph tracings. *a*, First tracing to right when mandible moves to left. *b*, Completed tracing (*see* text).

PROTRUSIVE TRACINGS

These are obtained by contact of the stylus with the table from the retruded to the protruded position. The stylus is then withdrawn and the mandible returned to the retruded position again. The stylus is re-engaged and the movement repeated.

Tables T1 and T4 will have moved forwards and back and tracings should have moved backwards in a straight line to the protruded position. Any interruption to this movement (such as a click) will be shown on this tracing (*Fig.* 53*c*).

Tables T2 and T5 should show identical backwards tracings and T3 and T6 should show similar downwards and backwards tracings at a less steep angle than those of the balancing condyle tracings. This demonstrates the Fischer angle.

Transfer of pantograph to articulator

Before making the transfer two important steps must be taken.

A reference pointer is attached to the upper frame and laid against a fixed point on the face in order to establish the level at which the tracings were made. This will allow future transfers to be made to the articulator at the same level as the original transfer and articulator adjustment were made. Future transfers must, therefore, have a pointer attached to the facebow and touching the same mark. The mark on the face can be a fixed distance from a tooth tip (normally a canine) but which cannot be cut or prepared when the subsequent transfer is made. Alternatively, it can be a tattooed mark as for the retruded axis points.

The upper and lower frames are joined together with the condyle axis retruded and the condyle pointers touching the retruded axis marks.

The joined pantograph frames are then removed with the clutches. The frames are removed together (*Fig.* 53*e*) and the whole assembly is taken to the articulator where the intercondylar distance is adjusted to touch the condyle pointers. The articulator and pantograph are rendered secure, usually by using a mounting frame, and the upper clutch is secured with plaster to the upper member of the articulator. The lower clutch is then secured to the lower arm of the articulator after which the clutches and frames can be separated and the articulator is ready to be adjusted to the tracings.

The mounting procedure is not a simple one and care has to be taken on many points to ensure accuracy. This requires separate instruction and practice following the details supplied in the relevant articulator manual.

Adjustment of the articulator

The upper pantograph frame (mounted to the upper member) should be freely movable along the tracings. The condyle and lateral shift mechanisms are then adjusted in a series of steps to follow all the tracings on the pantograph. The upper member of the articulator will then be able to move along the same paths as the mandible has moved relative to the maxilla during the border movements. The upper member will rotate on the same axis of rotation as the mandible rotates on its retruded condyle axis. The various adjustment angles are noted for the patient in question and the articulator can be used for the same patient on subsequent occasions. The articulator is now ready to receive casts of the teeth for examination, for treatment planning and, at a later date, for treatment. It is important to emphasize that the tracings, transfers and articulator adjustment are carried out before any treatment is planned.

Uses of the gnathological articulator

The gnathological approach to problems of occlusion and its application is set out by Guichet (1969) and will repay careful study.

RECOGNITION OF DISTURBANCES

The first use of these articulators is for the recognition of occlusal and articulation disturbances. When the articulator has been adjusted accurate casts of the upper and lower teeth are made. The upper cast is mounted on the upper arm of the articulator using a facebow transfer of the upper teeth in relation to the retruded condyle axis and to the vertical reference mark. The lower cast is mounted to lower member using a precontact record on the retruded axis. This latter step is of the greatest importance since the arc of closure must be on the retruded axis if the movements are to be copied accurately. It may be necessary to check this record and a method of doing this will be described in Chapter 10.

When mounted, the casts can be closed on the retruded axis and in all possible closures. All lateral and protrusive articular movements can be made on and within the border parcel of movement in the knowledge that they can be carried out in the mouth. Diagnosis of occlusal disturbances can be made and confirmed in the mouth and it is seldom that a return to a positional record articulator will be found satisfactory after a gnathological instrument has been used for this purpose.

TREATMENT PLANNING

Duplicate casts can be mounted and occlusal corrections and restorations can be created on the articular so as to achieve a plan of occlusion and articulation which can be discussed with technician and colleagues and presented to the patient. This provides opportunities for criticism and modifications in the knowledge that the closures and movements on the articulator are those performed in the mouth.

TREATMENT PROCEDURES

After the diagnosis and treatment plan have been made, casts of the prepared teeth are transferred to the articulator using a facebow transfer for the upper cast recorded at the same height relative to vertical mark on the face as the tracings were made and a precontact interocclusal record on the retruded axis. These procedures will be discussed in Chapter 10.

REMOUNT PROCEDURES

When reconstruction work has been seated in the mouth it is often necessary to remount it before cementing the restorations. This is done with a new precontact record and adjustments to the occlusal surfaces can be made if necessary.

Examples of gnathological articulators are shown in *Fig.* 55.

PLASTIC RECORD ARTICULATOR

This is a gnathological articulator which uses an *intra-oral*, fast-setting plastic record of the border movements for developing condyle movements on the articulator.

The *intra-oral plastic record* of the lateral border and protrusive movements is achieved by cutting studs which mould pathways into fast-setting acrylic resin. An upper clutch carrying three studs and a central bearing screw is seated securely on the upper teeth and a lower clutch on which three mounds of fast-setting resin is seated on the lower teeth. As the resin is setting the mandible performs the lateral border and protrusive movements. When set the clutches carrying the records (*Fig.* 56*b*) are transferred to a specially designed articulator carrying boxes in the condyle regions of the upper member (*Fig.* 56*c*). On the lower member are mounted the condyles with adjustable intercondylar

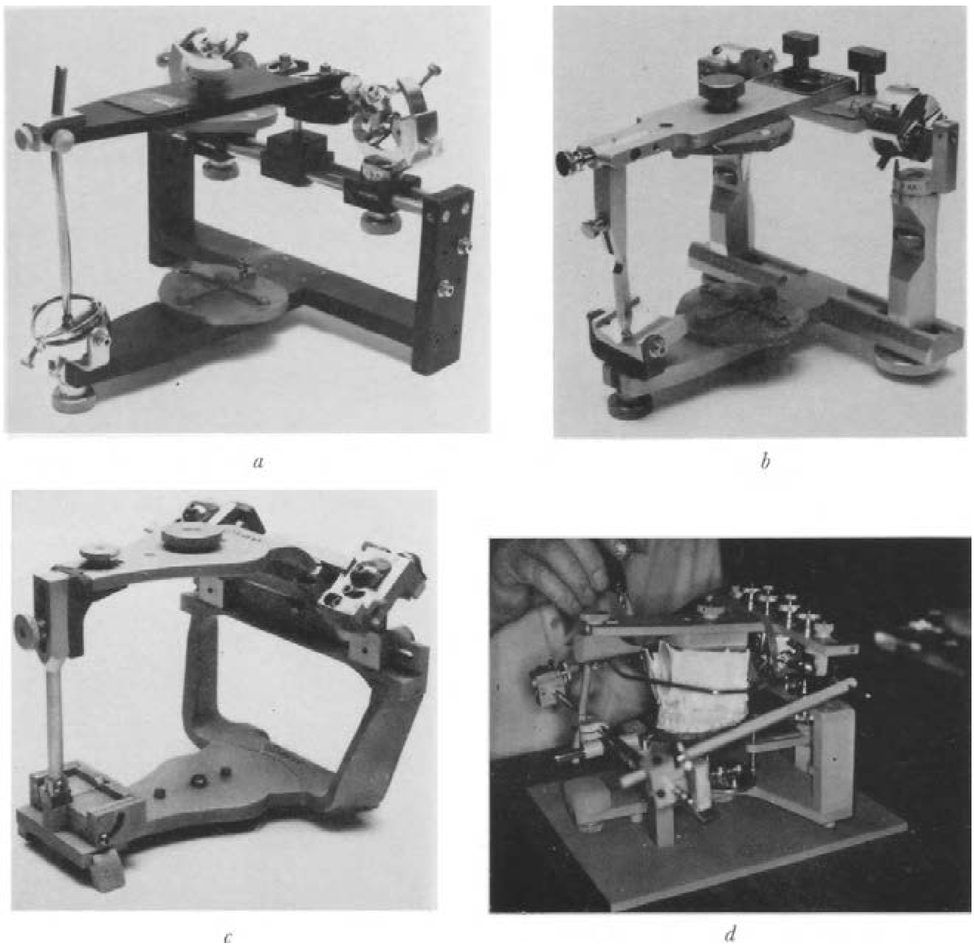

Fig. 55. Gnathological articulators. *a*, Granger gnatholator. *b*, Granger simulator. *c*, Denar articulation. *d*, Stuart. (*Photograph supplied by Dr. C. E. Stuart*).

distance (*Fig.* 56*d*). The transfer is made with the clutches in retruded relation to the retruded condyle axis and to a fixed mark on the face, as for the pantograph transfer. Fast-setting resin is then placed in the boxes and the movements determined by the intra-oral record are repeated on the articulator as the resin sets (*Fig.* 56*e*). The lower member condyles will then make a plastic record in the condyle boxes of the movements made in the mouth. The boxes are removable and accurately replaceable and can be used for studying the same movements when casts of the teeth are mounted (with retruded axis and retruded relation transfer) or for waxing restorations on casts of the prepared teeth similarly transferred.

The gnathological articulator developed for this procedure is the TMJ instrument (*Fig.* 56) and was developed by Swanson (1965) and Wipf. Instruction and practice are necessary, and the accuracy of the movements reproduced on the articulator depends on the knowledge and skill of the operator.

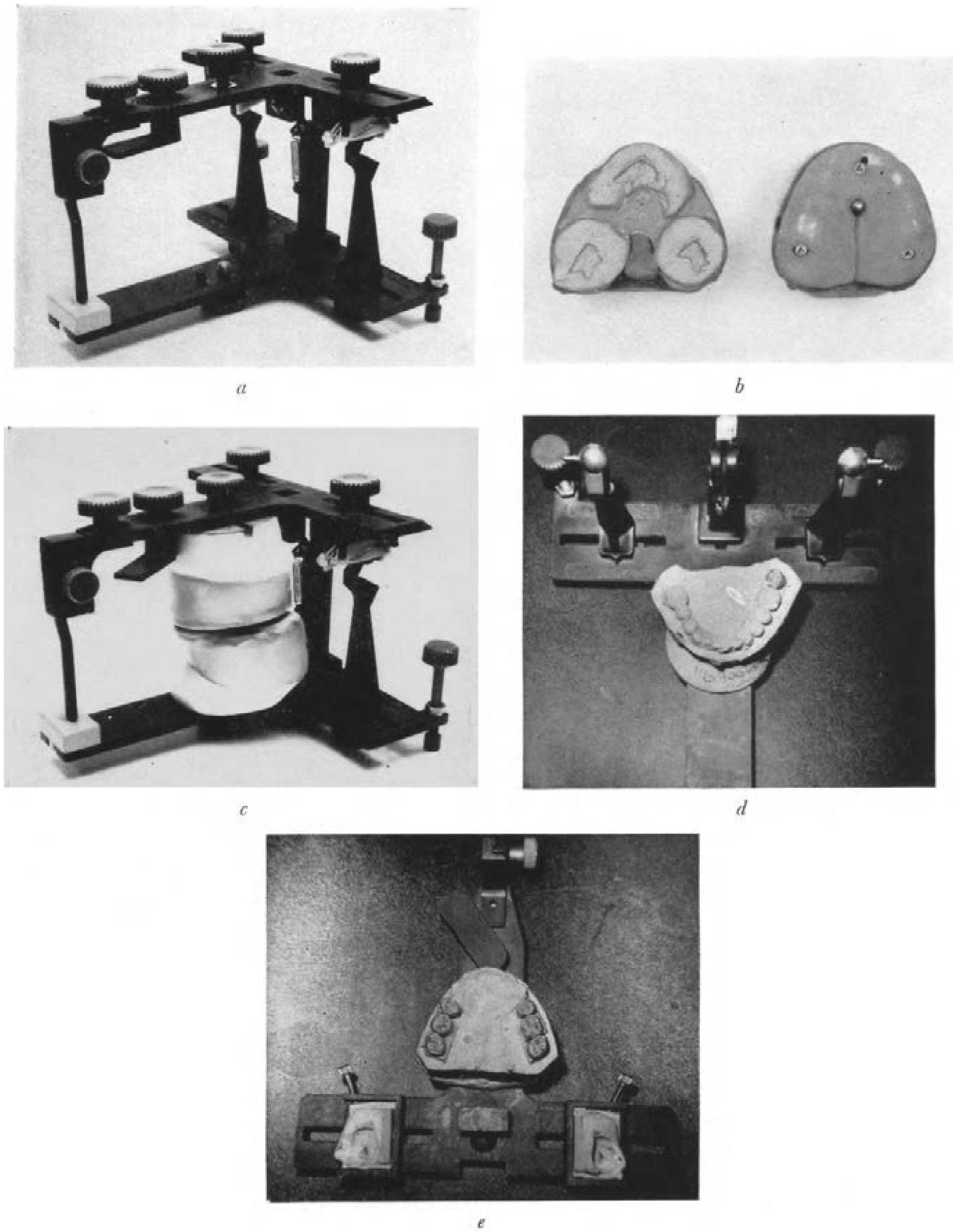

Fig. 56. *a*, TMJ articulator. *b*, Intra-oral plastic record. *c*, Record and casts mounted (transferred from retruded axis). *d*, Lower member with condyles (arcon). *e*, Upper member showing condyle boxes with record made on instrument from intra-oral record. Work in place.

General

The procedures require instruction, practice, supervision and patience with no immediate reward. The long-term rewards are accuracy of transfer from mouth to articulator and back to mouth again and these can be considerable. The justification for their cost and use is a problem for the individual, his aspirations, his knowledge and ability.

Gnathological articulators are designed to copy the vertical opening and closing movements of the mandible on its retruded condyle axis and the lateral border and straight protrusive horizontal movements at one level of jaw separation. The assumption then is that all movements on and within these borders are reproducible. There are three requirements for the accurate copy of these movements:

1. The retruded opening and lateral border movements must be free from any muscle or joint disability when the records are being made.
2. The adjustment of the instrument must be made so that the upper member of the articulator will follow the transferred records, either pantographic tracings or plastic pathways.
3. The transfer of casts of the teeth must be made with retruded axis and retruded interocclusal records and at the same level relative to the face as the tracings were made.

THE MOUTH AS AN ARTICULATOR

It is often claimed that the mouth is the best articulator since it is the movements which the mandible makes which determine the shape of the restorations being made or the occlusal adjustments necessary. The reasons why the mouth does *not* make a satisfactory articulator are as follows:

1. Adaptive movements are readily made if any interferences are encountered and the end-result of closure may not be the one desired. The difficulty of making a reproducible interocclusal wax record on any path of closure except on the retruded axis is proof of this. Direct wax patterns suffer for the same reason.
2. It is difficult to see tooth contacts, particularly lingual cusps, and the use of cheek retractors does not promote natural movements.
3. It is difficult to add to wax patterns or alter tooth positions in wax in the mouth.
4. The tongue, cheeks and lips are liable to dislodge wax patterns, teeth and articulating paper.

The occlusolator

This is a device which uses the mouth as an articulator. It is attached to the buccal surfaces of the upper and lower teeth and carries an extra-oral bearing screw and tracer (*Fig.* 57). If the attachment to the teeth is secure a Gothic arch tracing can indicate the retruded closure. The bearing screw can then be reduced gradually until tooth contacts are made on the retruded axis. Contacts can be marked with articulating paper or soft wax and an analysis made.

Comment

With all the skills and developments, both mechanical and electronic, now available it is possible to foresee more accurate copies of mandibular positions and movements on the laboratory bench. The weakest link in the chain of those transfers will continue to be the interocclusal record registered between opposing teeth ready to transmit stimuli and consequent adaptive movements, to say nothing of the dimensional instability of recording materials. These problems and the practical use of articulators will be discussed further in the chapters on diagnosis and treatment. Meanwhile, disturbances of occlusion and disorders of the tissues of the masticatory system will be described in the chapter which follows and these conditions will determine the need for diagnosis and treatment, or not, as the case may be.

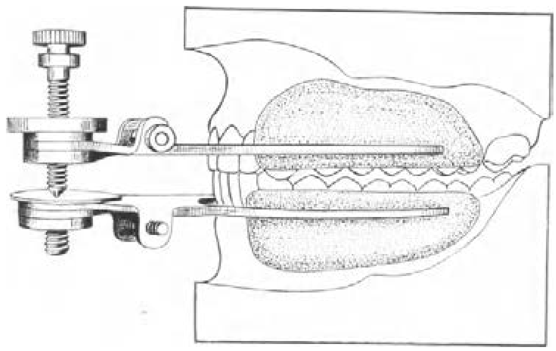

Fig. 57. Occlusolator. Extra-oral tracing device attached to buccal surfaces of the teeth.

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Chapter 8

Disturbances and disorders

IT is worth repeating that, from the time they erupt, the teeth are subject to alteration of their occlusal surfaces and supporting tissues by caries, periodontal disease and wear. The shapes of the teeth, the bone that supports them and the spaces between them are genetically predetermined and these factors do not always provide for optimal function. The phenomenon of adaptation provides for the best function in most circumstances, but this is not always adequate for the health of the masticatory system. It is on this basis of disease, change and adaptation that the various disturbances and disorders will be considered.

A fine distinction may be said to exist between the terms *disturbance*, *disorder* and *disease* and it may be pedantic to separate them. But it is necessary, in considering the effects of function in the masticatory system, to be able to distinguish between an alteration or interruption of function and any breakdown which may be the result. Also it is necessary to distinguish between these two conditions and disease itself which is a pathological response to infection or tissue change.

Definitions of the two terms used in this book are therefore given as follows:

A *disturbance* is any interruption or alteration of the established occlusal function of the masticatory system.

A *disorder* is any response to a disturbance which causes a pathological change in the tissues of the masticatory system.

Disturbances in the masticatory system may be developmental or functional.

DEVELOPMENTAL DISTURBANCES

These are as follows:

Malocclusions

These are the result of a malrelationship between bone growth and tooth size and position. They are classified according to the first molar relationships (I, II and III) or as normal, prenormal and postnormal relationships. They are also referred to as primary malocclusions which arise in the developing dentition as opposed to secondary malocclusions which arise in the adult as a result of tooth loss and consequent adjacent tooth movement.

Disturbances resulting from primary malocclusions are as follows:

1. Overcrowding with consequent rotation of individual teeth or development of teeth inside or outside the arch. These disturbances can lead to cusp interferences and displacing activities of the mandible, although in the developing dentition adaptation by tooth movement generally prevents this disturbance. Other consequential disturbances are unstable occlusal relationships (cusp to

cusp instead of cusp to fossa) and gingival disorders between the teeth due to insufficient room for the interdental epithelium.

2. Increased or decreased vertical overlap or horizontal overjet which can lead to unstable incisor function or the need for adaptive lip seal.

3. Deviation of upper and lower central midline which can indicate incisor interferences or cusp interferences in the posterior segments.

These disturbances often receive orthodontic treatment during adolescence. Unstable posterior cusp relationships are occasionally a sequel of this treatment, however, and an occlusal analysis is recommended to ensure stability of the posterior segments in function.

Lack of development of the dento-alveolar tissues

These are generally seen in the posterior segments, uni- or bilaterally, and result in overclosure of the mandible, if bilateral, and unilateral lack of functional occlusion if restricted to one side (*Fig.* 58*a*, *b*). These conditions constitute the posterior open bite. This disturbance can also occur in the upper anterior segment due to a lack of growth of the premaxillary bone.

Overdevelopment

Overgrowth of bone in the developmental regions of both condyles results in the anterior open bite (*Fig.* 58*c*) or, if excessive, to the acromegalic mandible. Such an overgrowth can also occur in the premaxilla bone.

Cleft palate and associated growth defects

These and the corrective surgery performed for them can present the orthodontist and prosthodontist with a well-known range of problems.

The response of the masticatory system to developmental disturbances is generally one of adaptation. As the growth and development of bone and the dento-alveolar structures proceed, adaptation by tooth movement and muscle activity to these disturbances take place and disorders are uncommon. This is not always so, however, and the adolescent or young adult has to be watched for signs and symptoms of disorders resulting from developmental disturbances.

FUNCTIONAL DISTURBANCES

These are numerous but not so varied in origin as their number suggests. The list for consideration is as follows:

Secondary malocclusions.
Unilateral and reduced function.
Supra- and infra-contacts.
Loss of occlusal curve.
Unstable cusp relationships.
Cusp interference.
Alteration of intercuspal position.
Mandibular overclosure.
Parafunction (bruxism).
Attrition of the occlusal surfaces.
Food impaction and the plunger cusp.
Denture disturbances.

These disturbances are inter-related and one is usually the cause of another.

They are not often conditions for which treatment is sought by the patient and the dentist has to assess the need for treatment as a preventive measure against the development of disorders. They will be considered separately although more than one is generally present.

a

b

c

Fig. 58. Developmental malocclusion. *a*, Lack of development of buccal dento-alveolar tissues. *b*, Unilateral lack of development of buccal dento-alveolar tissues. *c*, Mandibular overgrowth and 'anterior open bite'. Mandible in IP.

Secondary malocclusions

These are altered tooth positions resulting from loss of one or more teeth or from periodontal disease. The loss of a tooth leads to migration of the adjacent tooth or teeth only if the occlusion between them and their opponents is insufficiently stable to prevent it. Some migration generally occurs until a stable occlusion is re-established and this can lead to one or more of the other

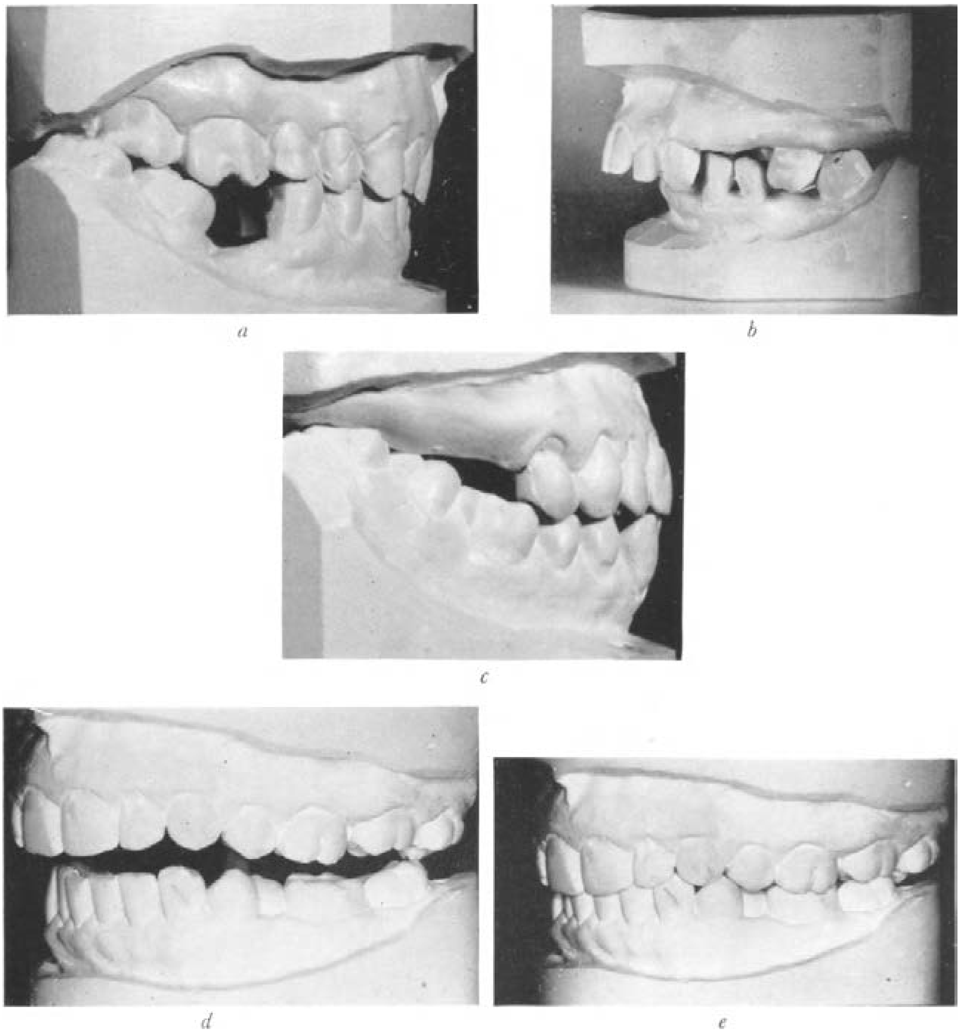


Fig. 59. Secondary malocclusions. *a*, Missing tooth with good adaptation. *b*, Over-eruption with mandibular overclosure. *c*, Opposing teeth in contact with residual ridge. *d*, *e*, Over-erupted third molar causing displacing activity from retruded contact. *d*, to IP.

disturbances. Over-eruption of unopposed teeth in this situation is common although it can be prevented by the muscle forces of tongue or cheek (*Fig.* 59*a*). Loss of periodontal support for the unopposed tooth is a common effect and can proceed to a disorder (*see Fig.* 65*b*, *c*, p. 153). It is particularly difficult to treat if a replacement for the missing tooth is planned (*Fig.* 59*b*). A disturbance impossible to treat restoratively but not yet causing a disorder is illustrated in *Fig.* 59*c*. An example of the unopposed tooth likely to cause a disorder of muscle or joint activity is that of the last molar tooth (*Fig.* 59*d*, *e*). Where periodontal disease is present, with or without loss of teeth, occlusal function can cause migration and further secondary malocclusion.

Unilateral and reduced function

Missing teeth, painful or sharp teeth, gingival or mucosal disorders can lead to mastication being confined to one side or even to the labial segment. Unilateral function in the complete dentition is, however, common enough to be considered normal and the association of being right or left 'handed' in mastication sometimes is claimed. This is not justified as a developmental factor since the two joints are connected to one bone. Adaptation to unilateral function is usually adequate to prevent disorders, but, conversely, the restoration of bilateral function is often a helpful treatment measure when pain in one or other joint region develops. An extension of this disturbance is lack of posterior tooth support which is commonly associated with the mandibular dysfunction syndrome. This can be manifest by the loss of one or more teeth in a buccal segment; and sometimes the loss of an occlusal surface has been sufficient to cause pain in the joint region. Questions to patients about the efficiency of their chewing ability often elicit such responses as: 'I have lost my bite' or 'I have a hole in my bite'. Reduced masticatory function is a widespread disturbance and disorders are uncommon as a direct result of it. On the other hand, its restoration is often beneficial when the musculature has suffered.

Supra- and infra-contacts

A *supra-contact* between opposing teeth occurs when a filling or crown has been over-contoured or when a tooth has become exfoliated by a periodontal abscess. It may constitute the sole contact and usually induces a parafunctional habit. It cannot be left alone. Until corrected it will cause tilting of the mandible on closure or a further pathological response in the periodontal tissues. A supra-contact should be differentiated from a deflective contact which causes a deflection in the path of movement to IP which may remain unchanged.

An *infra-contact* constitutes a loss of occlusal surface by attritional wear or by an under-contoured crown. It can also be caused by altering the shape of an opposing supporting cusp in order to relieve a 'high' filling or crown. Patients may complain of 'biting into a hole' or 'lost support for my bite'. This has often been associated with the mandibular dysfunction syndrome and represents an unfavourable response by the muscles to an alteration in the pattern of closing or chewing. In other words it can lead to a disorder.

Why it is that a missing tooth may not cause the symptoms mentioned while an infra-contact may, is not clear. It may be that the proprioceptors around the tooth in infra-occlusion are transmitting stimuli weaker than those which have established the reflex muscle activity in the particular case and that this alters the muscle pattern unfavourably. Where the tooth is missing there are no proprioceptors and a stable new pattern is adopted.

Loss of occlusal curve

This follows the loss of posterior teeth in a bounded saddle situation (*see Fig.* 76*a*, p. 176) and provides another example of secondary malocclusion. It is often followed by extrusion or tilting of teeth opposing the gap and by tilting of the teeth adjacent to the gap. It is a disturbance likely to cause further disturbances and other disorders. Attempts to correct this break in the occlusal curve should be made before replacements are planned, otherwise further disturbances may be promoted by the restoration.

Unstable cusp relationships

These are contacts in intercuspal position between cusps and opposing ridges or fossae where there is only one point of contact between the two opposing occlusal surfaces. They are a potential tipping force and cause of cusp interference. As has been previously said, good occlusion requires three sides of a cusp to be in contact with three opposing ridges forming a fossa. This constitutes the stable tripod of contact and is the optimal tooth relationship. It represents an objective in treatment.

Cusp interference

This is a contact between a cusp and an opposing tooth which interferes with the established closing or chewing movement.

The *causes* of cusp interference are: teeth in the process of being repositioned (following the loss of an adjacent tooth); teeth which have become loosened by loss of periodontal support; teeth incorrectly restored (supra-contact); teeth which have been moved by a parafunctional habit; or teeth incorrectly placed in a bridge or denture.

The *effects* of cusp interference are generally one of the following. Firstly, by a neuromuscular response to avoid the interference in order to maintain comfort and efficiency and this is achieved by a displacing activity whereby the mandible adopts an altered intercuspal position; this constitutes an initial contact followed by mandibular displacement. Secondly, the affected teeth may be displaced on sliding contact and replaced when the contact is past. Thirdly, one or both of the affected teeth may move to new positions, thus constituting a premature contact followed by reposition. Fourthly, a grinding habit may be induced in order to remove the interference and thus perpetuate what may have been the cause of the interference.

The total effect may be a combination of more than one of these responses and the system usually adapts without disorder. Unfavourable responses may, however, take place in the muscles, joints or periodontal tissues.

Cusp interferences may take place during mastication, swallowing or during the parafunctional activities of clenching, grinding or tapping closure.

During mastication cusp interferences may occur:

1. On the working side as the mandible moves into IP. As this interference occurs it is usually avoided and a more direct closure (chopping) to IP is performed.

2. On the balancing side when the mandible may tilt in the coronal plane and cause an unfavourable muscle response.

3. During protrusive closure between opposing incisors. This is generally avoided by direct closure although it is more likely to result in a parafunctional habit.

4. On habitual direct closure to IP, particularly when swallowing, when the mandible will be deflected or the affected teeth will move.

5. On retruded arc closure when the mandible will be deflected either forwards or laterally depending on whether the interference is uni- or bilateral. If the deflexion is laterally an unfavourable muscle response may result.

During parafunction cusp interferences may occur:

1. On the working or balancing sides as the mandible is forced to glide from one side to the other and the effects are likely to be more harmful to the teeth or muscles because the protective reflex responses tend to be overruled.

2. On the anterior segment as the mandible is forced to glide backwards and forwards.

In most natural dentitions and many artificial ones there is little balanced articulation. Parafunctional gliding brings the muscle forces to bear on one tooth. The effects are therefore exaggerated, especially when the gliding becomes grinding. These parafunctional habits are common in children, particularly during sleep, and cusp interferences serve either to bring the teeth into stable occlusion or to be repositioned as they develop. In addition to these habits, space availability for the developing teeth may be a cause of altered tooth relationships. As a tooth is forced out of the arch cusp interference is a common consequence.

In general, cusp interference during mastication results in fleeting deflective contacts and adaptation prevails. During parafunction the interference is more persistent and forceful and, as a result, more potentially harmful. Parafunctional grinding may even move teeth and *cause* cusp interference.

Alteration of intercuspal position

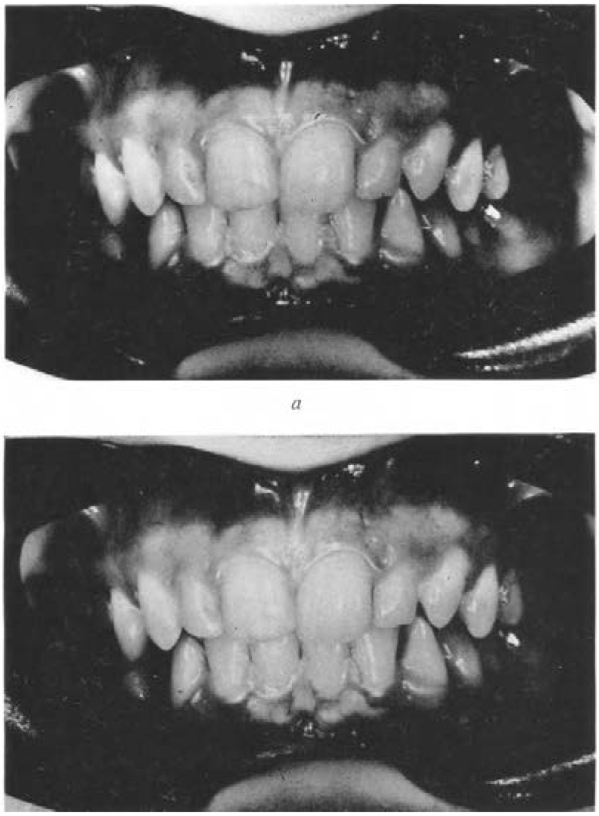
This is an IP which has been altered by cusp interference, wear or loss of the teeth. All intercuspal positions are habitual when referred to occlusion on the retruded arc and there is a continuing tendency for IP to alter because both the occlusal and interproximal surfaces continue to wear throughout life. In this respect reconstruction of the natural dentition can be justified since occlusal and interproximal wear will be arrested and the opportunities for a stable IP are increased. In the untreated dentition an alteration of IP implies that some of the teeth may have tilted in order to achieve the new IP caused by the deflected mandible. The deflexion (or displacement) of the mandible varies and sometimes is minute; and adaptation is usually, but not always, adequate to prevent an unfavourable muscle response (*Fig.* 60). None the less, this alteration is commonly associated with mandibular joint pain which has its cause in the muscle insertions to the joint tissues. Diagnosis of cusp interference and altered IP can be made by observing the path of closure from rest position to habitual IP and from retruded occlusion to IP.

Mandibular overclosure

This is the IP reached when the path of closure from rest position exceeds the established interocclusal distance (3–4 mm.). Expressed mathematically this reads: when $RVD + OVD < 4$ mm. There is a fine borderline between normal and abnormal and the clinician has to be skilled in assessing what is abnormal in terms of indications for treatment. Many methods for measurement are in use but the important position to recognize is the endogenous (as opposed to the habitual) rest position from which a measurement of the path of closure can be made. A temporary bite plane to engage the lower incisior teeth at an increased level is often necessary when the patient will respond to a 'better or worse' analysis. Tracings of condyle X-rays superimposed, one on top of the other, may be helpful in making a diagnosis. In the normal there is lineal superimposition; in overclosure the condyle may be distally related at IP (*see Fig.* 24*b*, p. 62).

Mandibular overclosure may be developmental or acquired.

Developmental overclosure is usually associated with Class II jaw relationships where the development of the posterior dento-alveolar tissues has been retarded. If the overclosure is developmental adaptation during growth will almost



a

b

Fig. 60. Minor displacing activity to left after initial contact between right canines. *a*, Initial contact by IP. *b*, IP after displacing activity to left.

always prevent unfavourable responses. Loss of teeth may increase the overclosure, however, and disorders result (*see* section on disorders, p. 139). A steep condyle path and increased vertical overlap of the upper incisors is often associated with this condition and any restorative procedures should be attempted with caution.

Acquired overclosure follows the loss of posterior teeth and represents a vertical alteration of IP. Disorders which may follow include discomfort at the loss of posterior tooth support, bruising or ulceration of the palatal or lower labial mucosa, and mandibular joint pain. These will be discussed in the next section.

Parafunction (bruxism)

This is a disturbance which has to be considered as a separate clinical condition since it can arise irrespective of occlusal disturbances or other oral irritation.

Stimuli relayed from the higher centres of the brain lead to hyperactivity of muscles (irrelevant muscle activity: Chapter 3). If the muscles affected are in the masticatory system parafunctional clenching or grinding of the teeth is the result. The impulses resulting in this activity are thought to be some form of emotional upset or anxiety and can be manifest in other groups of muscles. Examples are the clenching of fists, pacing the floor and other activities often more violent. Another acceptable theory is that the irrelevant activity takes place in a region where there is a weakness or defect as in the mouth where cusp interferences are to be found or in the back where the musculature is perhaps inadequate for the support required for it. This may be speculative reasoning but there is little doubt that muscular action provides an outlet for such emotional states as inadequacy, frustration, anger and anguish. The presence of irritations in the mouth may provide stimuli for these activities or may contribute to them by a feedback system and disturbances of the occlusion can provide such a stimulus. The wearing of unstable dentures provides another such irritation and the effects on the dentures are further instability and discomfort. Parafunctional activities of the masticatory system during sleep were mentioned in Chapter 3 and are not easily explained except through the activities of the reticular and limbic systems of the brain. Dreams may enter the cycle of impulses from these systems and become a cause or an effect of irrelevant muscle activity resulting in clenching of the teeth. In addition, the posture of the chin on the pillow may, by prolonged stretching of one or more muscles, provide a stimulus for contraction.

Attrition of the occlusal surfaces

This process of wear begins as soon as the teeth erupt and varies according to the quality of the diet, masticatory and parafunctional habits. Attrition can be localized to one or two opposing teeth or generalized in the dentition (*Fig.* 61*a–c*). Small alterations to the intercuspal position are therefore continuously taking place. Adaptations to this loss of occlusal vertical dimension take the form of further eruption by deposits of cementum over the root surfaces and neuromuscular responses to the altered IP. Also, the pulps of the affected teeth respond by deposits of secondary dentine. Artificial teeth, acrylic and porcelain, are equally subject to this disturbance. This condition is on the border between disturbance and disorder and will be considered again on p. 137.

Food impaction and the plunger cusp

This constitutes a disturbance of function and is generally associated with altered contact points between two teeth and an opposing supporting cusp which occludes in the space between the marginal ridges of the affected teeth. Food particles can then be forced between the teeth by these cusps which are often called 'plunger cusps'. It will be remembered that four out of the six supporting cusps of the four posterior teeth usually occlude in the opposing marginal ridge areas and are potential plunger cusps. Contact point relationships can be altered by tipped teeth, worn marginal ridges, or by incorrectly restored approximal or embrasure surfaces in fillings and crowns. A deepening of the interdental col epithelium may also promote this disturbance which occurs when food is forced by the tongue between the teeth during the act of swallowing. Food impaction has a nuisance value and a disorder of the interdental epithelium may result (p. 137).

Denture disturbances

Partial and complete dentures are subject to most of the foregoing disturbances but their responses are obviously limited by the absence of roots and periodontal receptors. Disorders of the supporting mucosa may result but a denture does have the merit of being removable.

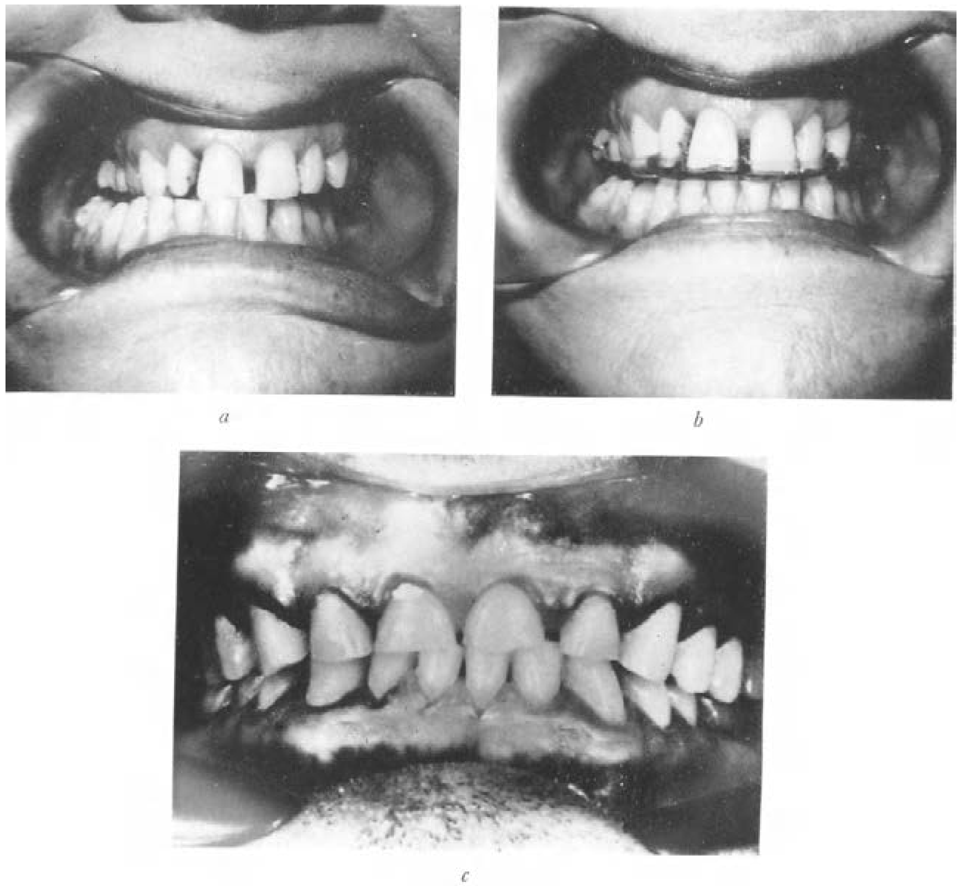


Fig. 61. Wear by parafunction. *a*, Localized. *b*, Treated with bite guard (*see also* Chapter 13). *c*, Generalized—not so easily treated.

This description and discussion of disturbances emphasizes the need for careful observation by the dentist and for a conservative approach to treatment which will prevent disorders. Disturbances of occlusion are potential disorders and a disturbance is prevented from becoming a disorder by the various processes of adaptation but this factor can diminish and treatment may be necessary. On the other hand, premature or excessive treatment can itself lead to disorders and the term *iatrogenic* is not unknown in dentistry (p. 140).

DISORDERS

As has been said a disorder of the occlusion is a response to a disturbance which causes a pathological change in the tissues of the masticatory system. In considering disorders as a group of conditions a clear idea of the existing disturbances is necessary since one is usually an extension of the other.

The following disorders will be described:

Attrition (or wear) of the occlusal and incisal surfaces.
Ulceration of the interdental epithelium.
Periodontal responses to occlusal forces.
Mobility, jiggling and migration.
Pulp necrosis.
Mucosal ulceration.
Disuse stagnation and atrophy (masticatory insufficiency).
Iatrogenic disorders.
Denture instability and discomfort.
Occlusal trauma.
Mandibular dysfunction syndrome (MDS).

These disorders demonstrate a failure to adapt to one or more disturbances often with an additional precipitating cause. They generally provide a reason for patients to attend the dentist (or doctor) and, as in the disease of caries, when it hurts the damage has often been done. In disorders of the occlusion pain is not the only symptom but others can be equally damaging and difficult to treat.

Attrition (or wear) of the occlusal and incisal surfaces

This disturbance becomes a disorder when the dentine is exposed. This becomes hollowed and is intermittently sensitive. The occlusal vertical dimension gradually closes and the appearance of the teeth deteriorates. The causes are a combination of parafunctional grinding, the quality of the diet and the production of acid by bacterial activity on the carbohydrates ingested. The end-result can sometimes be seen as flattened tooth surfaces with a reverse Monson curve which can be explained by heavier wear of the supporting cusps. The onset is gradual but the disorder can be precipitated by excessive grinding of the teeth.

Another effect of parafunctional forces is the cracked tooth which is a commoner cause of dental pain than is perhaps realized. This disorder can lead to longitudinal fracture of the tooth or to pulp involvement requiring treatment.

Ulceration of the interdental epithelium

This disorder results from the disturbance of food impaction and the plunger cusp. The development of an ulcer in the epithelium between the teeth is often predetermined by its col shape but the loss of an effective contact point and a cusp–ridge occlusion is usually the precipitating cause. If untreated, a periodontal disorder will follow and the occlusion (usually by plunger cusp) will continue to act as an aggravating factor. The symptoms are those of discomfort, bleeding, a bad taste in the mouth and bad breath from it.

Periodontal responses to occlusal forces

This is mentioned if only to exclude it as a disorder of the periodontium and it will be discussed further under occlusal trauma. The claim that a disorder of the periodontal tissues results from sustained adverse occlusal forces in the absence of any other initiating factor has never been proved. However, this does not exclude these forces from being aggravating factors to an already-established lesion of the periodontal tissues.

Mobility, jiggling and migration

Mobility or loosening of a tooth can be caused by an opposing occlusal force but, in the absence of a gingival or periodontal lesion, it will recover its stability when the occlusal force is removed. In the presence of a periodontal lesion and some degree of exfoliation occlusal forces will aggravate the mobility. Cusp

a *b*

Fig. 62. Migration of incisor teeth with lips failing to make seal. *a*, Rest position. *b*, Swallowing at IP.

interferences can therefore be created by periodontal breakdown and provide a cause of premature contact and tooth displacement. A vicious cycle of cause and effect is thus created.

Jiggling is the unscientific but descriptive term given to the movement of a tooth in one direction by a force (tooth, muscle or appliance) and its repositioning by an opposing force (tooth, muscle or removal of the appliance). Thus, an upper incisor tooth with loss of periodontal support can be pushed forwards by an opposing lower incisor and be repositioned by the activity of the lip muscles. Another example is the retraction of proclined upper incisors (usually with inadequate lip support) by a removable appliance worn at night and their repositioning during the day by tongue or opposing tooth when the appliance is withdrawn. In the former example a periodontal lesion was a predisposing cause; in the latter the treatment was the cause. A disorder may develop in the latter case, if the 'treatment' is sustained, by traumatic necrosis of the periodontal tissues. This activity may also predispose to disturbances in root development of the teeth in the adolescent patient. Intercuspal occlusion and parafunctional habits will aggravate both these examples and, as with mobility, become involved in the cycle of cause and effect.

Migration refers to the movement of a periodontally involved tooth by an opposing tooth or muscle action without the expectation of its reposition. The tooth will move until a stable position between opposing muscles or teeth is reached. This condition usually involves the upper incisor teeth which may migrate forwards or laterally. An inadequate lip seal is usually an associated cause. It is not uncommon for these teeth to drift outside the lips after which the lower lip becomes an additional displacing force (*Fig.* 62). In such a case conservative treatment can become difficult if not impossible.

There is always a combination of causes in these disorders and, in addition to those of periodontal lesion, occlusal and muscular forces, there is often the loss of posterior teeth and mandibular overclosure. One further pathological response is necrosis of the periodontal tissues following prolonged jiggling which need not be preceded by a gingival and subsequent periodontal lesion. This is a rare complication.

Pulp necrosis

This disorder can be the result of persistent clenching on an individual tooth when the blood-vessels passing through the apex are damaged and eventually destroyed. Death of the pulp follows and the resultant necrosis is sterile. Toxins

a

b

Fig. 63. Localized parafunction and death of pulp. *a*, Acknowledged habit. *b*, X-ray of affected tooth.

from the pulp may pass through the apex into the periodontal tissues causing a pathological response. Circulating bacteria may then initiate a diseased condition which the occlusal forces will further aggravate (*Fig.* 63). This condition may be painless throughout and it may take an X-ray or discoloration of the tooth to reveal it. A vague pain may be noticed from time to time, however, and should be noted in the taking of a history.

Mucosal ulceration

This is the result of injury by lower incisors on the epithelium behind the upper incisor teeth or by upper incisors on the labial epithelium in front of the lower incisor teeth. The cause is a progressive overclosure of the mandible and is usually associated with loss of posterior teeth (*see Fig.* 104*b*, p. 242). In addition to the pain on closure and irritation when eating, the mucosa may become detached from the affected tooth surfaces. It is a slowly deteriorating condition and dentists are often reluctant to treat it until it is too late for effective treatment.

Disuse stagnation and atrophy (masticatory insufficiency)

Reduced function promotes stagnation of food on the teeth and surrounding epithelium. The possible consequences of caries and gingival irritation need no emphasis. Ulceration and bleeding of the affected epithelium may follow when the teeth are brushed or during occasional encounters with tough foods.

Disuse atrophy can develop when a tooth is wholly out of contact with an opposing tooth or residual ridge. The condition most commonly affects the second or third molars. Changes take place in the periodontal membrane: fibroblasts tend to appear and the collagen fibres are replaced by a reticulum of fibrous connective tissue. The alveolar bone tends to have fewer and thinner trabeculae and such teeth do not respond well to restored function if they have been functionless for long periods. The replacement of periodontal fibres by fibrous connective tissue renders the teeth unsuitable for occlusal or abutment forces and the bone requires more rapid repair than can be provided for the sudden functional requirement. However, if function is restored gradually as by placing an opposing denture base without a tooth for a time, and then by adding the tooth, restoration of the affected tissues can take place.

Iatrogenic disorders

These are defined as pathological responses to treatment. They were mentioned in the concluding paragraph of the section on disturbances and constitute a group of disorders which may include:

1. *Awareness of the teeth.* This can follow a failure to correct a 'high' filling or crown (supra-contact). Reduction of an opposing cusp (usually supporting) instead of the fossa of a filling can lead to changes in the intercuspal position. This may become intolerable to the patient who, until then, has been 'unaware' of his teeth.

2. *Insufficient occlusion.* This can be caused by an under-contoured restoration (infra-contact) and can lead to food being stacked on the restoration or channelled to the contact area. Both can become intolerable and lead to interdental food stagnation. Infra-contact may also predispose to the mandibular dysfunction syndrome, as has been suggested.

3. *Painful teeth.* Pulpal reaction to grinding procedures on natural teeth are not uncommon and when this is accompanied by an unacceptable alteration of the intercuspal position a resentful patient is the result.

4. *The MDS (mandibular joint pain dysfunction syndrome).* This may be created by the dentist in restorative and denture procedures where increases or decreases in the OVD have not been tolerated. Horizontal alteration of the intercuspal position may lead to parafunctional habits between the teeth which themselves can cause the syndrome.

5. *Bruised or ulcerated mucosa.* This can be caused under dentures where cusp interferences cause the denture bases to move and bruise the supporting mucosa. Too often, attempts to correct such a disorder are attempted by removing the border or supporting surface of the denture when the correct treatment is to remove the interference and establish intercuspal occlusion.

One of the dangers to be avoided in any restorative treatment involving the occlusal surfaces of one or more teeth is that of failing to correct an existing disturbance before making the restoration and thus promoting further disturbance and possibly disorder.

There are ethical problems involved in dealing with other dentists' work which require care and courtesy, not forgetting that one's own may be under examination by other eyes. Conversely, the opportunity of praising a colleague's work should never be missed.

Denture instability and discomfort

Denture instability was mentioned as a disturbance and is often tolerated by the patient who has the ability to adapt and control a denture which does not have the properties of retention nor stability. This adaptability is usually associated with the denture teeth being in stable positions relative to the muscles of tongue, lips and cheeks. And this should always be an objective in setting denture teeth (Chapter 11). When this is not achieved and when the occlusal and articular relationships on the dentures do not correspond to the jaw positions and movements, tipping forces are exerted on the teeth and the denture bases either move or press on the supporting mucosa. The resulting instability or discomfort constitutes a disorder. Alternatively, if the bases are well fitting, the mandible may be forced into an altered interocclusal position, but the muscles may not tolerate the alteration as sometimes happens in the natural dentition. This, too, may constitute a disorder. Finally, the persistently cracking complete upper denture is almost always due to occlusal imbalance with parafunction added.

Occlusal trauma

This term has dominated studies of occlusion since it was introduced by Stillman and McCall (1927) as 'traumatic occlusion'. The terms are perhaps not interchangeable since the one suggests injury from occlusion and the other occlusion which *causes injury*. Either way, it cannot be left out of any list of disturbances or disorders of occlusion. However, it has engendered much confusion and should be used in a spirit of inquiry rather than dogma which has been its role.

The term has been defined as an injury to the periodontal tissues of a tooth as the result of occlusal forces by an opposing tooth or teeth. Occlusal trauma has been classified as primary or secondary; primary occlusal trauma referring to the effect of abnormal forces on healthy periodontal tissues while secondary occlusal trauma refers to the effect of occlusal forces on an already diseased periodontium. The term has caused disagreement and misunderstanding among clinicians and scientists and the reason is not hard to find: the term begs the question; it presumes a fact not proven, namely, that occlusal forces cause injury to the periodontium. The proposition has been made that it would seem to be so therefore it is so. This hypothesis has never been adequately tested, let alone proven. It is true that occlusal forces cause teeth to move and become mobile if the force is allowed to persist. But the teeth will recover their stability if the forces are removed; such forces will aggravate an existing periodontal lesion but they have not been shown to initiate such a lesion unless a gingival lesion already exists. In such a situation the occlusal forces may precipitate the periodontal breakdown. Equally, such a periodontal lesion will recover if the periodontal defect is repaired.

Occlusal forces, especially those directed along the axial plane, can cause injury to the vessels entering and leaving the pulp chamber of the tooth through the apex and death of the pulp can result (*see* p. 139). But this is not the periodontal lesion understood as being caused by occlusal trauma. Injury can also be caused by incisors on opposing gingivae as already mentioned but neither is this condition the one generally understood as occlusal trauma. Trauma can also be used to describe the wear on the occlusal surfaces caused by parafunctional grinding habits. The term 'traumatogenic occlusion', used by Box (1930) and implying the possibilities of producing trauma, was less presumptuous. None the less, it implied that injury could be caused by lateral occlusal forces on the periodontal membrane, and this has not been shown to occur without other causes.

'Occlusal trauma' is a term which can be applied to wear of the occlusal surfaces of the teeth, necrosis of the pulp vessels or to injury of the gingival or palatal mucosa, but not to a destruction of the periodontal tissues. It is a term which should be used when an awareness of its implications is understood.

Mandibular dysfunction syndrome (MDS)

This is the title given to a group of symptoms which involve the mandibular joint and its musculature. Molin (1973a) gives the syndrome the initials MDS which is not intended to exclude the symptom of pain but to provide a short title for purposes of communication. He offers the alternative title of myofascial pain dysfunction syndrome (MPD) suggested by Laskin (1969a, b), which is descriptive of the tissues and symptoms involved. MDS is preferred in acknowledgement of Schwartz's (1956) establishment of this syndrome for dentists to treat. Molin makes the comment that 'the disease, according to an increasing number of epidemiological findings throughout the world, has a much wider distribution with claims of incidence of up to 70 per cent of the total population'. He gives a comprehensive bibliography in support of this statement and of the studies he has made on the syndrome.

The syndrome is a functional disorder of the masticatory system and represents an interaction between the muscles, the joints and the teeth. It is neither infective nor degenerative and, while prolonged dysfunction may lead to a deforming arthritis of the meniscus (Sicher, 1948), correction by adaptation or treatment is usually achieved before such pathological responses occur.

Historically, the condition is reported to have existed in ancient Egypt as a fixation of the jaw and Hunter (1835) referred to 'nervous pains in the jaws sometimes brought on by or increased by affections of the mind'. He knew of cases where 'all the teeth of the affected side have been drawn out and the pain has continued in the jaw'. It was not until 1934, however, when Costen proposed his syndrome of ear and sinus symptoms dependent upon disturbed function of the mandibular joint that the symptom complex came into the province of the dentist. Costen observed that the syndrome was 'frequently observed in patients with edentulous mouths and marked overbite'. The anatomical basis for Costen's beliefs were disproved by Sicher (1948) who said that it was not possible for the condyle to exert pressure on the nerves or vessels behind the mandibular joint. Instead he suggested that the interaction of the muscles moving the condyle and the meniscus was the cause of the disturbance. From this observation came the beliefs that the origins of the syndrome were to be found in adverse muscle activities. Most studies of the syndrome contain a review of the literature of which the most recent and comprehensive is by Molin (1973a). Molin's work presents studies of muscle forces developed by MDS patients and a control group together with measurements of personality traits and pain tolerance. This latter aspect of the syndrome has come to have some significance when assessing the various alterations to muscle activities which are a feature of some of the symptoms experienced.

SYMPTOMS

One or more of the following symptoms are diagnostic: a dull ache in the pre-auricular area; pain during mastication; pain on opening wide; tenderness over and in front of the condyle; limitation of opening; fixation of the mandible; stiffness of the mandible on waking; clicking of the joint on opening or closing; crepitus or crackling in the joint cavity.

The pain and tenderness symptoms are generally unilateral, and they can change from one side to another. Patients may complain of difficulty in opening or eating and this may result in occasional 'locking'. More generalized headaches and pains in the neck and shoulders may be mentioned. The patient is usually able to point to painful areas and these may occur on the ramus, side of the head and neck as well as over the condyle itself. The symptoms are often intermittent and subside, for instance, during holiday periods.

CLINICAL FEATURES

On examination of the patient one or more of the following features may be observed by the dentist or acknowledged by the patient: displacement of the mandible from rest position to habitual IP; lateral displacement of the mandible from retruded occlusion to habitual IP; the preference for one side in mastication; a clenching or grinding habit; facets of wear on the teeth; lack of posterior tooth support; deviation of the mandible on opening wide to the affected side. In addition, the acknowledgement of some form of emotional tension can be elicited by discrete questioning. Such questions as: Do you feel tense when driving? Does this make you clench your teeth or fix your jaw? Is the habit helpful in relieving a tense emotional state? Finally, cold or damp weather may be associated with recurrences of the pain.

With the exceptions of emotional tension and weather these features can be elicited from the dentitions of many people examined (Thomson, 1959, 1971) and cannot be considered causative. However, on correction of these features in MDS patients the condition often subsides. This aspect will be discussed in the section on 'Explanations'.

ONSET

This may be sudden or gradual. If sudden there may be an association with a yawn or laugh, or with a visit to the dentist. If gradual the association may be with eating tough foods or posturing the mandible forwards for lip seal or appearance reasons.

AGE AND SEX

Most surveys of the MDS reveal a predominance of young females. There are many exceptions to this incidence and it should not be considered usual. The syndrome is becoming more widely recognized and with this recognition has come a wider distribution of age and sex incidence.

PATHOLOGY

The assumption that the causes of MDS are to be found in the muscles has had scant support from pathological studies. Fatigue, spasm, intramuscular injury and general disorders of muscles were discussed in Chapter 3 but the only histopathological studies mentioned were by Christensen and Moesmann (1967) where a diagnosis of aseptic serous inflammation of the muscular connective tissue was made. This was given the more general title of muscular fibrositis and was attributable to muscular hyperfunction.

Alteration in the viscosity of the synovial fluid may represent a pathological response to a circulating toxin and provide a cause of crepitus. It is unlikely that this could be associated with mandibular dysfunction although protrusive condylar movements may aggravate such a condition. On the other hand, effusion of tissue fluid into the joint space causing swelling and tenderness may represent a response to injury or to prolonged dysfunction. Occlusal relationships may be temporarily altered and rest from occlusal function may be required to prevent deterioration.

X-RAY EXAMINATION

X-rays taken at the closed and open positions may reveal a restricted or open joint space between condyle and fossa at the closed position (*Fig.* 64) and a restricted forward movement on the affected side on opening. Disturbances of the bony outline of the condyle are not a feature of MDS but should be excluded in differential diagnosis (*Fig.* 64).

DIFFERENTIAL DIAGNOSIS

As the condition is neither infective nor degenerative it is necessary to make a differential diagnosis from the following conditions: rheumatoid arthritis, osteoarthritis, trigeminal neuralgia, specific infective arthritis, headache of systemic origin, sinus and ear infections. Many MDS patients are referred to the dentist from medical colleagues and these conditions will generally have been excluded but a check list of the significant features of these conditions may prove helpful.

EXPLANATIONS

Some explanations of click, locking, pain and tenderness experienced in MDS will be offered on the assumption that they are speculative.

Click

This phenomenon can be described as an interference to the established translatory movements of the condyle and meniscus during the opening and closing movements of the mandible. As was said in Chapter 2, the superior ridge on the condyle makes it possible for interferences to occur between condyle and meniscus as each moves. Normally the muscle activity is such that the flexible meniscus moves smoothly between condyle and eminence. If the starting position of the condyle is altered (as by an altered IP) its starting path of movement can be altered and the thicker posterior zone becomes momentarily trapped between condyle and eminence. The neuromuscular response will generally provide the necessary adaptive movement to complete the opening. A deviation of the opening movement to avoid the click may follow and a further sequence of click and adaptive movement may be the result. Due to the absence of pain fibres in the meniscus click is seldom painful but if the resistance is increased (as by an increased viscosity of the synovial fluid) the movement required to continue the opening may result in torn muscle fibres

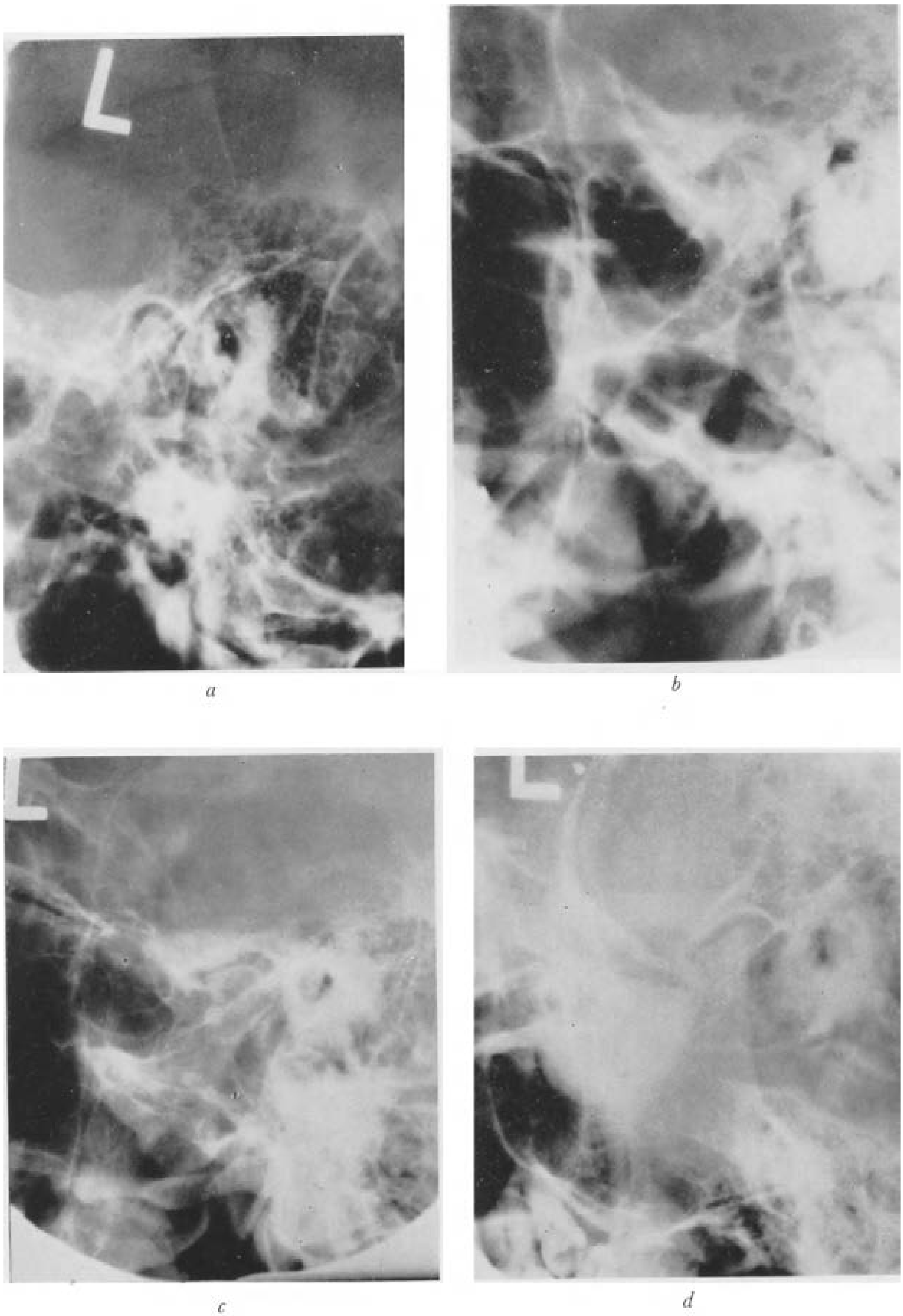


Fig. 64. Condyle X-rays. *a*, Space wider than normal. *b*, Space more closed. *c*, Flattening of fossa and condyle with sclerosis. Lipping of condyle. Changes seen in osteoarthritis. *d*, Long standing destruction of condyle, suggestive of rheumatoid arthritis with possible osteoarthritis superimposed. *See* p. 61 for normal outlines. (*By courtesy of Dr. J. J. Prior at the Eastman Dental Hospital.*)

(lateral pterygoid). A further adaptation follows with pain and stiffness as accompanying symptoms.

Click generally takes place during the opening movement but can occur just before closure as the meniscus moves backwards on an altered pathway.

The fact that click can be made to disappear by having the mandible open and close on its retruded axis or by placing a bite plane to engage the lower incisor teeth just before closure supports this explanation. Thus an alteration of the intercuspal position is a possible cause of click. Other causes are an excessive and sudden opening of the mandible displacing the meniscus or prolonged clenching of the teeth with consequent altered opening by fatigued muscles.

Click may also occur intermittently in the adolescent due to adaptive movements while growth is taking place. But here, too, it can be avoided by retruded opening and closing. The fact that click seldom produces a pathological response either in the joint tissues or the musculature speaks well for the adaptability of these tissues. Thus, while click justifies its inclusion in the syndrome it may be wrong to label it a disorder.

Locking (or fixation of the mandible)

This disturbing symptom which usually takes place at an open position may be an extension of click. A muscle spasm following persistent click can fix the mandible at the position where the click usually takes place, and therefore can be associated with an altered intercuspal position. Two other causes of locking are, firstly, muscle spasm following injury to the mandible by either a blow or excessive stretch; secondly, by spasm at a subluxated position associated with an articular eminence developmentally shaped to permit the condyles to slide forward in front of the eminence. Dislocation is an extension of this latter condition. An infective condition in the masticatory system may also produce spasm (trismus) which may seem to be protective but this has been questioned (p. 43). Alarm rather than pain is a feature of jaw fixation and reassurance as well as therapy to reduce the muscle spasm are required.

Pain

There are three factors which are associated with pain in the MDS: *cusp interference* resulting in a displacing activity of the masticatory muscles, *parafunctional* activities, and *emotional* disturbances. A combination of all three probably provides the explanation.

1. In considering a pathological response to alterations of condyle positions by occlusal disturbances it has to be remembered that the joint tissues are flexible and can adapt to these small changes in movement. It is also pointed out that the distribution of the pain fibres within the joint cavity ramify with the blood-vessels in the ligaments, synovial membrane and adjacent periosteum. The menisci are not supplied with pain fibres and only when they are displaced against the sensitive joint membranes can they cause pain. Non-infective intracapsular joint pain is, therefore, the result of relatively violent injury such as dislocation (when the periosteum is stretched) or distraction of the meniscus (by muscle spasm) against the joint membranes.

The symptoms in this syndrome which are associated with disturbances of the occlusion are generally unilateral as has been said, and often exist on the side opposite to the occlusal disturbance which, too, is almost always unilateral in its effect.

The part played by cusp interference and altered IP varies between minor displacements and mandibular overclosure. The effect was described by Grewcock and Ballard (1956) as an upset of the proprioceptive feedback to the reflex centres which could result either in acceptable adaptive movements or in incoordination and spasm of the stabilizing muscles, particularly the lateral pterygoids. What the factor is that determines whether the effect is adaptation or incoordination may be a measure of some disturbance in the limbic system (Chapter 3). This may provoke an exaggerated response to the peripheral stimulus by an impulse which disturbs the reflex muscle activity. The result may be injury of the muscle fibres, fatigue or spasm. Once the muscle lesion or response has been established it constitutes a weakened region of activity and further impulses from the higher centres have their effect in this region. It then becomes self-perpetuating so long as the peripheral stimulus (cusp interference) continues. Thus the displacing activity in these cases must be corrected. This constitutes the morpho-functional or tooth–muscle theory of MDS causes.

Pain in muscles has also been attributed to cold, vasoconstriction and acidosis and the possibility of these factors being causative should be excluded. Therefore, unless the pain is the result of injury and the effects are intracapsular, the cause of pain is in the muscles themselves. The pain of a torn muscle is sharp and the effect is prolonged and dull for a period of up to three weeks; the pain of spasm is severe and must be relieved (as witness the back ache or cramped calf muscle) after which it will become dull. Further use of these muscles may produce a dull ache for considerable periods. Stretching of the lateral pterygoids, as by opening and closing on the retruded axis, will often cause relief. The pain of a fatigued muscle is transient and recovery is assured unless the pattern of movement persists.

2. The part played by parafunctional activities has been emphasized throughout this text and the cause has been ascribed to irrelevant muscle activity. This may be the result of impulses from the higher centres (cortical or limbic) which are mediated through the reticular system and transmitted to the elevator muscles of mastication while the digastrics are inhibited. At the same time the protective reflexes are rendered less effective. Once again one questions why the masticatory muscles are affected and the answer may be that the effect is directed to muscles weakened by inelastic scar tissue. In the case of the masticatory system the teeth provide a ready means of relieving tension without demonstrating to the world that tension exists. Hence ‘gritting the teeth’, the ‘set jaw’ or ‘stiff upper lip’.

It has been suggested that the cusp interferences and mandibular displacements are secondary to this irrelevant muscle activity (Laskin, 1969a, b; Yemm, 1969a, b). This constitutes the psychophysiological theory of MDS causes.

3. The part played by emotional disturbances has already been incorporated in the two previous factors. They have been suspected as predisposing factors since Moulton’s (1955a) original work on oral and dental manifestations of anxiety. Her subsequent work on emotional factors in non-organic mandibular joint pain has given further impetus to dentists to have these factors in mind. Molin (1973b) now reports on two series of MDS patients and a control group who were investigated for personality traits and tolerance to experimentally

induced pain. He concludes that personality traits and emotional disturbances play an important role in the MDS and probably in its aetiology. It remains for dentists to co-operate with psychiatrists in evolving a method for investigating these factors without necessarily referring the patient for full-scale psychiatric care.

The present knowledge of this aspect of facial pain points to some form of emotional stress linked with muscle hyperactivity being causative and to occlusal disturbances being a peripheral stimulus which may act as a trigger to the onset of the syndrome or a perpetuation of it.

Tenderness

Pain on palpation is most common on or in front of the condyle and suggests the insertions of the lateral pterygoid muscles. The condyle itself may be tender and this may involve the capsule or the muscle insertions which may include the masseter. Tenderness may also be felt inside the mouth behind and lateral to the tuberosities suggesting the origins of the lateral or medial pterygoid muscles.

CO-FUNCTIONAL MUSCLE RESPONSE

This is a phenomenon of muscle activity whereby muscles adjacent to those adversely affected may become involved with fatigue or regions of spasm. Thus pain in the neck or back of the head may accompany the MDS.

ASSOCIATION WITH CHRONIC MINOR ILLNESS

As a postscript to this discussion on the MDS mention is made of Berry's (1969) observation of the coexistence of certain minor illnesses in 100 cases of mandibular pain dysfunction. These included migraine, back, neck and shoulder pain, pruritic skin diseases, hay fever and asthma. Sixty-four per cent of the sample had two or more of these diseases. Berry suggests that the common origin for these conditions may be a central perception of a state of stress mediated by hypothalamic function.

Comment

Disturbances of occlusion exist in the majority of mouths and many go unrecognized causing few complaints. Failure to adapt to a disturbance, however, will result in a disorder when a pathological response can be demonstrated. There will always be a tendency for occlusal disturbances to deteriorate since tooth surfaces once disturbed do not repair themselves. Also, a repositioned tooth will not recover its original position since opposing adjacent teeth will move in order to attain stability. Probably the most important aspect of recognizing disturbances is to ensure that they are corrected before further replacements of tooth surfaces or of the teeth themselves are made. Disorders constitute complaints by the patients and some pathological process is involved. The cause has to be diagnosed, the occlusion analysed and the disturbance treated. These topics will be the subject of the remaining chapters.

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Chapter 9

Analysis and diagnosis

DISTURBANCES in occlusal relationships are often overlooked in the routine examination of a patient's mouth. Caries and bleeding gums require immediate attention; replacement of missing teeth and appearance problems are often equally pressing; instructions on hygiene and prevention occupy as much consultation time as can be spared in the busy practice. Occlusal disturbances are so common as to be assumed within the normal limits of the average mouth and they seldom cause the patient to complain. It is, therefore, understandable that the philosophy of let well alone is justified. It can be argued that more damage can be done by trying to improve this or that occlusion. There is enough to do without bothering about the bite. This ambivalence justifiably persists until a disorder occurs; a symptom causes the patient to state a problem, a complaint or a pain. The practitioner must then be ready to make a careful examination and diagnosis and, if necessary, a thorough analysis of the occlusion. Whether this step is taken before or after the disorder appears is a matter for individual judgement. The replacement of missing teeth presents an example of the need for analysis where occlusal disturbances can all too easily be incorporated into restorations. Certainly the practice of dentistry becomes more interesting if the functional status of each mouth is assessed according to its potential comfort and efficiency, to say nothing of its potential harm.

The diagnosis of a patient's occlusal disturbances is based on consultation and examination followed by analysis of occlusal function. This analysis is carried out by clinical, gnathosonic and articulator examinations.

THE CONSULTATION

The objective in a consultation is to establish a preliminary diagnosis which can be defined as the identification of a disease or disorder by means of the symptoms described. It is always helpful in a consultation to establish an understanding by the patient of what the practitioner is trying to find out. This is best done comfortably in chairs, away from the operating area, and preferably in a room other than the surgery. The customary welcome and details of name and referral should be directed at developing a good rapport with the patient. It may be helpful for the practitioner to make a general statement of purpose before proceeding to the questionnaire. For example: 'Before asking about your dental problem may I say that my concern is with the health of your mouth, with its efficiency and comfort and, if necessary, with its appearance.' The consultation should begin by having the patient describe any symptoms rather than answering a check list. The open is preferred to the closed question. For example: 'Tell me if anything is wrong in your mouth' is more helpful in diagnosis than 'Which tooth hurts?' And, if pain is mentioned: 'Describe the pain' is preferred to 'Is it a sharp or dull pain?' The more leading, closed question can follow if there is difficulty in establishing a diagnosis.

Eight questions concerning function are suggested:

1. Do you have any difficulty in eating? Are you able to chew tough foods?
2. Do you prefer one side or do you use both in eating?
3. Do you feel any discomfort during or after eating? In the mouth or side of the face?
4. Do you hear or feel any noises in your jaw when eating?
5. Do you have difficulty or discomfort in opening wide?
6. Do you clench your teeth in moments of tension or concentration? Tap, slide or grind your teeth together? On waking?
7. Do you use your teeth for any other function: opening hair grips, rubbing on a pipe? Bite your nails or lips?
8. Does food become lodged between any of your teeth? Do the gums bleed?

These questions are a requirement if there is any suspicion of facial pain or joint dysfunction but are helpful in a routine consultation, when considering the status of a patient's occlusal function (*see* appendix for MDS questionnaire).

Past dental and medical histories can now be investigated. Caries incidence, extraction dates and difficulties, orthodontic treatment and denture history may prove helpful and information on any jaw injury either by extrinsic force or from the stretching involved in prolonged or difficult dental treatment, yawning or hard chewing. Medical history should include information on any joint or muscle disorders, blood dyscrasias, skin complaints and any condition currently being treated, including drug therapy.

Such a consultation can be extended or shortened depending on the patient's requirements in seeking dental care and on the interest of the dentist in oral health generally and occlusal function in particular.

The consultation generally closes with a general question on: 'Have you any other comments about the health and efficiency of your mouth?' and the suggestion that 'I should like to examine your mouth and teeth and perhaps take some X-rays'.

THE EXAMINATION

In addition to routine charting of decayed, missing and filled teeth and noting the condition of the gingival and oral epithelium information is required on several features of the teeth and gingivae with a view to establishing a diagnosis of any disturbance or disorder of occlusal function. This examination should include:

1. The state of cusp wear both on individual teeth and on the teeth in general. This can generally be related to patterns of grinding the teeth either currently or in the past. Loss of enamel and dentine is not naturally restored and could have occurred in the past. The possibility of its having been caused by the dental stone should be excluded, as should the less likely occurrence of a fibrous or sandy diet.
2. The inclination and stability of repositioned teeth. Mobility and antagonistic movements of any teeth. Central incisor midline.
3. Cusp–fossa and cusp–ridge relationships. This will indicate the possibilities of further repositioning of the teeth or of premature contacts.

4. Contact point relationships. Open contacts and plunger cusps indicate the possibilities of food lodgement.
5. The state of over-eruption of unopposed teeth.
6. Bleeding of the interdental epithelium. This may indicate disease but more commonly a failure to maintain interdental hygiene.
7. The incidence of gingival and intra-bony pockets. These may be associated with unstable occlusal forces which may be acting as aggravating factors.
8. Bruised or ulcerated mucosa behind upper incisors or in front of lower incisors indicating trauma of the mucosa by opposing incisors.

X-ray examination

Intra-oral and interocclusal X-rays will confirm the existence of unfavourable inclinations and over-eruption of the teeth, intra-bony pockets, and open contacts between the teeth. Interocclusal X-rays may also help to confirm static occlusal relationships but the angle of incidence of the X-rays has to be taken into account as has the position used for holding the film (*Fig.* 65).

This constitutes an examination of the dentition and epithelium with the mouth open and the possibilities of disturbances or disorders of occlusal function can only be deduced. In order to make a diagnosis based on function in the mouth a more comprehensive analysis of the occlusion becomes necessary.

ANALYSIS OF OCCLUSAL FUNCTION

What happens in the mouth during the three meals of each day and during the remaining hours of day and night when it is not occupied with eating is not easy to assess. It may even be wrong to assume that the evidence from a chair-side analysis bears any relationship to what happens when the patient is behaving naturally and away from the eyes or apparatus of the dentist. But an attempt must be made if improvements in occlusal function are to be made, if disturbances are to be prevented from becoming disorders, or if disorders are to be cured. No attempt to improve or change occlusal relationships should be made without making such an analysis. In the first place the treatment might not be necessary and secondly, if it is, and is performed incorrectly the fire may be worse than the frying pan.

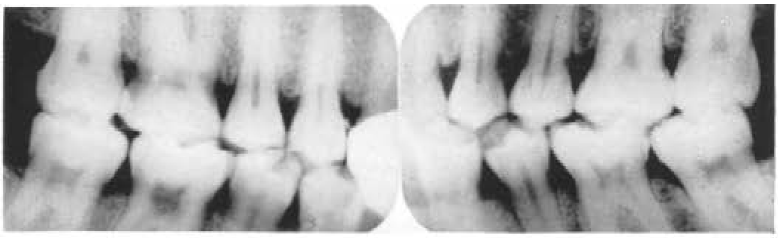
At the outset of the analysis, it is necessary to have a clear objective of what information is required and how this information may affect the optimal function of each masticatory system examined. This objective may be summarized as four requirements:

1. Information from the patient on all aspects of function.
2. Information from the examination of the mouth which leads to a comparison between the function as it seems to exist and the optimal function possible for that mouth.
3. The incidence of adaptive function and its potential harm.
4. The incidence of disturbances and disorders.

There are three methods of making an analysis of occlusal function: the *clinical*, the *gnathosonic* and by the *articulator*.

CLINICAL ANALYSIS OF OCCLUSAL FUNCTION

The information from the questionnaire and the examination of the open mouth should give an indication of what to expect from the examination of



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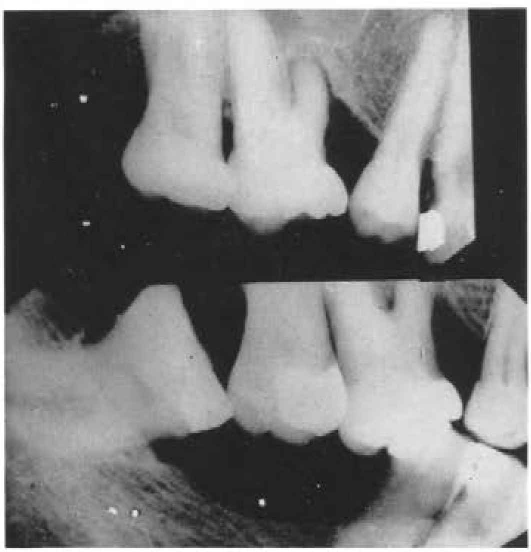

c

Fig. 65. Interproximal X-rays. *a*, Cusp–ridge occlusion. *b*, Antagonistic occlusal forces with potential extrusion of upper second bicuspid and incipient intra-bony pocket of distal upper first bicuspid. *c*, Antagonistic occlusal forces with advanced periodontal disease, with buccal segment view.

the mouth in its various movements. It should provide a basis for comparison between the mouth examined and the best possible function for that mouth. What is now envisaged is an examination of the mouth with a view to assessing adaptive and parafunctional movements. In the case of the latter some questions on the possibilities of emotional stress causing irrelevant muscle activity will be helpful in making a diagnosis.

The following aspects of function should then be observed.

Eating

The patient is given a piece of apple or hard biscuit and asked to eat it. Following this function, he is asked to confirm which side he prefers, if anything hurts, if any teeth get in the way, and if food lodges anywhere. If this does not provide positive answers a second mouthful is tried with a view to answering the questions. Observations of this function should include how the chin moves, if there are any forcible contractions of the circumoral muscles (suggesting adaptive movements) both during eating and swallowing. If teeth are 'getting in the way' an attempt should be made to determine whether this is a working or a balancing side premature contact. This function may be an embarrassment to some patients and can be delayed till the end of the analysis or excluded if it is not considered necessary. It is, however, particularly helpful in patients with denture problems.

Speech

Observations of the circumoral muscles in speech will indicate difficulties in making a lip seal and if the teeth are subject to unopposed forces. The incisor relationships should also be noted and, in the case of denture patients, the existence of any tooth contact noises. Difficulties with 'm', 'f' and 'v' sounds requiring excessive movements of the lips or chin may suggest overactivity of the lateral pterygoid muscles and a cause of muscle fatigue and pain. The 's' and 'ch' sounds, particularly in denture patients, should be noted with a view to assessing wrong tooth positions or shape of the muscle (polished) surfaces of the dentures. The closest speaking space will indicate faults in incisor positions and the OVD (*see* Chapter 6).

Rest position, lip competence and habitual closure

The endogenous *rest position* represents the rest vertical dimension (RVD) of the face and is a vertical plane of reference for the mandible in relation to the maxilla. The distance between it and intercuspal position (RP to IP) via habitual closure should be 2–4 mm. (*Fig.* 66). The distance between RP and RO (occlusion on the retruded axis) will be slightly less than RP to IP. Rest position is not on the retruded axis but its vertical level is still a reference plane when dentures or reconstruction are being planned on this axis. Lip competence at rest position is a requirement for stable incisor relationships.

The objective in observing these features is to assess if rest position is endogenous and not habitual and if there are any cusp interferences on habitual closure. The observations are carried out with the patient seated, relaxed and the head unsupported. Instructions such as 'Make the mouth comfortable, teeth parted, lips relaxed' or 'Close and swallow and say the letter M', help the patient to adopt RP. Any movement around the lips or chin will suggest effort being made by the lips and the adoption of a habitual posture. Closure to IP may then be uncertain and cusp interference may be encountered. In such an instance the instruction to part the lips may be followed by a gradual relaxation of the mandible to RP. This movement between RP and habitual posture is productive of fatigue.

Lip competence at RP can be difficult to assess for reasons suggested in Chapter 4. A test to determine borderline lip incompetence consists in asking the patient

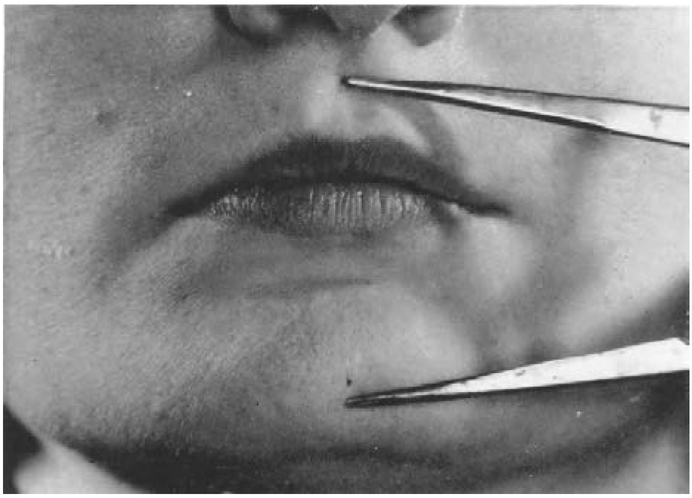

Fig. 66. RP to IP = 3 mm. Measured with dividers, this picture shows normal closure from rest position. See distance of spot on chin from lower arm of dividers.

to close the teeth and lips. He is then asked to part the teeth. If the lips are incompetent they will tend to remain together as a result of habit, especially if a closed-mouth appearance has been the objective of the habit. It is a significant piece of information since the stability of the upper incisor teeth and the activity of the postural muscles may be affected if the lips are incompetent.

The patient is then asked to close lightly on the back teeth and to report if one or all the teeth are touching. He is then asked to 'close lightly and close tightly' and report any movement between the two positions. Once these closures have been practised the lips are parted by the operator and observed. Care should be taken to avoid incisor tooth contact and the word 'bite' should never be used since it implies incision.

Cusp interferences seen from RP are usually those associated with overclosure since the horizontal deflexions of the mandible have become adaptive movements. It is then difficult to assess the original endogenous path of closure. Premature contacts with tooth displacement may be seen (or felt) as mandibular displacements since the relaxed closure from RP is not forceful enough to displace the tooth. These can be confirmed by firm closure.

Firm closure

The patient is asked to close firmly on the back teeth from an open-mouth position and asked if this is comfortable and if it is a secure position. Any discomfort is noted with a view to this being a cause of interference or the site of a periodontal disorder. Pain may indicate a cracked tooth or one demonstrating premature contact. This closure is repeated while the operator's forefinger is lightly placed on each upper tooth in turn. Premature contacts and mobile teeth can be diagnosed by a feeling of fremitus. The midline between the upper and lower central incisors can again be checked and any deviation of the lower in relation to the upper indicates that a movement of teeth has taken place and that an adaptive change in the intercuspal position has occurred.

The sounds of occlusion on firm closure as a method of diagnosis will be described in the section on gnathosonic analysis.

Parafunctional closure and movements

A further examination of facets of wear is made and these are pointed out to the patient who is then asked to press his teeth together and make the facets fit. This mandibular position may not coincide with the intercuspal position and may exist in one or more lateral or protruded positions. This evidence is also shown to the patient, in a mirror, and he is questioned if this represents a current habit. The wear may have taken place some time in the past: canine wear is common in the adolescent, often during sleep. If the habit is current the patient is advised of its possible harm both to the teeth and as a cause of fatigue in his muscles. The patient will often deny being aware of such a habit but may acknowledge it at a subsequent visit. (*See Fig.* 61, p. 136.)

Articulation movements

The patient is asked to open and to close 'coming in from one side and then from the other'. This may or may not represent the incoming movement in mastication but it should give an indication of cusp interferences on working and balancing sides. After he has made several such movements the patient is asked to stop at first contact on one side and then the other and the articulation pattern can be assessed. This examination is then repeated for the incoming protrusive movement. The whole procedure is repeated for the outgoing movements beginning at intercuspal position and moving laterally on each side and then protrusively. Difficulties experienced by the patient in making the movements will indicate that they are not used and that he probably adopts a simple (or chopping) closure in mastication.

The articulation can then be classified as *mutually protected* (canine or incisor guided), *unilaterally* or *bilaterally balanced* (*see* Chapter 5). Short or missing canines or incisors are often associated with uni- or bilateral balanced articulation. Alternatively, there may be interferences in such lateral excursions which can be harmful in parafunctional movements. These contacts can be observed more easily on casts mounted on an articulator with a pantographic transfer of border movements. The value of being able to see these articular movements on a gnathological articulator will be mentioned in the section on articulator analysis. For the purpose of the clinical examination it may be helpful to look upon uninterrupted articular movements as *isotonic* and parafunctional articulation as *isometric* contraction of muscles.

Retruded axis contact

This is probably the most significant movement and position to be assessed. It is sometimes the most difficult to examine and often the most puzzling to interpret and explain.

As was explained in Chapter 4, the retruded axis (or terminal hinge axis) is an imaginary line running between both condyles when they are fully retruded in their respective fossae. In this position the mandible can rotate about this axis for a distance of up to 20 mm. on an arc described by the midpoint of the two lower central incisors. This is a reproducible arc for each patient and the occlusion which takes place on it (retruded occlusion or contact) is reproducible. Following retruded occlusion (RO) the mandible glides to IP. It has been suggested that intercuspal occlusion takes place on this arc (retruded intercuspal occlusion) in childhood but in early adolescence the teeth tend to move forwards and intercuspal occlusion becomes habitually anterior to the retruded arc.

The *significance* of the retruded axis closure is the direction in which the mandible travels following RO. If the occlusion is bilateral and the resultant movement to intercuspal occlusion is forwards and slightly upwards (*see* Posselt's vertical envelope of motion, p. 54) this is recognized as habitual but normal. If RO is on one side only and the resultant movement to intercuspal occlusion is to one side or the other this indicates a potentially harmful adaptive movement. It means that each time the mandible closes to IP the muscles are not contracting according to their stable patterns and the condyles are adopting a more rotated position in their respective fossae. This can result in muscle fatigue or joint click.

In examining this movement it is helpful to have the patient perform it himself but this is not usually possible without some assistance from the operator and practice by the patient. In the first place, the movement may not be possible because of stiffness or discomfort in the muscles. Secondly, the adaptive movement to IP has become habitual (like an imperfect golf swing) and considerable effort is required to resume the movement of retruded closure.

The procedure is to sit the patient upright with the head supported. The operator rests his thumb-nail on the lower incisor teeth (*Fig.* 67) and assists an opening and closing movement on the retruded axis. The thumb-nail arrests the movement and removes the proprioceptive stimulus caused by occlusion. This prevents the adaptive movement to IP. When the mandible seems to be swinging on this axis, closure is allowed whereupon the patient is asked to stop as the teeth touch on the retruded arc. The completion of the movement to IP can then be observed. This requires practice and the operator requires the experience to know when the mandible is on the retruded axis and to differentiate this from a resisted retrusion. There are other methods of chin holding and the amount of force used can only be learned by practice and results. Relaxant drugs can be of assistance. The patient is then asked to try to repeat this movement on his own, and occlusion is prevented by holding a tongue or cement spatula against the upper teeth (*Fig.* 67*c*). The most consistently helpful instruction is 'push your upper teeth forwards'. Finally, the movement is observed with cheek retractors inserted so that the forward (or lateral) slide to IP can be seen and noted. This should not exceed 1 mm.

Penetration of a soft wax wafer on the retruded axis may indicate sites of retruded occlusion (*Fig.* 68). The analysis of this movement can also be observed on casts mounted on an articulator with a retruded axis transfer and this will be described in the section on articulator analysis. It is emphasized that this is only an analysis and whether steps are taken to alter or correct any deflective contacts depends on the diagnosis.

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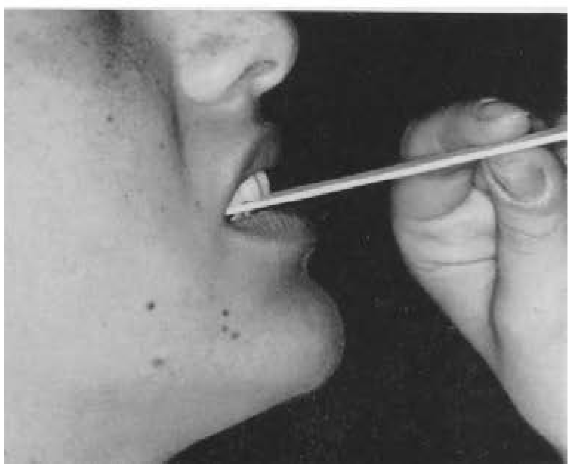

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Fig. 67. Retruded arc closure. *a*, Thumb nail on lower incisors guiding mandible. *b*, Thumb nail used as stop. *c*, Patient self-assisted with wooden spatula for pulling back mandible.

Where a lower denture is worn the operator must ensure its retention, and two methods are illustrated in *Fig.* 69. Method A is preferred since the right hand is free to guide the closure. It is rarely possible to allow the patient to perform this movement himself without the assistance of a clamp to stabilize the lower denture. Even with such a device and a fixative it can never be certain that the denture has not moved.

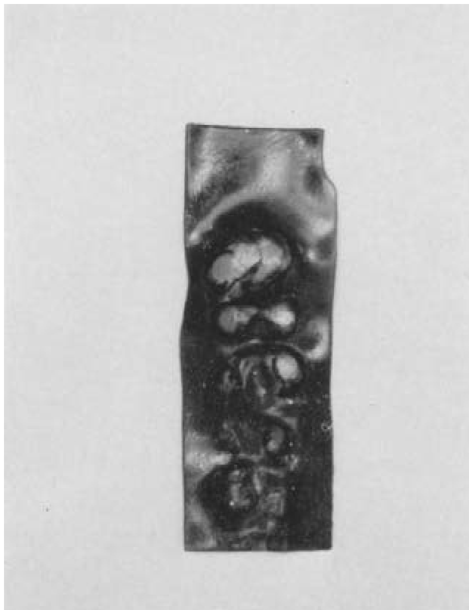


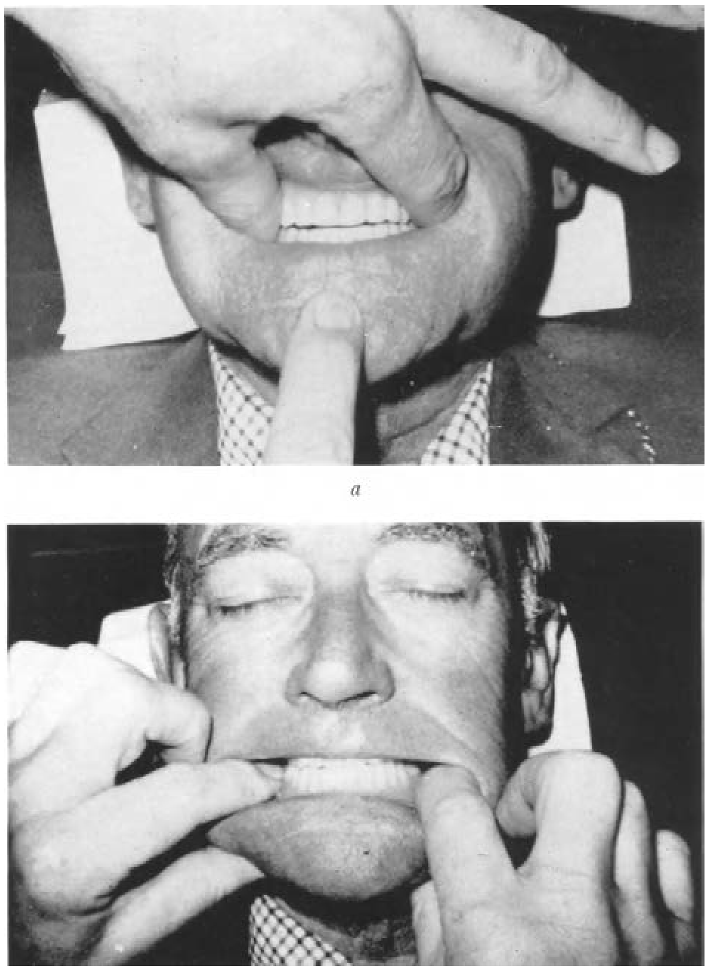
Fig. 68. Wax penetration on retruded arc.

Maximum active opening of the mandible

The patient is asked to open as widely as possible and to close the teeth comfortably. The observations should include: extent of opening which should be more than 40 mm. measured between the upper and lower incisors; any deviation of the mandible indicating resistance to free movement of the condyle or meniscus on the side to which the mandible deviates; any noise (click or crepitus) in one or other joint which is usually accompanied by an uneven opening or closing movement. Auscultation, using a stethoscope, can be helpful in confirming the presence of joint noises and on which side they occur.

Palpation of the condyles and muscles

This is most effectively performed while standing behind the patient with first or middle fingers lightly held over both condyles. Palpation of the condyles for tenderness is made at rest position, firm closure, and on opening widely and closing. The fingers are then moved slightly forwards into the depression in front of the condyles where the inner fibres of the masseters and possibly the lateral pterygoids can be palpated. The positions and movements are repeated. Palpation inside the ears may help in eliciting click and help the patient to tell which side the click occurs. Palpation of the masseter muscles over the mandibular rami may also elicit tenderness as may the temporalis muscles on both sides of the head. Finally, the origins of the lateral pterygoids may be palpated by inserting the forefingers behind and slightly lateral to the superior tuberosities inside the mouth where tenderness on one side may be experienced (the pterygoid sign). Tenderness from any of these regions will generally indicate injured muscles. Over the condyle itself tenderness may suggest a synovial disturbance although the diagnosis of muscle injury is generally the correct one.



a

b

Fig. 69. Retruded arc closure with complete dentures in place. *a*, Preferred method. *b*, Lower denture only held.

During this analysis of occlusal function the operator should be able to diagnose the existence of any disturbance or disorder and to assess the tolerance and adaptability of the patient to them. He should be deciding if the patient requires treatment as distinct from the patient's request for it.

Mandibular dysfunction syndrome

For patients who present with facial or joint pain or dysfunction suggestive of the MDS a form of examination can be found in the Glossary.

GNATHOSONIC ANALYSIS

The impact sounds made by the teeth meeting in intercuspal occlusion have been analysed and classified by Watt (1970). His methods are directed at estimating the sounds made by stable and deflective contacts and constitute a gnathosonic analysis of occlusion.

Watt stressed 'the need for a classification which relates broad variables of function to morphological variables'. More specifically, he has been able to discover the discrepancies which exist between the muscle position (the position to which the muscles, acting harmoniously, bring the mandible in order to produce intercuspal occlusion) and the tooth position (the intercuspal position itself). The premature or deflective contacts which cause these 'discrepancies' are minute in nature but are sufficient to be recordable by the method devised by Watt. By synchronizing the sounds emitted from tooth contacts (suitably amplified and recorded) with ultra-high-speed cinematography, Watt concluded that these sounds provide 'useful analogues of occlusion'. This is known as the gnathosonic method of analysing articulation.

Three classes of impact sounds can be distinguished:

Class A. All sounds are of short duration (less than 30 milliseconds) indicating that all tooth contacts are stable.

Class B. Some sounds are short and some prolonged, indicating that some are stable and some unstable contacts.

Class C. All sounds are prolonged (over 30 milliseconds) indicating that all the tooth contacts are unstable.

Clinical method

The equipment required to produce traced gnathosonic records is obviously not available to the practitioner but a stethoscope or, preferably, a stereo-stethoscope placed on the infra-orbital regions can be used to identify the three classes (Watt and Hedegard, 1967). Practice and comparison with the other methods mentioned in the previous section will bring a skill which can be most helpful in reaching a diagnosis of unstable contacts.

The patient is seated in the chair with the head supported while the operator stands behind the patient so that he can place the two ends of the stereo-stethoscope with equal pressure. Alternatively, the patient can be seated in a chair with his head against a wooden door when the operator can stand in front of the patient. The door will amplify the sounds slightly especially if it is hollow. The patient is then asked to tap his teeth together eight to ten times into the most comfortable closure of his back teeth. In addition to listening to the impact sounds the opening and closing movements are observed for any deviation or curving of the movements which would indicate imbalance or stiffness of the muscle activity. The quality of the sounds are noted and the patient is asked if he felt any pain or discomfort. This can be experienced in either a tooth or the muscles.

Conclusions

In Class A cases, where there is neither pain, discomfort nor deviation from the straight up-and-down movement, the classification A1 is given. Where the sounds are short but the mandible opens and closes on a curved or uneven arc indicating unbalanced muscle activity, the classification A2 is given. In Class A2 cases it is often possible to detect a slight blurring of the sound on separating the teeth. This separation noise is detectable on the gnathosonic records and suggests that one or more of the teeth have moved on occlusion and are heard to slide back on the slower opening movement. An alternative explanation is that the muscle activity on closure has proved uncomfortable and the separation movement is uncertain.

Watt emphasizes that a stable occlusal sound in the presence of pain may prove to be a Class C occlusion after muscle relaxation has been accomplished. Also, an unstable occlusal sound in the presence of muscle hypertonicity may prove to be stable when the hypertonicity is relieved. Pain limits movement. Stiff muscles produce uncertain movements. It is therefore important to emphasize that the occlusion should not be classified when pain symptoms are present.

In Class B cases where the sounds are mixed the conclusion is that the degree of unbalanced muscle activity required to bring the teeth into stable contact is greater than in Class A2 cases. These sounds may also suggest that a loose tooth or teeth have become temporarily repositioned on closure and the contact is therefore a sliding one.

Class C occlusions exist in those cases where the patient is unable to find a stable position of closure. All the sounds are prolonged and separation noises exist in the majority.

Discussion

The conclusions which Watt draws from his observations are that the adaptive closures in the majority of mouths do not necessarily result in a precise intercuspal occlusion. It would seem that there is imbalance in much mandibular activity and that this causes, or is caused by, minor occlusal interferences. There is therefore a close relationship between these two disturbances of occlusal function, namely, unbalanced muscle activity and minor occlusal interferences. The conclusions from gnathosonic studies emphasize the fine degree of tooth movement or adaptive jaw movement which may alter the existing intercuspal position. These alterations may require corrections of a relatively minute nature in order to restore comfort and efficiency to occlusal function. This assumes that there are symptoms or signs to justify treatment.

It should be emphasized that these observations are made in the empty mouth. Therefore, it would be fair to conclude that the disturbances are caused in the empty mouth, namely, by grinding habits which can cause tooth movement or muscle fatigue with consequent unbalanced muscle activity. However, persistent chewing of resistant foods is a likely cause as would be chewing on pipes or pens.

Clinical applications

In addition to the value of gnathosonic analysis in making a diagnosis there are two further clinical applications which should be mentioned.

Firstly, prior to making fixed or removable prostheses it provides a simple and quick method (for the trained ear) of assessing the intercuspal position and, after the appliances have been placed, of checking it. The sound of a 'high' filling, crown or pontic (supra-contacts) is unmistakable. A Class A intercuspal occlusion should therefore be established before any prosthesis is made.

Secondly, it provides a continuing check on the intercuspal occlusion in view of its tendency to change.

THE TEN POINT TEST FOR OCCLUSAL FUNCTION

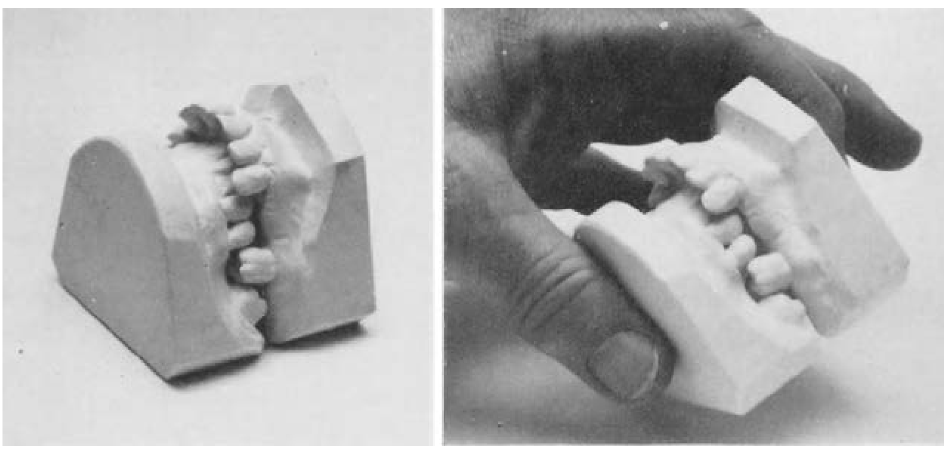
The following points should provide a revision of what has been described and a reference list for assessing occlusal problems:

1. Patient's assessment of function and parafunction.
2. Stability of rest position and lip competence.
3. The interocclusal distance and any cusp interference from rest position.
4. The incisor midlines and any altered tooth inclinations.
5. Palpation and sounds of intercuspal occlusion on firm closure.
6. Length and direction of slide from retruded to intercuspal occlusion.
7. Wear facets as indicators of parafunction.
8. Articulation movements to and from IP.
9. Maximum active opening of mandible: deviation and noises.
10. Palpation of joints and muscles.

The compilation of this list is the result of a generous series of letters from Professor Krogh Poulson (1971).

HAND-HELD STUDY CASTS

Before proceeding to the topic of articulator analysis the useful practice of looking at occlusal positions on hand-held study casts will be briefly discussed.



a *b*

Fig. 70. Hand-held study casts. Note occlusal curve disturbance.

The casts should be made from fully extended alginate or reversible hydrocolloid impressions. The plaster bases should be trimmed so that the teeth fit into intercuspal occlusion when placed on the bench on their back or side surfaces (*Fig.* 70). When picked up from these positions they will be in intercuspal occlusion. They should be freed from plaster bubbles and impression faults so that the eye is not distracted by imperfections. They should be pleasing to look at. The following disturbances can be noted:

1. Facets of wear and otherwise altered occlusal surfaces: indications of parafunction and improperly contoured restorations.
2. Tipped teeth and potential causes of cusp interference.

3. Migration of teeth and the need to check tongue–lip muscle activity and to examine for periodontal lesions.
4. Over-erupted teeth and loss of occlusal curve.
5. The possibilities of altered intercuspal position.
6. Open contact points and possible plunger cusps.
7. Certain developmental anomalies.

Other aids to diagnosis from these casts include the classification of buccal segment relationships, central incisor midline deviations, incisor overjet and overlap, rotations, overcrowding and views of the teeth from the lingual side.

When seen in conjunction with a set of X-rays, provisional conclusions can be made on the effects of occlusal forces on already disordered periodontal tissues and indications for treatment can be decided. However, *hand-held study casts can only provide guesses at occlusal positions and articulations.* Where radical treatment measures are being planned they should serve as indicators for articulator analysis. At all stages in analysis and diagnosis it is important to consider the potentially harmful effects of gap-filling restorative measures before any occlusal disturbances have been diagnosed and treated.

ARTICULATOR ANALYSIS

Occlusal function is performed, for the most part, behind closed lips and attempts to study it are much hindered by its being out of sight. The parting of the lips reveals only buccal and labial contacts and even those are partly obscured by the vertical overlap. In addition, parting of the lips by the operator usually results in adaptive movements which are not those of the natural function being analysed. Consequently, the ability to see casts of the teeth on an articulator moving on the same paths which they follow in the mouth provides a substantial aid in diagnosis and treatment planning. The requirement of accuracy has not yet been fully met but it can be provided in direct proportion to the quality of the instrument selected and the expertise of the operator using it.

It is important to distinguish between the use of an articulator for diagnosis and for treatment. The majority of restorative treatment procedures are carried out on plain hinge or arbitrary face bow adjustable articulators and more on the former than on the latter. And the reason they succeed is due to the precision of the preparations and impressions, the skill of the technician and the adaptability of the masticatory system. For purposes of diagnosis any copy of the closing or horizontal articular movements on an articulator should be made on the retruded condyle axis and lateral retruded border movements since they alone are reproducible. Any other movements copied on an articulator are unlikely to be those causing disturbances and are of comparatively little value in diagnosis.

An arbitrary face bow and habitual precontact transfers to an adjustable face bow articulator will be more accurate than hand-held casts but the fine adjustments on closure made in the mouth cannot be accurately copied by these transfers. On a gnathological articulator the retruded axis transfer will reproduce the first contact on the retruded arc after which the upper member of the articulator is free to allow movements dictated by cusp inclines as they occur in the mouth. These can then be compared to the movements determined by the condyle mechanisms which are a copy of the patient's lateral border movements. Of particular value is the difference between the *cusp-determined lateral articular movements* and those determined by the *immediate side-shift components of the Bennett movement.* It is here that the potentially harmful cusp interferences can be analysed and disturbances diagnosed. It is worth repeating that in treatment the adaptability of the system will usually permit adequate function by restorations which do not conform to the border movements but in diagnosis it is important to know what in fact is happening.

Choice of articulator

With these requirements there is seldom any choice since few practitioners possess a gnathological articulator. The realism of this section is therefore suspect. However, a knowledge of the limitations of the instruments in use and of what is required may help in making use of what is available. The chief requirement is the transfer of the retruded axis and this can be achieved on those adjustable articulators which have extendable condyle rods or movable condyle poles. For this, however, a face bow with adjustable side-arms and clutch attachment to the lower teeth (axis locator) is required (p. 103). The slide to IP from RO can then be copied provided the condyle mechanisms are free to move in any path. The arbitrary face bow transfer is not accurate enough for purposes of diagnosis. The adjustment of the condyle mechanisms to allow the articulator to copy the patient's protrusive and lateral movements can be made with precontact protruded and lateral positional records. These movements cannot be accurate copies since straight-line paths or tracks on the articulator are assumed to be those taking place in the mouth. Their value in analysis is therefore doubtful. Of more value than positional record adjustments is the adjustable incisal guidance table and pin which can be tilted to follow the movements determined by the lingual surfaces of the upper incisors and the cusp relationships in the buccal segments. The plain hinge articulator must be excluded as valueless in the analysis of movements since only IP can be copied and even this is of doubtful accuracy. Hand-held casts have more value in diagnosis than the limited plain hinge.

The choice of articulator for analysis of movements leading to occlusal positions and articulator movements is between one which will accept a retruded axis transfer and one which will adjust to lateral border movements in addition to the retruded axis (a gnathological articulator).

Retruded axis articulator

For purposes of diagnosis this articulator should have four requirements.

1. Adjustable condyle poles or extendable condyle rods in order to receive the intercondylar distance determined by the retruded axis transfer.
2. Adjustable incisal guidance table and pin.
3. Adjustable condyle path surfaces or tracks in order to follow the movements determined by the teeth.
4. The arcon condyle mechanism is preferred to the condylar.

Procedures

THE LOCATION AND TRANSFER OF THE RETRUDED CONDYLE AXIS

This has been described in Chapter 7 (p. 103). Emphasis is placed on a rigid fit of clutch to the lower teeth and the assurance that when the condyle pointers are rotating the mandible is rotating on the retruded axis. Care is taken to prevent the pointers touching the cheeks during the movement. The pointers are then extended to touch the cheeks lightly and their positions marked. These should be tattooed if subsequent restorations are planned. The transfer of this axis is then made using an adjustable face bow (the locator itself can be used) for mounting the upper cast to the upper member of the articulator taking care to adjust the articulator intercondylar axis to that of the face bow axis and not the converse.

THE RETRUDED ARC PRECONTACT RECORD

This is registered using two thicknesses of hard wax, plaster or compound as a medium making sure that the medium is not penetrated (indicating tooth

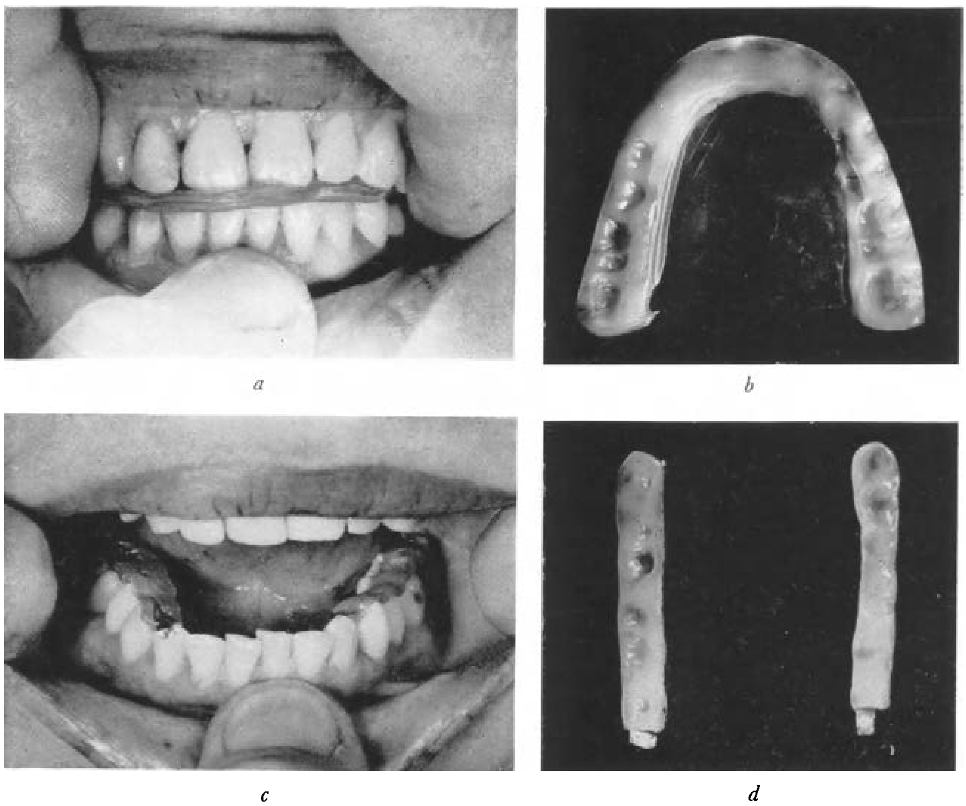


Fig. 71. Retruded arc registration. *a*, With metal supported wax wafer. *b*, Record. *c*, With wax strips. *d*, Records.

contact and probable deflexion) and that the mandible is on the retruded axis (*Fig.* 71). Alternatively, two double layers of hard wax (separated by tin foil) softened in warm water can be used. The record is then used for mounting the lower cast to the upper on the articulator. Closure of the upper member will demonstrate the first contact on the retruded arc after which the upper member will displace backwards until the teeth slide into intercuspal occlusion. This represents the lower teeth sliding forwards from retruded occlusion to the intercuspal position.

In making this registration it is important to ensure that mandibular muscles are relaxed. Any resistance to the retruded arc movements by stiffness, pain or voluntary effort by the patient should first be resolved. If any uncertainty exists the record should be confirmed by repeated records checked by the split cast (p. 186) or other method.

The value of being able to see the retruded arc of closure and subsequent movement to IP lies in the direction which the mandible moves following RP. If this movement has a lateral component it means that the muscles have adapted to a lateral habitual IP and that unbalanced muscle activity can be expected. A forward movement to IP is the normal expectation. This will prove a valuable guide if occlusal adjustment procedures are being planned (Chapter 12).

INCISAL AND CUSP GUIDANCE

The incisal guidance table is adjusted so that the incisal pin will remain on the table as the upper incisor teeth are made to glide backwards on the tips of the lower incisors. This is repeated for the lateral movements guided by either the canines (and perhaps the incisors) or the posterior cusps. The condyle guidance mechanisms are freed and can be fixed at the angles determined by the incisal and cusp guidances.

PROTRUDED AND LATERAL POSITIONAL RECORDS

As was explained (p. 165) these are not accurate records for purposes of determining condyle guidances in occlusal analysis but they may be registered as a means of comparison with those made by the incisal guidances. They are made with a medium of choice placed between the posterior teeth on both sides. For the protruded registration the incisor teeth are brought almost in contact with the incisor midlines as they appear in IP. For the lateral registrations the mandible is made to move laterally and retrusively so that the buccal cusps oppose each other. The records are then transferred to the articulator and the condyle guidance mechanisms adjusted so that the cast teeth fit accurately into the records. A difference in angle of condyle descent is usually noted between the protruded and lateral records, the lateral angle of descent being steeper than the protruded one. This means that the angle has to be changed for each movement.

THE LATERAL (BENNETT) SHIFT

Only the gnathological articulators can accurately copy this movement since it begins immediately the rotations of both condyles begin. Many of the adjustable articulators allow a lateral component of movement but it is either determined by the horizontal inclination of the guide paths (*see Fig.* 46, p. 108) or guessed by a hand-directed movement. The value of being able to see the immediate side-shift in the Bennett movement is again emphasized and for this aid in diagnosis the gnathological instrument is required.

The gnathological articulator

The principles and practice of the gnathological articulator have been outlined in Chapter 7. These articulators have been criticized for being too complex and too costly for any but the specialist who can command high-enough fees to justify the expense and education necessary for using them. Without commenting further on the economics or morality of this particular problem it can be said that once the complexity of any of these instruments has been understood and their adoption tried the rewards of understanding occlusal problems are considerable.

If this type of articulator is selected for treatment it is imperative that it is used for analysis and diagnosis. The location of the retruded condyle axis is registered and marked on the face. The frames are then used for the pantographic tracings which are locked together in the retruded position of the mandible and a pointer is attached so as to relate the level at which the tracings are made to a fixed point on the face. The condyle pointers are adjusted to touch the retruded axis marks and their positions relative to the frame noted so that they can be withdrawn to prevent scratching the face on removal and be replaced accurately for mounting. The clutches and frames are then removed from the mouth and reassembled on the articulator. The intercondylar distance of the articulator is adjusted to fit the patient's intercondylar distance and the upper and lower clutches are plastered to the upper and lower members of the articulator respectively. The clutches are then adjusted to follow the tracings after which the casts of the upper and lower teeth can be mounted using the adjustable face bow and a retruded axis precontact interocclusal record. As has been said, this latter record is the weakest link in the chain of accurate transfer of positions and movements and it should be checked against the split cast (p. 186) or by any other method which may be evolved. Two methods of checking will be described in Chapter 10.

It is now possible to observe the border movements of mandibular function on mounted casts and all the movements and positions within the parcel of movement. All possibilities of cusp interferences, parafunctional movements and the likelihood of unbalanced muscle activity are available for inspection.

Comment

Obviously, routine dental care does not require these painstaking examinations and analyses. What is advised, however, is a few questions and observations concerning the comfort and efficiency of the mouth, emphasizing to the patient that these qualities contribute to good function and health which, in turn, help to prevent disturbances and disorders. The ten-point test will provide an adequate examination which is not time-consuming and will indicate if further investigations are required. If disturbances are present and disorders suspected the more comprehensive functional, gnathosonic and articulator investigations are advised.

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Chapter 10

Occlusion in fixed restorative procedures

MOST dental treatment procedures involve considerations of occlusion. However, many are carried out with little attention paid to occlusal function on the assumption that most patients get along adequately with fewer and flatter teeth. Every practitioner has, in his case history memory, a patient who had 'six upper and lower fronts only and could eat anything'. There is no doubt of such patients' existence and it would be a misuse of dental care to saddle them with partial dentures. A healthy enough life can be maintained without teeth or with small numbers of them, but the prospect of a dish-faced community and the decline of a hard-working profession is a depressing one. The prospect for some people with dentitions deteriorating, with muscles aching, teeth clenching and gums bleeding is even more depressing and if the objective for the dental practitioner can be comfort, efficiency and health in the mouths of his patients together with a lack of awareness of teeth, both the profession and the community can feel grateful.

Extent of treatment

The objective in restorative treatment measures is that which is necessary to restore health and function and to prevent disturbances. In planning dental restorative measures a choice of plan has often to be made and the determining factors may be the future health of the pulps and periodontal tissues and the existence and effects of parafunction. The choice also concerns the ability of the dentist and technician and the cost to patient or to the state. This choice does not involve the life or death of the patient but it requires thought and care. Two heads will always be better than one and three often better than two. The patient should be invited to participate and even to make the final choice. The value of group practice is never better illustrated than in this field where the practitioners respect each other's opinions, abilities and experience. To do nothing and wait can be justified but the thin line between watchful therapy and supervised neglect has to be seen and itself watched. The preventive treatment of a bridge to replace a lower first molar has to be seen against the incidence of bridgework failure or the failure to correct a pre-existing occlusal disturbance. The decision to extract teeth in order to give a better prognosis to a partial denture has to be weighed against the resentment of the patient in losing 'a perfectly good tooth'. Finally, the advice to the patient that his best interests would be served by complete dentures has to be seen against the prospect of that patient with a boxful of failed dentures in the years to come.

One decision which can be taken with confidence is that if restorative dentistry, either for one or many teeth, is required it will be better done with the greatest possible attention to accuracy in occlusal relationships.

Application of principles

There are six principles of muscle activity and occlusal function which apply to all restorative procedures and are worth restating.

1. There is an innate pattern of jaw movements which governs the function of mastication. Reflex adaptation to interferences of this pattern by alterations of tooth shapes and relationships will take place usually without disturbance, but the tolerance of the teeth, muscles and joints is not unlimited.

2. The teeth respond to occlusal forces by omnidirectional movements within their supporting tissues. The teeth will return to their original positions on removal of the forces provided the forces do not cause reposition of the teeth.

3. The most stable occlusion between opposing teeth is that of a tripod contact between supporting cusp ridges and opposing fossa ridges. This principle includes the provision of adequate overjet and overlap (or underlap) by the guiding cusps.

4. The majority of intercuspal positions are habitual and stable. If they are diagnosed as being unfavourably altered by cusp interferences or loss of teeth they should be restored on the retruded arc at a vertical level 2–3 mm. above that of rest position.

5. A stable pattern of articular movements exists in the majority of mouths. Restorations should conform to this pattern without added articular contacts. If a new pattern of articulation is deemed necessary, as in reconstruction procedures, careful consideration should be given to the scheme chosen so as to prevent articular interferences and any alteration of the innate masticatory movements.

6. Two phases or levels of occlusion exist; the first, light contact and the second, full contact when the teeth of both arches are firmly in occlusion. At the second phase the teeth have all moved slightly and it is not possible to duplicate these tooth positions and their occlusion on plaster casts. The cast teeth are related to each other at the first phase of contact.

Rehabilitation and reconstruction

Before proceeding with restorative procedures these terms are introduced to differentiate between restoration of mandibular function and reconstruction of tooth surfaces. *Rehabilitation* is defined as procedures directed at restoring optimal muscle and joint function. When applied to the masticatory system, these include bilateral back-teeth chewing, movements which will encourage this function and the avoidance of parafunctional activities. *Reconstruction* is defined as procedures directed at restoring or replacing the occlusal surfaces of the teeth in order to promote optimal occlusal function.

The application of these principles to the following restorative procedures will be described and discussed:

Single-tooth restorations (unit dentistry).
Quadrant restorations and the unilateral bridge.
One complete arch restored.
Two complete arches restored (complete reconstruction).

THE SINGLE RESTORATION

The amalgam

No matter how much of the tooth is being restored this restoration will be the better for having a tripod contact with an opposing supporting cusp, fissures to channel food away from contact points and the prevention of any articular interferences. Before filling a cavity with amalgam the tooth and its opponent should be seen in IP. If the cavity is Class II or MOD, IP should be seen with the matrix band in place. This may require trimming of the band and careful placement of the band holder. This can be difficult with deep overlapping guiding cusps but it will help to prevent the breakage of marginal ridges on

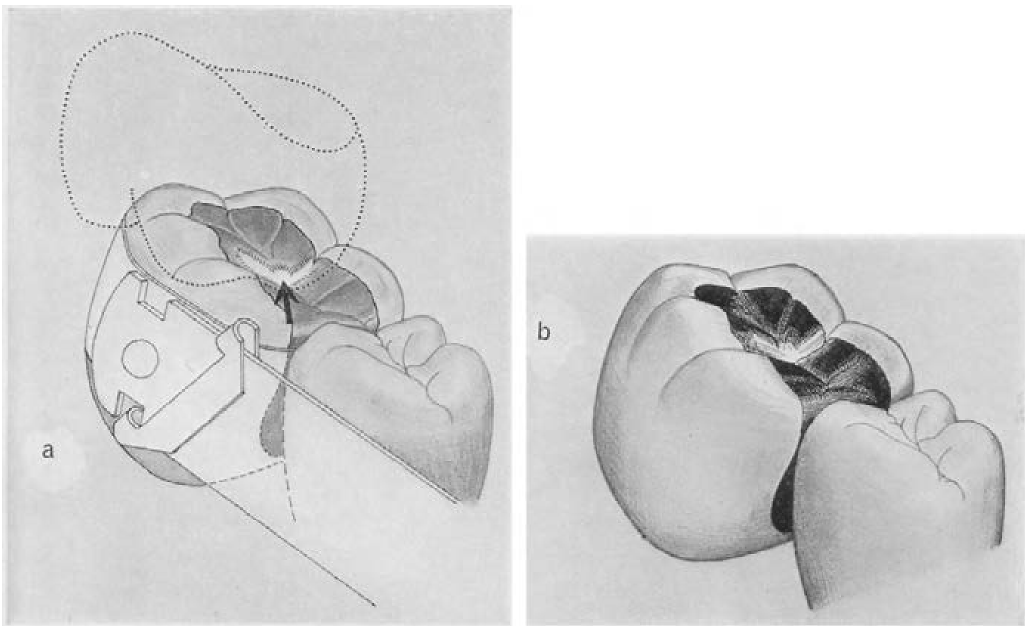


Fig. 72. Diagram. Amalgam filling. *a*, IP and articulation in soft amalgam with matrix band in place. *b*, Finished restoration with cusp contact area relieved and tripod contact developed in IP and articulation.

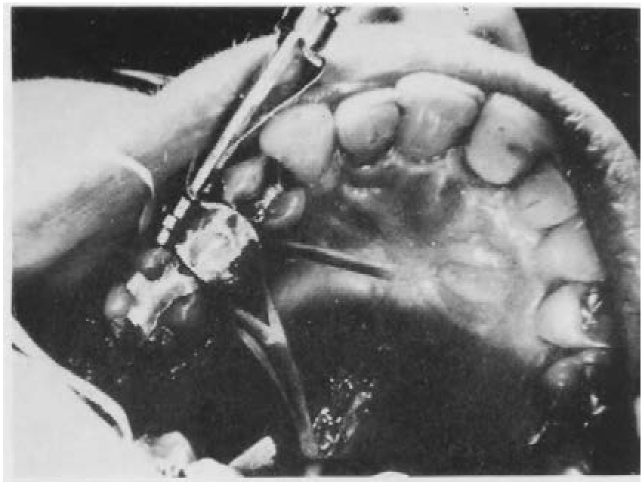
closure after filling. After preliminary carving, IO can be achieved before the matrix band is removed. It is often possible to have the patient perform the articular movements and if so these should be carried out before IO is attempted. A blunt Gothic arch can often be seen on the amalgam surface and this can be helpful in carving the fossa and shaping the triangular ridges into the fossa so as to develop the tripod contact (*Fig.* 72*a*). After removal of the band the marginal ridge can be shaped and the fissure to the lingual embrasure carved. In the central fossa carving is completed so as to achieve these ridges in contact with the opposing supporting cusp ridges and no contact with the tip of the cusp itself (*Figs.* 72*b*, 73).

The cusp tipping inlay or crown

If the direct wax method is used the same principles as for amalgam carving can be used. With the indirect method and where an opposing tooth has to be accommodated in occlusal function four methods are suggested.

WAX RECORD

Two thicknesses of hard wax separated by one thickness of gauge-40 tin foil are softened in a water bath. When soft, it is placed on the opposing teeth and fingered over the occlusal surfaces though not beyond the greatest convexity of the lingual and buccal surfaces. Firm closure is made while the operator holds



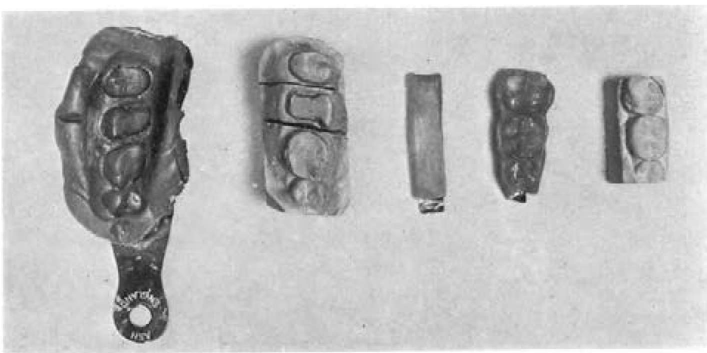
a

b

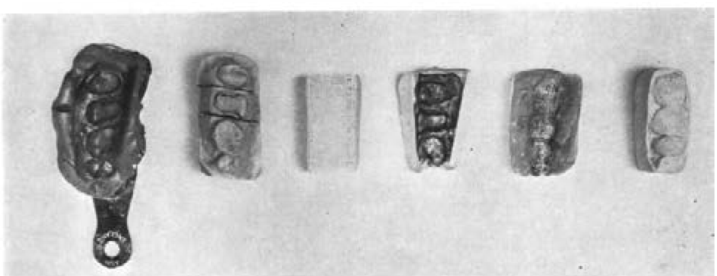
Fig. 73. Amalgam in mouth. *a*, First contact. *b*, Finished (not yet polished) restoration. (Tape is for finishing gingival margin.)

down the buccal wax and the patient presses against the lingual wax with his tongue. The wax must be penetrated on the adjacent teeth. The record should not extend more than a tooth mesial and distal from the opposing prepared tooth in order to reduce the possibilities of deformation on removal (*Fig.* 74). Since force is necessary to make contact through the wax it is likely that the prepared tooth will be displaced (omnidirectionally) and the distance between it and the opposing tooth slightly increased so allowing the familiar supra-contact or 'high bite' to follow. Consequently the softer the medium can be at the time of registration the less likely will be the displacement.

After joining the opposing casts by a plain hinge, waxing is carried out by adding cones of wax to the cast of the prepared tooth until tripod contact is achieved between the supporting cusps of the prepared tooth and the opposing central fossa. Sites of proposed contact can be marked in pencil on the cast of the opposing tooth. This method will not allow for articular contacts and



a



b

Fig. 74. Records for making working and opposing casts for single restoration. *a*, Impression, cast, two layers of wax with tinfoil, IP record, opposing cast. *b*, Impression, cast, 'bite tray', both sides of FGP record, opposing cast showing extent of cusp movement in functionally generated path.

they will have to receive adjustment in the mouth. By using a plain hinge the paths of closure between mouth and articulator will not correspond and this may result in a premature contact on closure and apparent supra-contact.

F.G.P. REGISTRATION

The functionally generated path method allows articular contacts to be made by the opposing tooth. For this a paper 'bite tray' is required. On one side are placed two layers of softened hard wax and on the other a quarter-inch thickness of carding wax. The softened hard wax is placed against the prepared tooth and its two neighbours. Closure is made into the soft wax and articular movements are made half a tooth width in each direction. Care has to be taken to ensure that the wax on the prepared tooth does not move during the registration. A small Gothic arch is carved by the opposing cusps (*Fig.* 74) and a stone cast is made to oppose the cast of the prepared tooth. Waxing of the crown is carried out with the casts held firmly together.

Both these methods have the disadvantage of exerting a certain amount of force on the teeth with consequent movement.

COMBINED IMPRESSION AND REGISTRATION

This is provided by a specialized tray with a fibrous paper insert between the two halves of the tray (*Fig.* 75). The impression material is placed on both sides

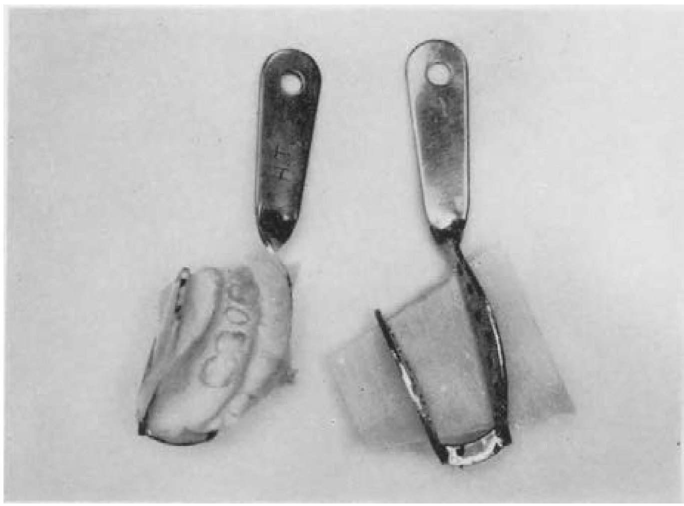


Fig. 75. Combined impression and record.

and the patient instructed to close into IP and remain closed until the impression has set. This method has the disadvantage of a prolonged setting time permitting jaw (and tooth) movement. On the other hand, the impression material is usually sufficiently soft to prevent tooth displacement.

TWO COMPLETE CASTS

The alternative to those methods is two complete casts with one carrying the prepared tooth. For reasons already explained, it is difficult to place these casts together with the accuracy required, and the so-called 'squash bite' for relating two dentate models cannot be expected to produce an accurate IP. A facebow adjustable articulator is recommended for mounting the casts.

ERRORS AND EXCUSES

There are difficulties and possibilities for errors in all methods of relating plaster casts of teeth to one another. These are as follows: (1) The movement of the teeth is not copied in the related casts. (2) Plaster expands on setting. (3) The interocclusal registrations at IP will move the teeth. (4) Precontact interocclusal registrations are inaccurate unless made on the retruded axis. (5) Registration materials are seldom soft enough to avoid moving the teeth. (6) They are not dimensionally stable after removal from the mouth.

The use of silicone or thiokol rubber materials has been recommended for making these registrations, but they have the disadvantage of a prolonged setting time during which jaw movement and separation can take place. Also the record is often too thin to be reliable.

There are, then, many excuses for failure to reproduce accurate occlusion in restorations waxed and cast on the bench by these methods but a clear idea of the limitations will help in overcoming them. The technician should be the last cause for blame provided his restoration fits the cast and the occlusion is correctly developed. A layer of tin foil over the opposing tooth to allow for supra-contacts is a common practice and emphasizes the inaccuracy. One improvement which would help to solve the problems of occlusion transfers would be a registration material which would have minimal viscosity (the consistency of whipped cream) and which would set instantaneously on command. It should also be tough and dimensionally stable after removal from the mouth. We dentists deserve better than wax, plaster, compound and paste for this important procedure.

Incisor crowns

Complete casts are recommended for the labial segment transfer since it is difficult to place a wax record accurately on the lingual surfaces of the upper incisor teeth. The wax coverage generally includes the mucosa which is liable to more displacement on closure than the teeth. The making of incisor crowns (particularly upper) requires clearance in protrusive and lateral articular movements and this suggests the need for a facebow transfer of the retruded axis and protrusive and lateral records to provide an accurate copy of the relevant movements. This is often too much to ask. The common practice of two hand-held casts is a compromise often successful. In this the technician makes the restoration at IP of the casts and allows for the movements by sliding the casts against each other. Final adjustments in the mouth are generally necessary but this requires further glazing or polishing of the porcelain or gold used.

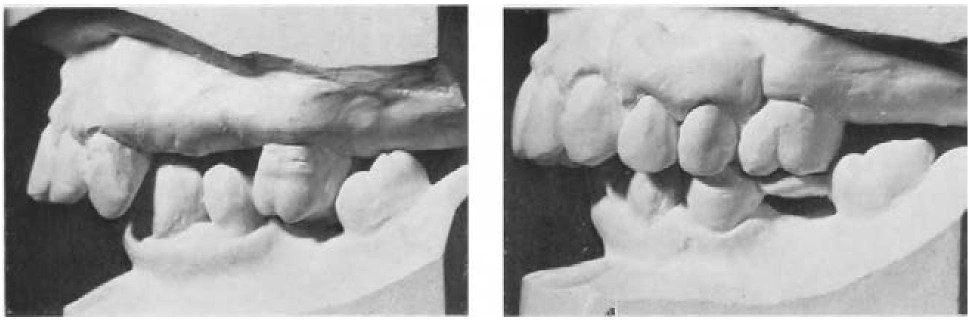
QUADRANT RESTORATIONS AND THE UNILATERAL BRIDGE

Where all the teeth in one quadrant are being restored or a bridge is being made a treatment plan based on an occlusal analysis is desirable. Missing and unopposed teeth lead to adaptive function and this can lead to disturbances which should be corrected before the restorations are made. This may require occlusal adjustment (Chapter 12) and reshaping of extruded teeth (*Fig.* 76). Otherwise the restorations will reinforce the disturbance (*Fig.* 77). Another example of incorrect restorative treatment is the production of textbook occlusal anatomy in a mouth where the cusps are worn or the teeth have departed from their textbook relationships. Here, form is in danger of becoming uniform and will often result in awareness of the new cusps. This can lead to parafunction or avoidance of function both of which can be disturbing to the musculature.

Pretreatment correction of occlusal disturbances is recommended before proceeding to more extensive restorative procedures.

Registration and transfer

If no alteration of the existing IP is planned and there is adequate tooth support on the other quadrant two complete casts as outlined in the previous section can be used with reservations. The use of complete arch casts with facebow and positional records for transfer to an adjustable articulator may not be accurate enough to transfer those movements from the mouth. One is left with the alternative of a gnathological articulator and its required transfer records, and there is no better way. The choice is therefore not an easy one. If unilateral opposing casts are used for making the restorations in quadrant work (either



a *b*

Fig. 76. *a*, Bounded saddle occlusal curve disturbed by tilted lower molar, over-erupted upper molar, and overclosed OVD. *b*, Upper molar (26) reduced and crowned as bridge abutment; pontics 24 and 25 covered by acrylic insert. OVD restored by lower bridge (with sanitary pontic) as part of reconstruction.

by the wax record in IP or the FGP) it is desirable that the technician should have complete casts of the mouth with all the pretreatment corrections made in order that he can modify the anatomy so as to conform to the remaining teeth and their supposed movements. What is *not* recommended in quadrant work is the use of unilateral casts of opposing segments with a wax record to relate them. The possibilities of tipping the casts are too great to risk.

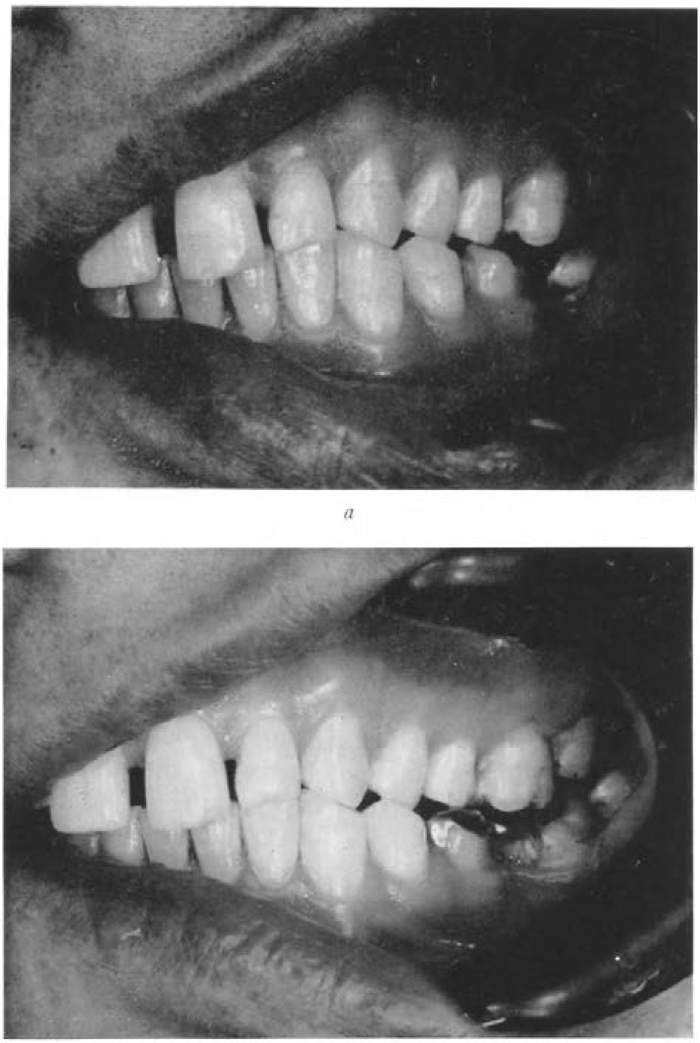
Any method short of using the gnathological articulator will probably require adjustment both in IP and to prevent cusp interferences after the restorations have been seated. This tends to be unreliable since movements made on command are not necessarily those made in function or parafunction. It is emphasized that if the difficulties are known steps can be taken to control them.

ONE COMPLETE ARCH RESTORED

This is an uncommon situation unless it forms a stage in the complete restoration of both arches. Further, if one arch alone is being restored it is suggested that the incisors be treated first in order to establish the planned IP and articulation. Both buccal quadrants can then be restored. Alternatively, if the incisors are maintaining the planned IP before treatment, the buccal quadrants can be treated first and the incisal and canine guidances used to make the lateral and protrusive adjustments on the articulator. In this latter situation it may be desirable to restore one buccal quadrant and then the other. Again, one may restore four molar teeth and then build the remaining teeth to conform to the IP and movements created by these four. The decision will depend on the analysis, diagnosis and the extent of the treatment ultimately planned.

Registration and transfer

From the point of view of the development of the occlusion, which is the concern of this text, the acceptance of the principles and difficulties should determine what method of registration is used. Retruded axis transfer and a reproducible precontact record on the arc of this axis will always lead to



a

b

Fig. 77. Bridgework promoting the disturbance. *a*, Before treatment. *b*, Bridge made with no attempt to restore good occlusal function nor to correct parafunction (made by the author in 1952).

accuracy of transfer and to an attitude of accuracy which will benefit every step and every stage in the creation of a healthy, comfortable, efficient occlusion.

The success of preparing the teeth and transferring accurate casts of them to the articulator is often a sufficient triumph on which to rest one's laurels. The transfer of the opposing arch and of both casts, accurately related, to the articulator is often cursorily performed. The technician is expected to know about occlusion since he does the waxing and casting and unjustly gets the blame when the occlusion is faulty. It is, therefore, advisable to relax momentarily and allow the patient to do likewise. A further hour may be required for jaw registrations and a further visit is advisable. In addition, time has to be allowed for the making and seating of temporary restorations. These present their own problems of occlusion and further disturbances can be added if they are incorrectly formed. Haste and a full waiting room are the real enemies of this kind of dentistry.

As with unit or quadrant procedures there is a choice of methods for transfer: by positional records to the adjustable articulator or by the functionally generated path.

Positional records

After preparation of the teeth it is preferable to have the master cast of the preparations and opposing cast at hand before making the registrations. The records can then be tried on the casts and their fit assured. Also they can be used for immediate mounting and so reduce the possibility of dimensional change of the records. The opposing cast should be made of the hardest material possible and freed from casting bubbles. The IP to record will be that of light contact between the incisor teeth already established and the registration medium used should have the qualities of low viscosity, rapid set and dimensional stability. Lateral and protrusive records are not necessary if the articulation has been satisfactorily developed on the incisor crowns. The condyle guidances on the adjustable instrument can be adjusted to copy these movements. A facebow transfer is required so that the path of closure and lateral and protrusive movements can be copied.

WAXING

The opposing cast should be marked in pencil where the cusp ridges are required to occlude and the waxing carried out by building cones of wax on the prepared teeth and completing the wax anatomy according to the requirements of articulation, protection of opposing marginal ridges and channels for food elimination. Castings are returned to the master cast and adjusted before seating in the mouth.

Functionally generated paths

These are made bilaterally using two paper bite trays. The method is as described for the single-tooth restoration and applied to the upper or lower arch whichever is being restored. The opposing cast is made by casting stone plaster into the two soft wax path records. A second opposing cast is made from an impression of the opposing teeth as they stand. A second jaw registration is made in wax or plaster between the two posterior quadrants with the incisor teeth in IP. The facebow and second wax record are used to mount the master cast and opposing-teeth cast. The FGP cast then replaces the opposing-teeth cast and is plastered to the relevant member of the articulator. Thus the master cast has two interchangeable opposing casts, the FGP and the teeth as they are in the mouth.

Waxing is carried out so as to contact the stone plaster paths on the FGP cast. This cast is then exchanged for the opposing teeth and the buccolingual dimensions of the waxed teeth are adjusted to conform to the opposing natural teeth. Embrasures, contact points and marginal ridges are completed. After making the restorations they are returned to the articulator for finishing and adjustments.

A gnathological articulator can, of course, be used for one complete arch reconstruction. However, where the articulator movements are determined by

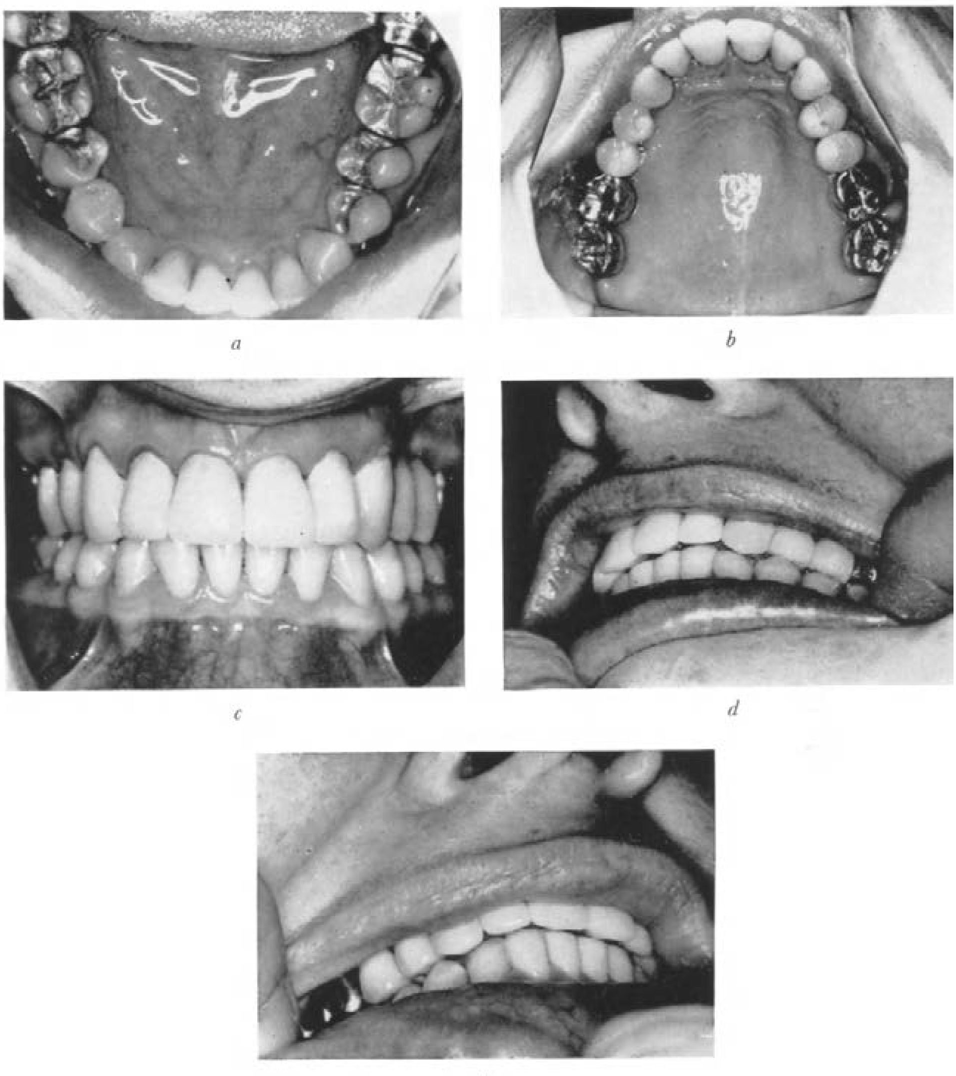


Fig. 78. Upper arch with all teeth restored. *a*, Lower arch with occlusal features emphasized on existing restorations. *b*, Upper arch completed. *c*, IP. *d*, Cusp–fossa IO. *e*, Cusp–fossa IO. (Work carried out in practice but photographed at Eastman Dental Hospital.)

the incisors and canines and these can be copied on the adjustable instrument there is a lesser need for the gnathological instrument.

A completed case is illustrated in *Fig.* 78. The lower teeth were adjusted to emphasize occlusal features. The upper arch was completed in two stages. The posterior quadrants were temporarily restored with resin crowns while the anterior segment was completed. The posterior quadrants were restored permanently using a retruded axis transfer and retruded arc positional record. A Dentatus articulator with extendable condyle axis rods was used.

COMPLETE RECONSTRUCTION

The decision to restore all teeth in the mouth must be made on a basis of prevention, namely, to prevent the premature loss of existing teeth and the need for any further treatment over an indefinite period. Most mouths can be kept in a reasonable state of health and function by regular repair and hygiene and, by the time middle age is reached, the prognosis for the future should be relatively easy to assess. The objectives for reconstruction therefore should be preventive as well as curative, the need genuine, and the work performed with the closest attention to good occlusal function.

Indications

1. Loss of occlusal surfaces by wear or flat fillings and the inability to find a 'comfortable bite'.
2. Missing teeth and subsequent drift of adjacent teeth resulting in disorders which cannot be successfully treated by simple removable prostheses.
3. Incipient periodontal breakdown aggravated by adverse occlusal forces causing or having caused repositioning of teeth.
4. Multiple restorative failures which have to be treated in any event.
5. Restoration of balanced activity to the muscles of the masticatory system.

Contra-indications

These include advanced periodontal disease, high caries susceptibility, patients with poor self-care and those who are obviously heading for complete dentures in the foreseeable future. In addition there are those patients who do not require reconstruction.

Requirements

These include the exclusion of the contra-indications, an optimistic and co-operative attitude of the patient and his or her spouse, the ability of the dentist and his technician to do the work, the funds required to pay for it and, of first importance, the genuine need in the dentition of the patient.

Pre-reconstruction treatment

Before making and deciding the final plan for reconstructing a dentition there are three series of treatment measures which should be considered: caries control, periodontal therapy and orthodontic correction.

Caries control in middle age may be akin to closing the stable door after the horse has bolted, but in susceptible mouths all caries and suspect restorations should be removed and cement (hardened zinc-oxide–eugenol, for example) inserted in the cavities for a period of 2–3 months. Temporary crowns may be necessary. During this period hygiene and its effects can be assessed, pulps tested and root-canal therapy performed if necessary. The obvious moral is better now than later.

Periodontal therapy for the reduction of pockets and the assessment of future periodontal hygiene and health is always better done before than after reconstruction. It will provide a better basis for diagnosis, treatment plan and prognosis.

Orthodontic movement of the teeth is possible at any age although the later the slower. Its success depends on maintaining the restored positions and treating the causes which moved them which, in middle age, are generally a combination of periodontal breakdown and muscle and occlusal forces. The objective for the orthodontist is to achieve an approximate cusp–fossa occlusal relationship which can be refined by the reconstruction.

Diagnosis and decision

This begins with the consultation (*see* Chapter 9). If, at the outset, it is apparent that the patient is bent on reconstruction he should be discouraged. If it becomes obvious that he requires it the patient should be made to want it and be discouraged. The point being made is that the patient must persuade the dentist to carry out the work in spite of warnings about time, discomfort and cost. A second consultation should be conducted with X-rays and hand-held study casts available and preferably in the presence of a third party (spouse, relative or physician). A plan and an alternative plan should be presented and this will often mean a decision between supervised neglect, dentures and reconstruction. If the patient and adviser now persist with reconstruction the dentist must be satisfied that there is a genuine need and that the work will succeed for a stipulated period. Letters should now be exchanged to establish the plan, an understanding of the difficulties and a realistic approach to the problem of cost and payment. A clear understanding on these aspects of treatment will help to assuage recrimination and disappointment should these arise.

The plan

Emphasis on the need for a plan cannot be too strong, if for no other reason than to be able to change it. Circumstances alter cases and both dentist and patient should be aware of dangers ahead with the consequent need to adapt. Success may depend on correctly assessing the adaptability of the dentist's plan and his patient's tissues.

The following aspects of planning will be mentioned and briefly discussed.

ARTICULATOR ANALYSIS

No diagnosis leading to treatment by reconstruction can be complete without a transfer of the retruded axis and lateral border movements by pantograph to a gnathological articulator. The observation of the movements possible by the patient and the effect they have on the teeth will prove invaluable. The registration of the border movements will also reveal any inhibition of muscle movement, particularly in reaching the retruded relation of mandible to maxilla (apex of the Gothic arch). These will be evident by a failure to reach a sharp apex to the Gothic arch: a click will often be revealed by an interruption on the protrusive movement (p. 117, *Fig.* 53*c*). These muscle problems should be cured by rehabilitation procedures (p. 244) and a renewed attempt to get a good pantographic tracing made before proceeding. This articulator analysis takes place on the third visit and more may be necessary before a good pantograph is available. These early procedures may seem to be over-emphasized but it is better to be discouraged now than to fail when the work is done.

PROPOSED EXTRACTIONS AND ROOT-CANAL THERAPY

All the dentist's experience with failed bridgework and pulp death should be brought to bear on deciding the future health of the teeth to be prepared, crowned and used anew. Better a tooth or a pulp lost now than later to lose a bridge abutment or incisor crown.

ORDER OF TOOTH PREPARATION

The decision in which order the teeth are to be prepared and whether to establish the OVD by restoring the anterior or posterior segments first should now be made and this plan presented to the patient.

ANAESTHESIA

Although not the concern of this text the topic must be dicussed with the patient. General anaesthesia in hospital is always tempting for the patient but the number of restorations involved, the impressions to be made and the jaw relationships to be registered will require more visits to the hospital than could be justified or perhaps afforded. The compromise of local anaesthesia and intravenous diazepam is worth consideration. Diazepam has also proved most helpful in registering jaw positions on the retruded arc. When it comes to impressions, the introduction of atropine or one of its substitutes can be invaluable in obtaining a dry field. An anaesthetist is recommended to perform these services.

TEMPORARY RESTORATIONS

The patient should be assured that comfortable temporary crowns will be supplied at all stages and this often poses unwelcome problems. The most comfortable temporary crowns are those made using an impression of the teeth before preparations are begun. A fast-setting acrylic is placed in the impression and applied to the prepared teeth, taking care to protect sensitive dentine against the heat of polymerization. This will solve the temporary problems of occlusion and the fitting of teeth to partial denture retainers. Time and the co-operation of the technician have to be planned and the situation to be avoided is the announcement of the next patient before the temporaries are made, let alone cemented, let alone adjusted for intercuspal occlusion. The homily on haste and the full waiting room is recalled. In reconstruction work it is often advisable to make temporary restorations for the whole mouth, or part of it, to include the new occlusal scheme and so assess the responses of the patient as to comfort and efficiency before proceeding with the permanent work. This will involve more time and expense and these factors have to be weighed against the long-term expectations of the treatment. There are many pathways up the mountain and, in this type of work, the summit is high. Base camps are required on the way to restore the stamina of both patient and dentist. No specific advice can be offered on this decision except to consider fully all possibilities.

REMOVABLE PROSTHESES

When required these will require careful planning with especial reference to restorations on abutment teeth. These may have to carry retaining devices which should be planned ahead. Where the posterior segments are to be waxed opposing each other according to a planned scheme the pontic teeth on the denture should be waxed and cast as a separate occlusal surface. They are then processed to the denture saddle.

MATERIAL FOR THE OCCLUSAL SURFACES

The patient will want to have a say on the choice of materials and this will generally be between gold and porcelain. Porcelain will be preferred by most patients for the lower arch and for the anterior teeth. However, the choice of techniques for developing the posterior occlusal surfaces will determine whether gold or porcelain can be used. On this topic one recalls Jules Leaf's dictum two decades ago, 'Behind the cuspid I'm the boss' in a rich New York brogue. Advances have been made since then and the latest developments in the uses of porcelain make their use in the additive techniques seem possible. In the functionally generated path techniques of Mann and Pankey (p. 195) the use of porcelain for the lower posterior segments is indicated.

OCCLUSAL SCHEME

This must be planned in advance with the technician and one of the methods advocated today will be briefly outlined in the section on development of the occlusal surfaces. The patient's existing intercuspal occlusion and its functional success or failure should be noted. Also the articulation pattern should be decided in relation to the existing pattern. Care should be taken to avoid changing from a pattern of unilateral or bilateral balance to the disclusion scheme of the mutually protected occlusion or the converse if the existing scheme has proved comfortable. At this preparatory stage it is often advisable to remove the occlusal surfaces of the cast teeth mounted on the articulator and to make a 'mock-up' of the occlusal scheme. This is especially desirable where alterations to the occlusal curve are to be made, where over-erupted teeth have to be cut down, or tilted teeth uprighted by restorations.

Any proposed alterations to the existing OVD should be considered carefully against its intolerance by the musculature or the periodontal tissues of the teeth. Bergström's (1950) conclusion on this subject, quoted on p. 235, provides a note of caution. Temporary crowns or a removable appliance increasing the OVD should be worn for at least 1 month to estimate its tolerance if such an increase is deemed necessary.

COMMENT

There are many aspects of planning to be considered and their importance cannot be overestimated if pulps, periodontia, muscles, joints and occlusal schemes are to survive the test of preparation and prolonged function in the future. Four visits will have elapsed by now and nothing that has been done is irreversible. A registration of the patient's RCA will have been tattooed on the patient's face but this is not noticeable. A pantographic tracing of the patient's healthy border movements will have been registered and transferred to the gnathological articulator which will have been adjusted to copy it. This can now be used for the work planned or at a future date provided the muscles remain healthy. It is not too late to back out, and the question should be seriously asked either by the patient or by the dentist to himself: 'What is the prognosis?' Despite the optimism of the dentist and the trust of the patient, reputations and purses are soon lost if the soil be sour. But if this section is to proceed let Shakespeare (1602) have the last word:

> 'Our doubts are traitors,
> And make us lose the good we oft might win,
> By fearing to attempt.'

Procedures

TOOTH PREPARATIONS

Although this is not a text on restorative procedures some features of preparations and transfer are suggested.

1. The shape and extension of the preparations should be considered with a view to future periodontal health and caries recurrence. 'Full coverage' is a term often given to reconstruction work but this should not imply that each tooth receive a full crown. A crown margin extended below the gingival margin is a potential source of irritation to the crevicular epithelium and a site for plaque lodgement. Where possible crown margins should be sited above the gingival margin. This principle applies equally to the buccal and lingual as to the approximal surfaces where, from the aspect of hygiene, it is just as easy to maintain an enamel surface as a gold one with an interdental woodstick. Subgingival extensions will depend on the requirements of active caries and crown height for retention. The latter factor is an important consideration when allowing sufficient room for the new occlusal surfaces, especially where porcelain–gold materials are being used. It is also necessary to extend upper anterior crowns below the gingival margins for appearance reasons. On the other hand, a further advantage of limiting gingival extension is the damaging effect of tissue-retracting devices and chemicals on the crevicular epithelium. Electrosurgical removal of the gingival epithelium has proved a satisfactory alternative to these measures. Decisions on these factors require consideration.

The buccal and lingual shapes of crowns should copy the original tooth shapes. Fat crowns lead to wide separation of cusps and this will disturb the direction of occlusal forces and the effects of function will become potentially harmful. A close look at these surfaces in relation to supporting and guiding cusps, as mentioned in Chapter 2, may be helpful. Finally, the aproximal surfaces in the natural dentition should be viewed again. Below the contact points posterior teeth surfaces are more concave than convex and this makes for easy woodstick hygiene and the promotion of good gingival health. This feature should be emphasized in the completed restorations.

2. Each die must be rigid when seated in the cast and bear an accurate relation to each other die. To assure this requirement, a duplicate cast is often advised. The margins can then be waxed on the removable dies from the working cast and the patterns transferred to the complete cast for occlusal and contact point waxing.

3. The prepared margins of each die must be clearly seen.

4. Preparation and restoration by segments is usually advised but in order to illustrate the principles of reconstruction it will be assumed that all the teeth in both arches have been prepared and casts made. In the event of uncertainty the anterior segment crowns can be completed and seated temporarily in the mouth before proceeding with the posterior quadrants. If mistakes have been

made they can be corrected by adjustments and a new interocclusal record made and transferred.

TRANSFER OF THE RETRUDED CONDYLE AXIS

This is made using a facebow with adjustable side-arms. The prepared teeth must be seated accurately on the bite fork where hard compound or impression paste is preferred to wax. There must be no movement of the bite fork on the prepared teeth while the condyle pointers are adjusted to touch lightly on the tattooed axis marks. The holding can be done by the assistant or by the patient's thumbs (*see Figs.* 43*b*, 44*c*, pp. 102, 104), but closure on the bite fork by the mandible is not recommended since movement is too likely. The orbital pointer is then adjusted to touch the mark (preferably tattooed) on the face so that this transfer corresponds to the same level at which the pantograph was made. The dentist should then hold the bite fork and check that there has been no movement. The upper master cast can then be secured to the upper member of the articulator making sure that the orbital pointer touches the same plane of reference on the articulator as was used when the pantograph was originally transferred. If the split-cast method for checking the interocclusal record (described below) is to be used the master cast should be notched (*Fig.* 80) before plastering to the upper member.

THE INTEROCCLUSAL RECORD

This is made at a predetermined vertical level with the mandible on its retruded condyle axis (RCA) and before tooth contact. If, as in this example, all the

Fig. 79. Pre-contact registration. Anterior stop predetermines IP level and anteroposterior relation of mandible. Registration subsequently made between buccal quadrants.

teeth have been prepared, a stop (made of compound or plastic) is seated on two of the anterior teeth so as to engage the lower incisors at the correct vertical level. Alternatively, this may not be necessary if the correct vertical level is to be selected on the articulator. The choice of material for registering the record has been previously discussed. If an anterior stop is being used two rolls of rapid-setting acrylic resin (or hard wax or compound) can be used for the posterior segments (*Fig.* 79). The dentist must decide which is best in his own hands. If the anterior stop is not being used a sandwich of waxes is advised. This consists of a double layer of hard wax made to fit accurately on the upper prepared teeth and of lower fusing wax added to the lower facing surface (*Fig.* 71, p. 166).

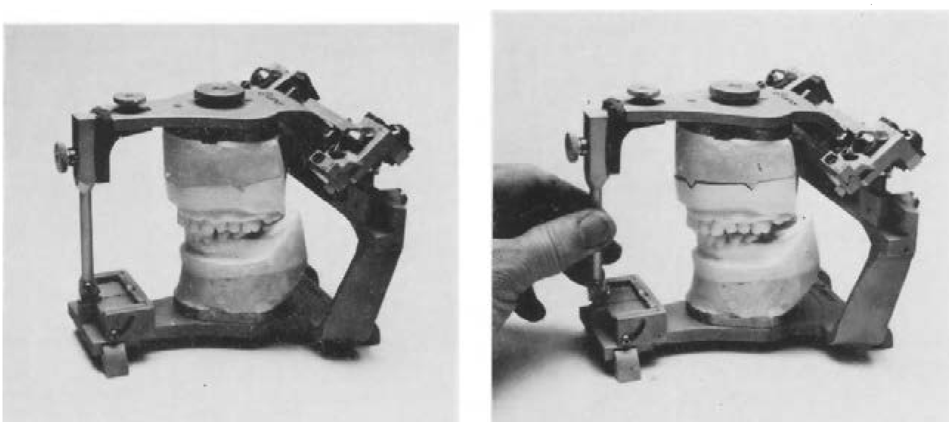
The record is then held against the upper teeth with the left finger and thumb while the mandible is guided by the dentist's right hand to close into the softer wax while on the RCA arc. The lower master cast is then related to the upper and secured to the lower member of the articulator. If the split-cast method of checking this record is to be used three or more records should be made.

CHECKING THE RECORD

This precontact interocclusal record made on the RCA arc is the weakest link in the chain of procedures. If the record has not been registered on this arc it will not be reproducible in the mouth and the costly occlusal surfaces will not meet accurately when returned to the mouth. It should therefore be checked for reproducibility since only if it is reproducible can it be said to be on the RCA arc. Two methods are suggested:

The split cast

This method consists of comparing three or more records and assuming that if two coincide these will be on the RCA arc. The upper cast is prepared with



a *b*

Fig. 80. Split cast method to check record. *a*, First mounting. *b*, Second record does not coincide with first. Repeat until two records coincide. Only on retruded arc will two coincide.

notches as mentioned in the previous section and the stone plaster mounting on the upper member is cast into these notches and is removable from them. The lower cast is secured to the upper using one of the records and secured to the lower member of the articulator. The upper mounting cast and master cast are secured together with an adhesive tape (masking tape is suggested). After mounting, and with the record still in place, the tape is removed. The upper member is made to open and close into the notches (*Fig.* 80). The first record is then exchanged for the others in turn. The upper cast is held on to the lower with the record in place and the upper member closed into the plaster notches. Only when two records are identical will the points of the mounting cast seat into the notches. It can then be assumed that the record has been registered on the RCA arc. If none coincides, the registration should be continued until two do. This may seem a rigorous discipline but time is better spent at this procedure than in cutting or remaking gold and porcelain crowns.

Plastic pins and caps

This method consists of making fast-setting plastic caps on three teeth in each arch, opposing each other, after the first mounting of the lower cast has been made. Into each cap is processed a pin which will accurately contact a similar pin in the opposing cap (*Fig.* 81). These are then transferred to the mouth and if they contact similarly the assumption is that the original record was made on the RCA arc. If not, the amount of error can be seen. An anterior stop is then

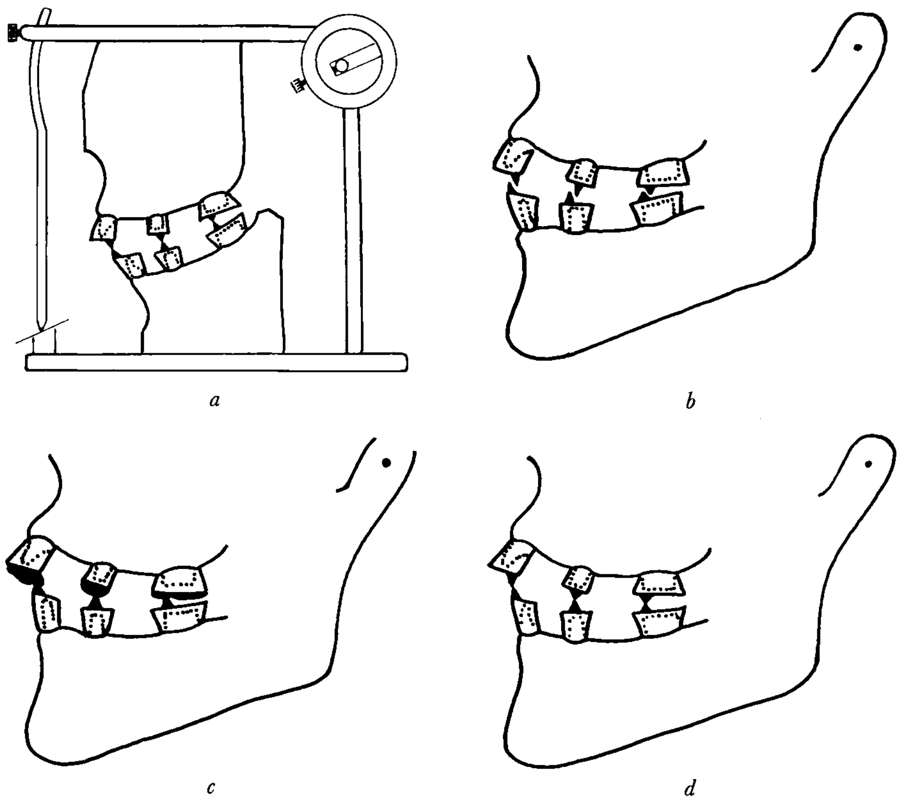


Fig. 81. Pin method to check record. *a*, Pins mounted on acrylic caps to touch. *b*, Pins do not oppose in mouth. *c*, Re-registration. Upper pins removed and compound used. *d*, Pins touch (after being adjusted to touch on articulator, as in *a*).

placed in position while fast-setting plastic (or plaster) is placed around the pins and a new registration made. The caps and pins are removed in pairs and used to remount the lower cast. The pins are then re-set to touch again and tried in the mouth. Only when the pins touch in the mouth in the same relation as they do on the mounted casts can it be assumed that the record has been made on the RCA arc. This is a modification of Brewer's method of checking such a record for complete dentures (p. 203).

DEVELOPMENT OF THE OCCLUSAL SURFACES

The mounted casts and dies are now ready for the waxing procedures which will result in crowns, bridges and/or dentures with the properties of occlusion and articulation planned in the occlusal scheme. Reference is made to the subject of articulation in Chapter 5 in which the three schemes are outlined together with the five factors affecting it. The choice is between bilateral balanced, unilateral balanced and anterior segment articulation. In the case of the last this includes disclusion of the posterior quadrants in all articular movements away from IP and this scheme is given the alternative title of 'mutually protected occlusion'.

The *objectives* in reconstruction procedures are to provide intercuspal occlusion on the RCA at a vertical level 2–3 mm. above that of rest position

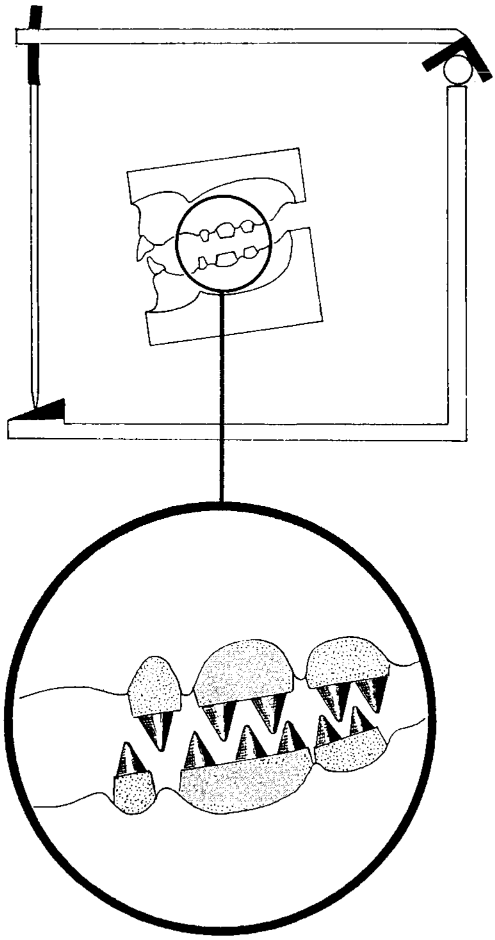


Fig. 82. Wax additive method for waxing opposing restorations. This stage shows the preliminary cones (*see* text).

and to reduce to a minimum the possibilities of cusp interference and parafunctional grinding habits. The patient should be able to carry out the instructions to 'leave your teeth alone and to feel them in contact only when swallowing' without discomfort or lack of efficiency. To meet these objectives the anterior segment articulation scheme is the one of choice provided no radical change is involved which might endanger muscular function or periodontal health. Closure into the retruded IP involves a degree of effort and is seen as a discouragement to all tooth contacts except when swallowing.

The *waxing procedures* which follow will be carried out as for the anterior segment articulation scheme.

The anterior crowns are made first and the movements of the articulator are used to develop articular contacts in the protrusive and lateral movements as determined by the pantographic tracings. As was previously suggested, it is usually desirable to seat these crowns temporarily in the mouth and to check that IO corresponds to the desired IP and that the articular contacts are correct.

The waxing of the posterior teeth is now carried out according to the wax additive or drop wax technique introduced by Payne and developed by Thomas. This is described and illustrated in *Procedures for Occlusal Treatment* produced by the Denar Corporation and written by Guichet (1968). A résumé of the main features follows.

Wax cones are formed by dropping heated wax from a thin instrument, such as a blunted sickle probe, on the dies. These cones are built up to represent the supporting cusps (lingual upper and buccal lower) of the posterior teeth (*Fig.* 82). The occlusal curve and plane of occlusion are established by the heights of these cones. The apex of each cone is sited approximately one-third of the buccolingual distance from relevant lingual or buccal surface and is directed towards the central fossa or embrasure area of the opposing tooth. As each opposing cone is placed, the upper member of the articulator is closed and then moved right, left and backwards to copy the mandibular movements and so ensure that there is no interference. The guiding cusps (buccal upper, lingual lower) are then added and the movements repeated. The cusp and marginal ridges are then dropped on and the movements repeated at each stage. The buccal and lingual contours are added, followed by the triangular and oblique cusp ridges thus gradually building up the central fossae to receive the opposing supporting cusps. Intercuspal occlusion is then checked for tripod contact, avoiding contact between cusp tip and bottom of fossa. Disclusion in all movements away from IP should be ensured.

This brief outline of the waxing procedures should be implemented by a study of the presentation already mentioned, followed by practice on mounted casts preferably under instruction.

Cusp–fossa or cusp–ridge

Wherever possible a cusp should make contact in an opposing fossa in IP. This principle will keep the forces of occlusion within the outline of the tooth and not between adjacent teeth, as with cusp–ridge relationships. The relationships of the opposing teeth will determine whether this is possible or not.

CASTINGS

Castings should fit the dies firmly but without force being necessary. Any scratching of the dies will indicate too firm a fit on the prepared teeth. A thin layer of varnish painted on the dies, short of the margins, before waxing may help to produce this property. The addition of small 'blisters' buccally and lingually on the gold just above the margins will be helpful in removing the castings from the teeth especially if they are to be temporarily cemented. After polishing, the castings should be sandblasted so that premature contacts can be seen after they have been in function for a few days. In order to ensure accurate seatings of all castings they should be worn in the mouth for 2–3 days before cementing, either temporarily or permanently.

TESTING THE OCCLUSION AND ARTICULATION

After ensuring that the castings are seated the occlusion can be tested by placing an ultra-thin strip of plastic sheet or cellophane between each opposing pair of teeth in turn and the mandible closed into IP. It should not be possible to remove the strip. The plastic sheets separating the leaves of articulating paper are useful for this purpose. The strips are then replaced with the mandible in lateral and protruded positions in succession when it should be possible to remove the strips. This will indicate disclusion and freedom from interferences.

REMOUNTING

In spite of the care taken in the foregoing procedures inaccuracies occur. Teeth may move and relationships will therefore change.

'The bestlaid schemes o' mice an' men
Gang aft a-gley,
An lea'e us nought but grief an' pain
For promised joy!' (BURNS, 1759–1796)

Consequently, the following procedures will be necessary:

1. A new pre-contact registration on the retruded arc.
2. A new facebow transfer of the retruded axis.
3. Plaster impressions of both arches to remove the restorations in their altered positions.
4. Casts made from these impressions.
5. Casts secured to the articulator using the facebow and pre-contact records.
6. Occlusal adjustments to restore:
    a. IP on the retruded arc.
    b. The planned articular scheme.

PERMANENT SEATING

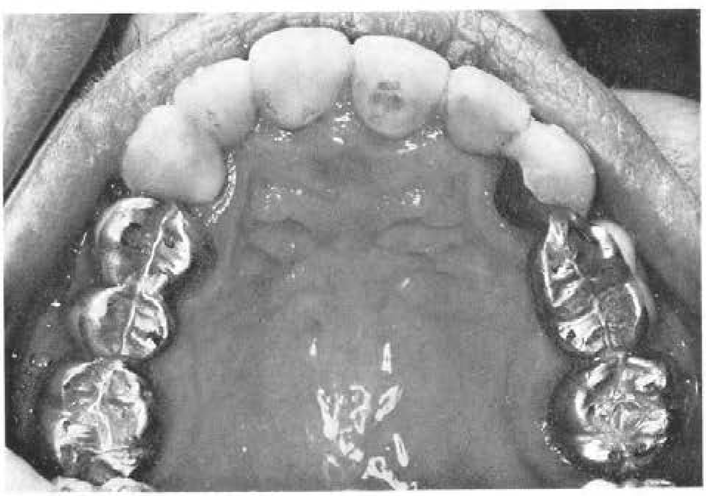
This can be delayed for a period of months provided the temporary cement holds and the patient is within easy reach. When a prolonged period of comfort and good function has been enjoyed and the patient is practising regular woodstick hygiene permanent cementation can be carried out. The temptation to cement on completion of the work should be resisted until patient and dentist are satisfied that the occlusion is stable and the articulation free.

Two cases carried out in practice are illustrated in *Figs*. 83 and 84. The preparations and impressions were shared with Jean Lagesse. In *Fig*. 83 the TMJ instrument was used (*see also Fig*. 56, p. 124). A retruded axis transfer and plastic record pantograph were made and the articulation scheme was anterior segment. *Fig*. 83*e* shows a bite guard made to protect the labial restorations during sleep.

Fig. 84 shows a case completed in 1962 with a bilateral balanced articulation scheme. The patient had resolutely refused the advice of complete dentures. Too much was expected of the incisor crowns and 3 out of the 4 have sheared off in the following 6 years. They received root-canal therapy and post crowns. However, no tooth has been lost to date. Photographs before and after treatment illustrate only that the work was done. They do not show the numerous stages, at the chairside and in the laboratory.

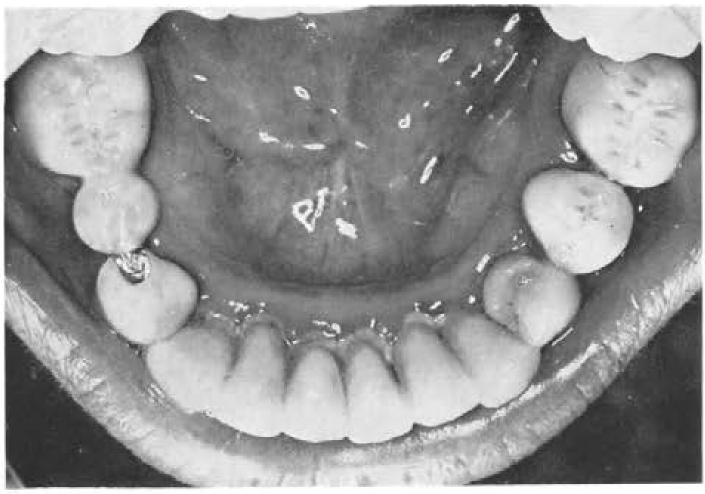
a

b



c

(*Fig.* 83 — *see* over.)



d

e

f

g

h

Fig. 83. Two complete arches restored, central incisor to first molar only in each segment. *a*, On examination, all teeth required treatment and the following were extracted: 15, 24, 25, 45. *b*, Completed reconstruction with mandible at RP. *c–h*, 2½ years after completion with no intermediate inspection or treatment: *c*, Upper arch. *d*, Lower arch. *e*, Bite guard worn nightly. *f*, IP. *g*, Protrusion (anterior segment articulator). *h*, Use of interdental wood sticks.

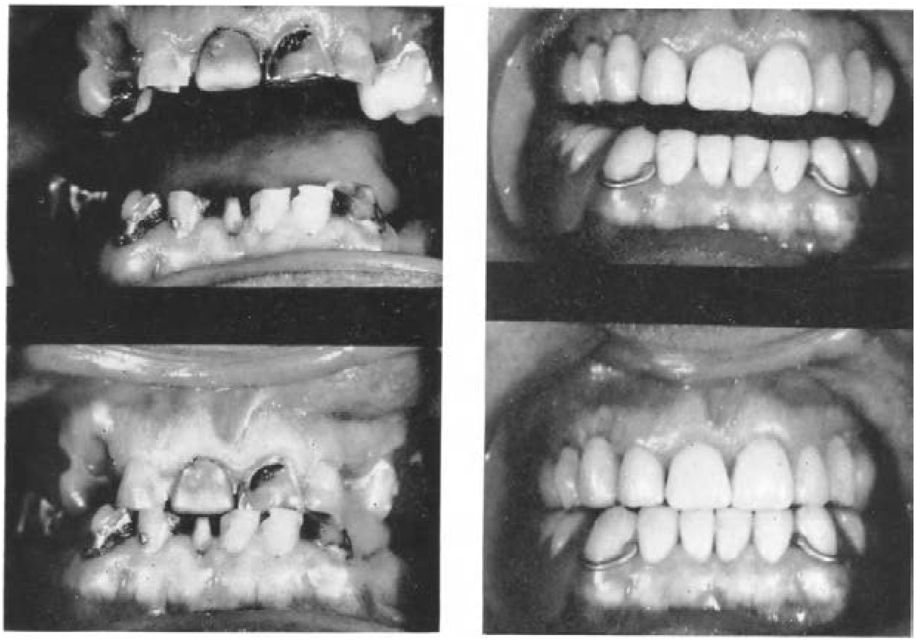
Disadvantages of bilateral balanced articulation

Pokorny (1971) reports the following comments from a series of patients whose reconstruction had been based on this articulation scheme.

1. They bit their cheeks and tongues.
2. The long mandibular lingual cusps hindered their chewing.
3. Balancing contacts disturbed their chewing.
4. Cross-tooth and cross-arch balance prevented chewing freedom.
5. Awareness of friction in those patients who constantly 'tested' their occlusion.
6. They had lost their lower jaw.

7. So many closures were possible that they could not distinguish retruded IP from other positions.

Stuart and Stallard (1960) report from their early procedures which included bilateral balanced articulation that cusp tips wore and ridges became 'faceted' with consequent loss of OVD. They also noted that working-side contacts wore faster than balancing contacts.



a *b*

Fig. 84. Two complete arches restored. *a*, Before treatment, with increased freeway space. *b*, Completed treatment. All upper restorations and lower incisors, canines and one molar were fixed. Partial lower denture with one free end saddle.

Many of these complaints would seem to derive from parafunctional grinding habits or from too much occlusal awareness. This latter phenomenon may have been present before treatment but bilateral balance in articulation would seem to accentuate it. The principle of disclusion in all movements from retruded IP will reduce this tendency to a minimum and the tripod contacts between cusps and fossae provide a stable occlusion and ease of movement from it.

Choice of articulator

All gnathological articulators are complex and costly. Their use requires instruction and supervision which implies the need for study groups and for group usage. The positional record adjustable articulators have proved an adequate alternative to the gnathological articulators in many hands. Their limitations in providing accurate copies of the lateral border movements of the mandible have already been stated. However, it is during these movements when cusp interferences commonly occur and adjustments will have to be carried out in the mouth. In complete reconstruction all that can be expected on the adjustable articulator is an accurate IP on the retruded arc and an approximation of the lateral articular movements. Choice of a gnathological articulator should be made after consultation with colleagues who use one.

The Mann and Pankey method

Some notes on the procedures for reconstruction advocated by Mann and Pankey and based on a different concept are now given. Mann and Pankey (1960, 1963) combined the previous concepts of Monson's spherical occlusion (1932) and Meyer's 'chew-in' (or functionally generated path) technique for complete dentures (1938). Monson's theory (Chapter 5) was that the centre of a sphere with a radius of approximately 4 inches is equidistant from the occlusal surfaces of the posterior teeth and the centres of the condyles and that the long axes of the posterior teeth form extensions of radii from the centre of this sphere. The centre of this sphere can be found by using an adjustable facebow articulator with a 'centering plate' mounted on the upper member as originally devised by Wadsworth (p. 113). Casts of the upper and lower teeth are mounted and a pair of dividers used to measure the distance between the condyle centre and the median lower incisor position. The dividers are then used to scribe arcs on the centering plate with condyle and the median incisal position respectively as centres. The point where the arcs cross is then used as a centre for determining the occlusal plane and a radius of approximately 4 inches is found to touch the buccal cusps of the lower teeth.

Mann and Pankey devised an articulator (the P–M instrument) which embodies a facebow transfer for the casts and a fixed centre for the sphere of occlusion. After mounting preliminary casts of the teeth to be treated, specialized dividers are used to determine the optimal occlusal plane on the lower cast. One arm of the dividers has a cutting edge and this carves the lower posterior teeth to the desired plane. Preparations on the lower posterior teeth are then planned and carried out on the plaster teeth. 'Plane guides' are made on the prepared lower cast which are transferred to the mouth for ensuring that the teeth in the mouth receive the same level of preparation as the mounted plaster teeth.

Three stages in the procedures then follow:

1. The lower teeth are prepared and impressions made. A master cast of the prepared teeth is then related to a cast of the unprepared upper teeth. Wax patterns are made to conform to the arc of the occlusal plane and to the upper teeth. The plaster upper teeth are cut where necessary to conform to the arc and to wax cusps and fossae of the lower. The lower castings are made and cemented.

2. The upper incisor and canine teeth are adjusted, if necessary, in order to provide optimal protrusive and lateral movements. Allowance is made for 'long centric' between retruded and intercuspal positions. If there is insufficient contact between the upper and lower incisors and canines, 'guide-pin castings' are made on the lingual surfaces of the upper incisors and canines in order to establish these articular movements.

3. The upper posterior teeth are prepared and a sufficient clearance is left to allow for the articular movements. A master cast of the upper prepared teeth is made and mounted. A cast of the completed lower teeth is also made and the 'functional bite' follows. This is registered using extra hard wax to face the upper prepared teeth. Softened lower fusing inlay wax on the lower facing surface of the hard wax is used for making the functionally generated path.

This record is first used for relating the lower completed cast to the upper cast taking care not to disturb the inlay wax marks. It is then secured to the lower member of the articulator and the record removed. Stone plaster is then cast into the generated paths of this record. The hard wax indentations on the upper aspect of the record are seated on the upper master cast. The lower cast (with the functionally generated path) is then plastered to the lower member of the articulator. There are, therefore, two opposing casts for developing the wax restorations on the upper prepared teeth, namely, the completed lower teeth and a functionally generated path of them. The castings are made and cemented.

This brief summary is condensed from the various writings of Mann and Pankey and from the manual of the P–M instrument.* Further study of the method is necessary since the techniques and instruments used are changing.

Four principles are advised by Mann and Pankey which will contribute to this study of occlusion and articulation.

1. The provision of 'long centric' is advocated which allows intercuspal occlusion between retruded and habitual IP.

2. Unilateral cross-tooth balance in lateral movement to the working side is used.

3. Unilateral disclusion on the balancing side follows.

4. Disclusion on protrusion from habitual IP.

This will now be familiar as unilateral balanced articulation incorporating free gliding movements between retruded and intercuspal positions. The only criticism offered is that the 'long centric' contact will promote grinding movements between the two positions.

Gnathic relator

Before concluding this section on complete reconstruction mention is made of a principle which utilizes lateral movements of the mandible for making an intra-oral registration on mounds of fast-setting acrylic resin. This record is used for developing the occlusal surfaces of the prepared teeth by seating the record between the master casts. No articulator is used. This method incorporates the principle used by Swanson and Wipf for the TMJ instrument without transferring the record to an articulator. The method is also advocated for complete dentures although an adjustable articulator (with facebow transfer) is advised for remounting the dentures 'for the elimination of acrylic processing errors'. The equipment consists of a series of plates and supports and is called the Gnathic Relator.† Without having used or seen the equipment no comment can be made. It would seem to have possibilities in hands guided by a knowledge of the masticatory system with its talent for proprioception.

Care of the reconstructed dentition

Two aspects of care are emphasized, hygiene and limited occlusion.

Every cement margin is a potential source of caries recurrence and gingival irritation. In spite of the best operative techniques and the most skilled hands no margin should be left unclean. The most vulnerable regions are between the teeth where the toothbrush cannot reach. The dental woodstick will provide not only clean interdental tooth surfaces but will reduce irritation to the

* J. F. Jelenko & Co. (1959).

† Dental Dynamics Inc., Florida.

gingival papillae to a minimum. Any suspicion of col development (Cohen, 1959) should be seen as a warning sign for periodontal disease and be treated with dispatch.

Instructions to the patient on the use of his new occlusion should centre on the avoidance of abuse. The natural position for the jaw is with the teeth parted. 'Lips together, teeth apart, never from this rule depart' has been imported from the U.S.A. and should be imparted to all people as well as to patients. The avoidance of parafunctional clenching and grinding habits has become a text in this book and its effects are to be ranked with caries and periodontal disease. As always, prevention is preferable to cure but is often more difficult to prescribe. Irrelevant muscle activity is almost universal and is often directed to the mandibular muscles and whether it is preferable to grind one's teeth or to smoke, pace the floor or perform acts of violence is not a subject for this text. Alternative activities can be suggested. 'Keep the tongue between the teeth'; 'Move the jaw without touching the teeth'. For clenching or grinding habits while asleep the anterior bite guard has proved helpful and its construction will be described in Chapter 13. It will undoubtedly prevent the breakage of many porcelain crowns (*Fig.* 83*e*). The bite guard can also be worn while driving a car whence many of these activities derive. Many other situations lend themselves to the use of this preventive appliance not excluding the dentist at his chairside.

Comment

Complete reconstruction is a far cry from the amalgam filling but the principles and objectives are the same, namely, to appreciate the behaviour of the muscles and teeth in function and to produce comfortable and efficient occlusal function. One can argue and moralize about the justification for reconstruction procedures, either partial or complete, and whether so much care for so few patients at such cost is practicable or justifiable when so much care is required for the community at large. The justification lies in the work being genuinely necessary and being accurately done, thus preventing the need for further restorative treatment for an indefinite period. Implied in this justification is the suggestion that this type of work should be carried out by groups of trained specialists working together, in consultation and in practice, for their common benefit and that of the patient. The moral, if there is one, is to prevent the need for such work by comprehensive care of the adolescent and young adult. The emphasis is on the prevention of caries and periodontal disease and on the development and maintenance of good occlusal function.

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Chapter 11

Occlusion in complete and partial dentures

COMPLETE DENTURES

THE importance of occlusion and articulation for maintaining the stability of complete dentures has never been underestimated but it is often overlooked. The registration of jaw relations is often cursorily performed especially when the procedure is combined with setting the incisor teeth. This divides the priorities, usually in favour of appearance. The placing of the posterior teeth is left to the technician who, with more skill than he is credited, often produces the correct positions and occlusions. Here, if ever, the dentist and technician should form a team but too often communicate by phone or on hastily written slips of paper. Such a situation is inevitable for the solo practitioner but is hard on the dentist, technician and patient alike when it comes to setting teeth.

There are four properties required by complete dentures which will be briefly defined in order to clarify the objectives of this chapter. *Support* is the property of the residual ridges and mucosa which allows them comfortably to support the dentures. *Retention* is the property of the denture bases which causes them to resist vertical displacement. *Stability* is the property of the dentures which causes them to resist displacement during function and parafunction. *Appearance* is the property which makes the dentures pleasing to the dentist and patient.

Stability is the property chiefly affected by the various occlusions of the teeth. The objectives in this chapter are to discuss the principles and describe the methods of registering jaw relationship and of setting the teeth for complete and, in the next section, for partial dentures in order to achieve optimal stability in occlusal function.

Jaw relationships

In complete dentures the dentist is presented with the ultimate exercise in reconstruction where he can choose innumerable jaw and tooth positions for his dentures. However, if he requires the jaw relationship transferred to the articulator to be reproducible when brought back to the mouth it should be registered on the retruded condyle arc. If the muscles are healthy and permit this movement the registration presents few difficulties. The difficult patient in this respect is he who has suffered changing intercuspal positions in the decline through diminishing and painful teeth, through insecure partial and complete dentures. His muscles have spent years in adapting to changing tooth positions and are fatigued, bruised and sometimes spastic. The patient is then blamed for having a 'difficult bite'. When he is encountered, and before his jaw relationships are registered, his muscles should receive some rehabilitation and his psyche some tranquillity.

The *mandible on the retruded arc* assures a reproducible horizontal relationship and the remaining problem is to select the correct vertical position. This should exist, as has been stated many times, at a level 3 mm. above that of rest position. This is not to say that the relationship should be registered with the mandible moving up from rest position, but that rest position is used as the reference level whose distance from the maxilla can be measured.

One further principle pleaded but seldom heeded is that of *registering the required relationship using the permanent bases*. During the moment of registration the bases must fit the residual ridges with the greatest possible accuracy. If they move, the registration will not represent what was registered. This inaccuracy can seldom be seen to take place and the subsequent diagnosis of what went wrong is made more difficult. The use of wax or processed trial bases and fixatives does not approach the accuracy of using the bases which will be used in the completed dentures. An additional advantage of making the permanent bases before the jaw registration is made is that the bases can be checked for retention before they are subjected to the requirements of stability. Consequently, permanent bases are recommended and mounting casts made before the registration. A thin sprinkling of fixative can be used for the bases if there are doubts about retention but at least the bases will fit the mounting casts as accurately as they fit the residual ridges.

Jaw registration

Horizontal and vertical relationships. Compound occlusion rims are formed on the bases and a preliminary closure into them allows the rims to be shaped for height. At this stage the upper rim should be aligned to the alar–tragus plane (*see Fig.* 87) if this is used or trimmed to Monson's sphere (p. 111). The occlusal vertical dimension is then decided by measuring the distance between spots marked on the nose and chin with the mandible in rest position (*see Fig.* 66, p. 155). The bases and rims are then replaced in the mouth with the compound on the lower softened and closure stopped at the level of rest position. The lower rim is then reduced by 4–5 mm. in height and notches are cut in the upper rim, at the region of the first molars. Movement on the retruded arc of the mandible is then practised by the patient with the assistance of the dentist. The bases are inserted and a compound stop placed on the lower rim in the incisor region to arrest closure at the planned OVD. Alternatively, two compound stops can be placed on each buccal segment. The posterior segments of the lower rim are then loaded with the registration material (minimal viscosity, rapid setting and dimensional stability after setting) and the registration made. The upper base is held lightly in place by the forefinger and thumb of the left hand while the right is free to guide the mandible on the retruded arc into light closure and held while the registration material sets (*see Fig.* 69, p. 160). Care is required to ensure that the bases do not move during the closure or setting, and this aspect of the operation cannot receive too much emphasis. Only the compound stops should penetrate the record. A facebow record is then made to transfer the upper base to the adjustable articulator (*Fig.* 85).

DISCUSSION

The assessment of the OVD in relation to rest position is arbitrary and it is not easy to assess the RVD when the patient is edentulous. The edentulous mouth has no periodontal receptors and this may result in an increased tonus of the mandibular elevators (Attwood, 1956), thus closing the RVD. A further cause of RVD closure may be the lack of lip support by the teeth. It is, therefore

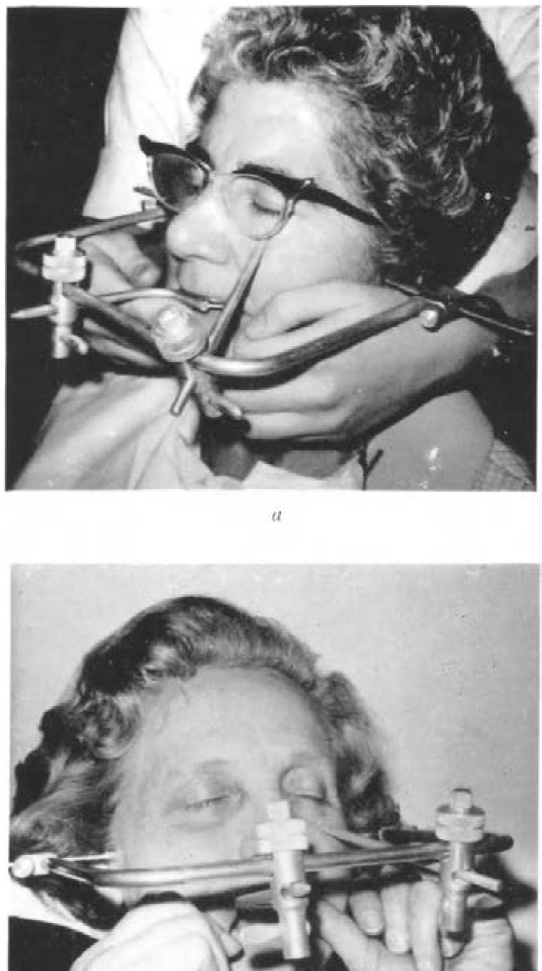

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Fig. 85. Facebow registration. *a*, Assistant holding the bite fork. *b*, Patient holding.

advisable to ask the patient to part his lips (but only slightly) when rest position is being measured. This emphasizes the arbitrary nature of the procedure. Movement of the lips (the 'm' sound) followed by rest is one of many methods. The marking and measuring of this distance are subject to error and the Willis bite gauge can be used if a constant light touch in method can be achieved. The use of the facebow permits the OVD to be altered on the articulator and this is often done when the OVD is checked by the speech test at the try-in stage. A comment is made concerning the absence of opposing teeth while making this registration. Opposing artificial teeth will always tend to meet and dislodge the bases. Even if they do not meet, they tend to exert forces in many directions as they engage the wax, compound, plaster or paste. It is true that remount registrations are made with the teeth in place and additional care is required to ensure that the teeth do not meet and that the medium has minimal viscosity.

ALTERNATIVE METHOD

An alternative method of registering the OVD is by patient assessment devised by Timmer (1968). A central bearing screw is fixed to the lower base and a plate secured to the upper behind the incisor region. By altering the height of the screw and instructing the patient to close after each change the patient is able to assess the most comfortable level of closure. This method is proving increasingly successful and can be recommended (L'Estrange, 1974). It will also allow the registration to be made using the screw and plate as a Gothic arch tracer.

Checking the record

Before setting the teeth it is always advisable to check the record transferred to the articulator. The split cast method using three or more records has already been described (p. 186) as has Brewer's pin method applied to reconstruction (p. 187). For complete dentures this latter method is particularly applicable and has proved helpful in the author's hands for 15 years. For this two sets of four pins are set up on the articulator with the pins in edge-to-edge contact (*Fig.* 86). The bases carrying the opposing pins are transferred (with the cups removed) to the mouth. If the pins do not meet on the retruded arc the conclusion is that closure on the articulator is different from closure in the mouth. The extent of the difference, in both anteroposterior and buccolingual planes, can be seen as the pins approach each other. To complete the set-up at this relationship would lead to unbalanced occlusion on closure in the mouth. Replaceable cups are now screwed on to the lower pins and filled with compound, plaster or acrylic resin and the retruded arc registration made again. Remounting of the lower base and cast is made, the pins re-set to touch again, and the bases re-tried in the mouth. This procedure is repeated until the pins meet in the mouth as they do on the articulator (Thomson, 1961). If this method is to succeed the retruded closing arc must be used each time. Registration on any other arc of closure is certain to produce a difference between the mounting on the articulator and the closure in the mouth since no two habitual arcs of closure will be similar. The reason for this dogma is that the strangeness of the bases, the bulk of the occlusal rims and the operator's fingers will always produce an adaptive closure on any but the retruded arc when the stimuli from these agencies will be overruled.

The vertical and horizontal jaw relationships have now been decided and no re-registration of the RCA relation is made until the dentures are completed. Theoretically this should not be necessary but practically it often is due to processing errors and the further seating of the bases after wear.

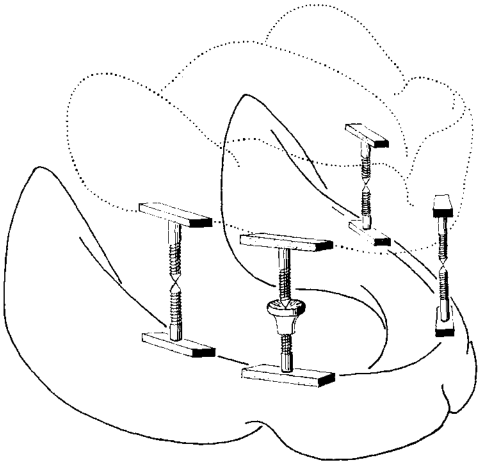

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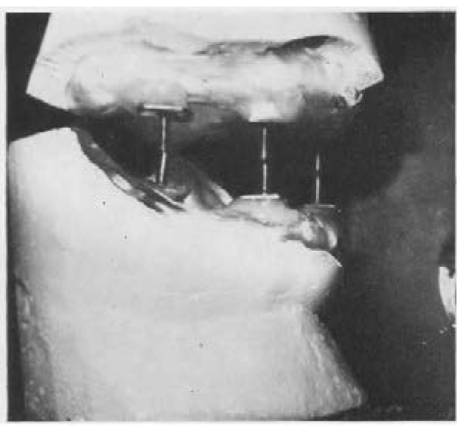
Fig. 86. Opposing pin method to check mounted bases. *a*, Diagram. Pins (screws) with screw-on cups (one example shown) for re-registration. *b*, Pins mounted and touching on bases previously mounted by preliminary record. *c*, Pins in mouth not touching on retruded arc. Therefore mouth different from articulator. *d*, Re-registration using cups filled with compound. *e*, After remounting and pins re-set to touch, they are returned to mouth where they are now touching (mandible on retruded arc). Therefore mouth closure is same as on articulator.



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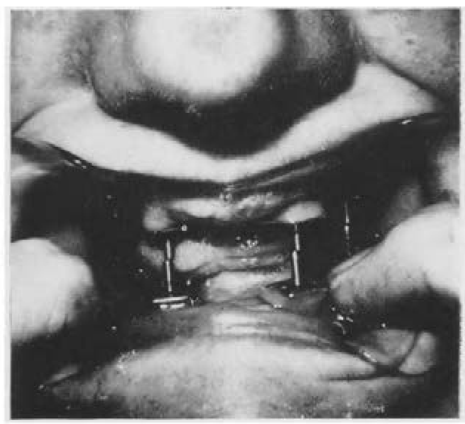

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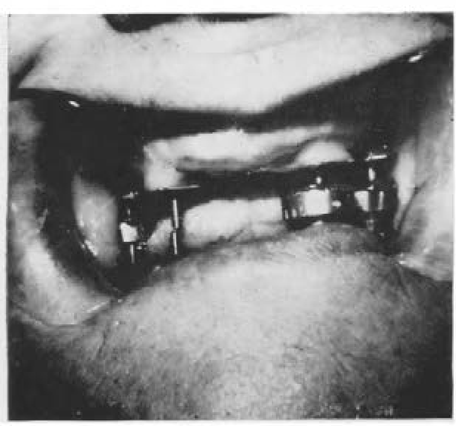

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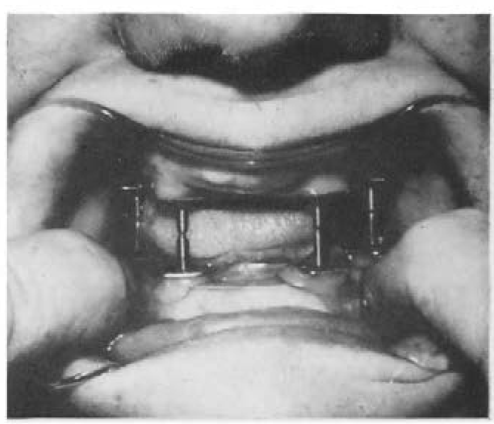

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The protruded relationship

A preliminary protruded relationship is registered before the occlusal rims are removed in order to make a provisional assessment of the condyle guidance. This will be checked at the try-in stage and probably re-registered.

Setting the teeth

This is a subject with which all undergraduates are familiar but which is often forgotten when the commitments of practice allow the technician to take it over. For complete dentures to succeed the responsibilities for this procedure should be shared. Two principles are suggested. Firstly, the artificial teeth should be set as closely as possible to the positions of their natural predecessors. Secondly, balanced occlusion and free articulation should be developed for all positions and movements where compatible with the first principle. These can be described as the *natural* and the *mechanical* principles respectively, and the chief skill in making dentures depends on how closely they can be linked.

NATURAL TOOTH POSITIONS

The setting of artificial teeth to copy their natural predecessors involves considerations of lip posture and competence, tongue and cheek posture in the formation of the neutral zone, and appearance. It is a skill which has been left largely to the intuitive sense of the dentist but which is receiving more scientific attention by L'Estrange (1974). For the present, the clinician must be satisfied with some well-tried suggestions. Pre-extraction photographs and casts provide invaluable guidance where available.

The *upper incisors* should copy a smiling (? wedding day) photograph of the patient's natural front teeth. Some technicians are extremely skilled in this art and craft of copying. The teeth should be tested for lip tolerance and approval by the patient. A mechanical guide for the central incisors is the distance of 10 mm. in front of the incisive papilla although this gives no guide for the inclination. On smiling the incisal edges should lightly touch the lower lip.

The *upper canines* should be vertical and only the mesial surface should be visible from the front. The tip of the canine should be level or shorter than the incisal edges of the centrals. The lower incisors and canines present the most difficult problem in copying the natural tooth positions since attempts are often wrongly made to provide a Class I incisor relationship. The empirical tests of appearance and speech, by trial and error, are usually helpful but faults are often not found until the dentures are completed. The allowance of an oblique angle between the incisors and muscle (polished) surface is often helpful in accommodating the mentalis and orbicularis muscle activities which can provide dislodging forces. A smile test will help to determine this factor. On opening the mouth the canine and first bicuspid should lie just below the lower lip line.

The upper and lower incisor positions can be determined by applying alginate to compound blocks in these regions and having the patient swallow sips of water. The lip muscles will then indent the alginate as it sets.

The quality of a pleasing appearance for the teeth should be developed and this goes with efficient function and comfortable lip activity. Lee's (1962) work in this respect repays study.

The *lower bicuspid and molar teeth* should be set and seen as early as possible in the procedures so that they can be altered by repeated tests. The assessment of the neutral zone is rendered difficult by tongues which will not stay still. When strange teeth are set beside the tongue the effect can be that of a cork at sea. The teeth should lie below the greatest convexity of the tongue at rest with their lingual cusps just covered. The buccal mucosa should not be indented. The modiolus effect on the bicuspids should be tested during the swallow and by pursing the lips.

The *upper bicuspids and molars* may have to take what is left but the requirements of the tongue in the 'sh' sound (as in 'should') have to be met. The temptation to 'cross the bite' where this problem arises should be resisted and it is preferable, and often mechanically desirable, to leave off the second molars. The articulation requirements of orientation plane and occlusal curve should not be forgotten and a good rule for these teeth is to ensure that the two bicuspids are touching the plane while the first molar and second (if used) are curved upwards and outwards.

At no time is it necessary to 'keep the teeth on the ridge' although this may be their position by the methods suggested. The objective is to place the artificial teeth where the orofacial muscles caused the natural predecessors to develop, otherwise they will be moved by these muscles. Resorption of the residual ridges takes place in varying degrees and positions and the ridges are not a reliable guide for artificial teeth.

Balanced occlusion and free articulation

The mechanical properties of uniform contact on closure and freedom from interferences during articular movements of the mandible are as essential to stability as the correct positions of the teeth. In support of this precept it is claimed that if artificial teeth present no interferences to closure or articular movements in the empty mouth there will be fewer stimuli arising from the mouth to promote parafunctional movements which can be so damaging to complete dentures. The ability to combine these properties of occlusion and tooth positions presents a major challenge to the teamwork of dentist and technician. Reference is again made to the five factors affecting articulation (Chapter 5) and these should be decided at the outset of setting the teeth.

The *condyle guidance* has been adjusted but it can be altered. It should be remembered that the protrusive path is usually a few degrees closer to the horizontal plane than the lateral path (Fischer's angle). In adjusting articular contacts for the lateral movements the condyle guidance should be increased by 5° over that used by the protrusive movement.

The *incisal guidance* will be determined by the setting of the incisor teeth to conform to tongue and lip activity. This, too, can be altered but care should be taken not to interfere with the latter activity. The vertical incisor overlap and horizontal overjet will also have been determined, where possible, by the natural teeth predecessors but a slight increase in the overjet may be permissible to allow for articular movements. The angle of the incisal guidance table should be set when the inclination of the upper incisors has been decided. This is achieved by moving the table until the incisal guidance pin remains in contact with it while the opposing incisors maintain articular contact in the protrusive movement. The combination of the condyle and incisal guidances thus provides a curved path of motion for all points between the guidances unless the guidance angles are identical (p. 81).

The *plane of orientation* is usually determined by laying a rigid flat plane to touch the lower canines and the retromolar pads on the cast. Alternatively, this may have been decided by the alar–tragus transfer (*Fig.* 87). Such a plane can then be temporarily attached to the upper cast while the height of the posterior teeth are adjusted to it. This level may conflict with the height decided by the tooth positions in relation to the tongue and the latter level must take precedence, if correct. A compromise may be necessary and is justified if the dentist and technician realize the requirements of both neutral zone and plane of orientation.

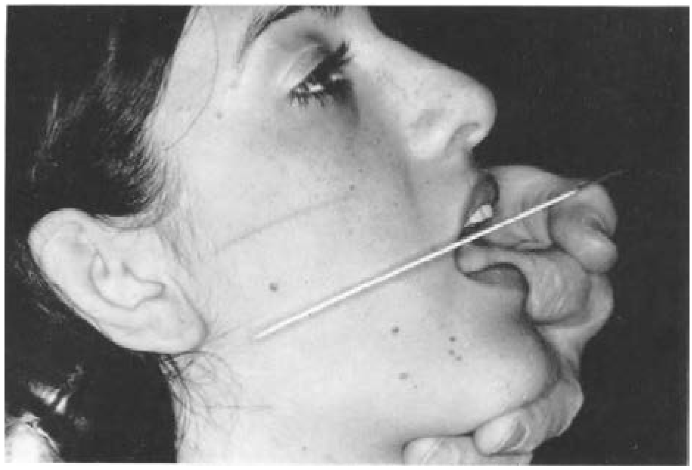

Fig. 87. Fox's bite plane parallel to alar–tragus line.

The *occlusal curve* is vital to requirements of free articulation. The steeper the condyle guidance the steeper will the occlusal curve have to be. Monson's curve developed by Wadsworth and described on p. 113 may be of value if the articulator possesses a centering plate. This method brings a mathematical certainty to the curve but it may not be harmonious with the requirements of the condyle and incisal guidances. However, as these guidances are by no means certain, Monson's curve may yet be revived.

The *cusp height* of the posterior teeth is determined by the limited choice of available teeth. Cusp heights can be altered provided the curves of the triangular ridges are not flattened and the teeth allowed to lock into each other like cogs. The occlusion of artificial posterior teeth should be by tripod contact for the supporting cusps and adequate overjet and overlap by the guiding cusps. This preserves the principle of minimal occlusion and will reduce parafunctional grinding provided the jaw relationship has been correctly registered. The overjet will prevent cheek and tongue biting. Stability in IP will be provided and gliding to and from IP during the articular movements will be more easily developed. The occlusal surfaces of artificial posterior teeth have undergone many changes of design but the natural design is still available and, if correctly used, is reliable. Teeth without cusps provide an unstable IP and articulation cannot be balanced. To be successful the cuspless-tooth denture must have its teeth accurately placed in the neutral zone and its wearer not given to clenching or grinding habits.

The development of *balanced occlusion on closure* presents few difficulties to the technician. It should, however, be combined with free articulation as each pair of opposing teeth is set. *Cross-tooth balance* is developed for the lower first molar and its upper counterpart. This requires a slight buccal tilt of the upper molar and a corresponding lingual tilt of the lower. The opposite first molars are then set together and *cross-arch balance* is developed for both pairs. The bicuspids tend to be set more vertically and the property of group cross-tooth and cross-arch balance is developed (*Fig.* 88). Protrusive balance can be

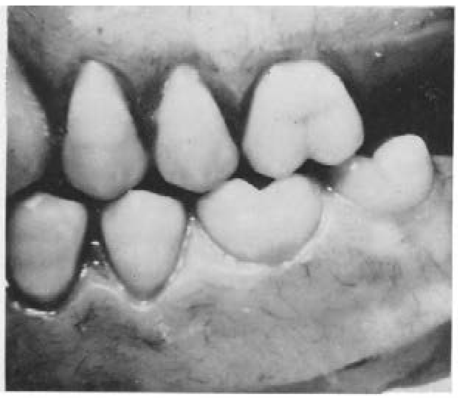

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Fig. 88. Bilateral balanced articulation. *a*, At end of protrusive articular movement. *b*, Working side. *c*, Balancing side.

achieved only if the occlusal curve is correct and the incisal guidance, overjet and overlap permit. As was mentioned previously, the upper second molars can be left off and this reduces the demand of protrusive articular balance.

Free articulation consists of an innumerable series of balanced occlusal contacts and the chief difficulty in achieving this mechanical requirement is the inaccuracy of the transferred positional records which are at best a guess of what happens in the mouth. Nairn's (1973) three recommendations are worth repeating: achieve unobstructed movements into IP from lateral and protruded occlusions; avoid premature balancing contacts in lateral occlusions; do not pay too high a price for protrusive balance.

It can be argued that the provision of free articulation will promote parafunctional grinding movements. The patient can only be advised of its dangers and be rewarded with stability and comfort if the contacts between his teeth are restricted to the final act of swallowing.

The try-in

Many features of complete dentures can be checked at the try-in stage and a helpful reference on this topic is Lawson (1959). The closest speaking space is a useful check for the OVD. Incisor midline at rest and intercuspal positions are observed and the patient's observations on the balance or 'level feeling' of the teeth are requested. If the jaw relationships have been checked previously temptations to remount at this stage should be resisted. The strangeness of the new teeth and bases will tend to promote new adaptive movements and the relaxation required to achieve RCA closure may be difficult for the patient at this time. The protruded occlusion developed on the articulator is checked in the mouth and may be altered empirically if incorrect. If the incisors and not the molars are in contact the guidance angle should be increased and the occlusal curve deepened. The converse applies when the molars only are in contact. Alternatively, a new protrusive precontact record can be registered and the condyle guidance reassessed with this record. Care should be taken to avoid incisor tooth contact in making the registration.

Laboratory procedures

The development of the articulation factors should be the constant concern of both dentist and technician. The refinement of the articulation is a skill that should be shared by both. Processing of the teeth to the bases is now carried out without any impairment of the dimensional stability of the bases or movement of the teeth provided processing temperatures are carefully observed. None the less it is always reassuring to be able to return the processed dentures to the mounting casts on the articulator where the occlusion and articulation can be checked. If the incisal guidance pin reaches the incisal table on the articulator the OVD will correspond to the one registered in the mouth.

Remounting

This is often advised immediately the dentures are delivered but it has proved more practicable one or two days later. It may not be necessary if patient and dentist are satisfied. If the jaw relationships are incorrect, however, and remounting is required fast-setting plaster is recommended for the registration. This will reduce to a minimum the possibilities of tipping the dentures but the procedure should be reinforced by careful handling of the dentures in the mouth as has been previously described. Care must be taken to avoid any tooth contact in making the registration.

If the mounting casts have been preserved no further facebow transfer is necessary. For future remounting it may be desirable to make a plaster cast attached to the lower member of the articulator with imprints of the upper mounted denture. This will not be necessary if the upper mounting cast is preserved.

Choice of teeth

No opinion is offered on the choice between porcelain or plastic teeth, but for reasons already given, cusps are preferred to flat teeth. Twenty years' experience of trying to make satisfactory dentures encourages the conclusion that the security of a uniform intercuspal position is preferable to the aimless wandering of a mandible seeking support.

Faults and complaints

The complaints of denture failures are varied and often tragicomic. Some are attributed to psychoses (often induced by unsatisfactory dentures) but most are related to clinical, diagnosable faults. *Lack of stability* is one of the most common and this is attributable more often to failures of occlusion than to retention. Inability to chew is a not uncommon complaint in otherwise successful dentures. 'The dentures fit well and look fine, but I can't eat with them.' This can be due to incorrect OVD (increased or decreased) or to a failure to develop cusp–fossa occlusion. An improvement in the latter requirement has often proved successful in curing this complaint (*Fig.* 89). There are few stability problems that

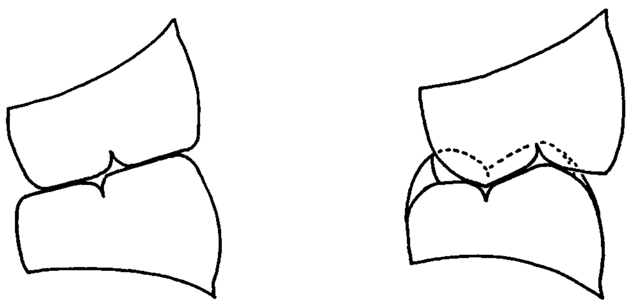


Fig. 89. Flat cusps and cusp–fossa contact.

will not respond well to occlusal adjustment following facebow transfer and a retruded arc precontact interocclusal accord. Conversely, there is seldom any improvement gained by relining such dentures without adjusting the occlusion.

Occlusal adjustment for complete dentures

Some procedural notes are now given on this topic and are advised as treatment for dentures with problems of stability. These are often manifest by sores on the residual ridges (which are not due to over-extension of the bases) in addition to complaints of looseness and inability to eat. If relining the bases is planned for reasons of poor retention the dentures should invariably be remounted and the occlusion adjusted since the alterations to the supporting (fitting) surfaces will usually increase the OVD and almost always alter the IP.

OBJECTIVES

I. To restore intercuspal occlusion of the dentures at the retruded horizontal and correct vertical position of mandible.

Registrations required

1. Facebow transfer of arbitrary retruded axis.
2. Precontact registration on retruded axis.
3. Confirmation of (2) by a check registration.

Procedure

1. Achieve equal contact on closure by deepening fossae: avoid reduction of cusp height if possible.

2. If premature contact is greater than half the width or height of one tooth, re-set the teeth.

3. On incisors and canines remove palatal surfaces of uppers. If incisal edges of lowers require shortening for speech or appearance, shorten lowers.

II. To produce balanced occlusion in the lateral and protrusive positions and free articulation between these contacts.

Registration required

Precontact registration with mandible in 6 mm. of protrusion. Adjust condyle guidance on articulator. Add 5° for lateral movement.

Procedure

1. In protrusive movements, relieve distal inclines of buccal upper cusp ridges, mesial inclines of lingual lower cusp ridges. Intercuspal position will be disturbed if lingual upper or buccal lower cusps or cusp ridges are removed. On labial segment remove lingual surface of upper teeth.

2. In lateral movements: on working side remove buccal upper or lingual lower cusp ridges (Bull rule); on balancing side remove lower buccal cusp, inner triangular ridge.

Intercuspal occlusion on the retruded arc

No doubt this will continue to be arguable as long as dentists make dentures. This occlusal position does involve effort and elderly patients will tend to find a more comfortable habitual position of closure forward of the retruded IP. Consequently, the compromise of providing free articulation between the retruded and habitual positions ('long centric') may be justifiable. On the other hand, if patients can be persuaded to close their teeth only when swallowing and avoid all other parafunctional contacts the retruded IP is advisable.

INEXPENSIVE COMPLETE DENTURES

The foregoing procedures involve time and therefore expense and will prove unrealistic for dentures which have to be made on a strict budget. As has been implied, more problems derive from failures of occlusion (stability) than of impressions (retention) and emphasis on the following features may prove helpful in low budget dentures.

1. The cost and correct use of a facebow adjustable articulator will soon be offset and rewarded if a large output of dentures is involved. A facebow record, with practice, takes 2 minutes on the patient in the chair and the same in the laboratory. The upper cast has to be secured to an articulator in any event.

2. The retruded arc interocclusal record can be achieved quickly with practice and a good patient rapport.

3. If wax bases are used for this registration the wax should be hard, when chilled, trimmed short of the proposed denture borders to reduce displacement. A fixative is advised to reduce displacement of the bases to a minimum when making the registration.

4. If wax occlusion rims are used they should be trimmed short of the OVD. For the registration plaster or a lower-fusing wax should be used.

5. Before jaw registration the proposed buccolingual position of the posterior teeth may be carved in the wax and the anterior teeth set up. However, the emphasis on the registration should not be diminished.

6. The bite fork of the facebow can then be inserted into the labial and buccal surfaces of the upper wax base.

7. In practices where the laboratory work has to be sent out there are difficulties of transporting the facebow and articulator. Even if the articulator can be kept with the technician it is valueless without a facebow. The dental assistant is, however, well able to perform the operation of mounting the casts. Somehow an understanding between dentist and technician on matters of occlusion must be established in these difficult circumstances.

8. If the plain-hinge articulator is used for complete dentures its limitations must be understood and more emphasis placed on the need to record the correct OVD when making the jaw relationship registration. The OVD should *not* be altered on this articulator.

Improvement of existing dentures

It is often more profitable to improve existing complete dentures than to embark on new ones. This is always advised when the tooth positions are correct. Extension of under-extended borders can be performed with compound additions which are later processed. This is preferred to the complete rebase because rebased dentures have to be remounted in any event. A retruded axis precontact registration and facebow record will provide the requirements necessary for remounting the dentures. Occlusal adjustment can then be carried out according to the foregoing notes. Any border additions made can be processed at the same time.

Occlusal adjustments carried out in the mouth will be described and discussed at the end of the section on partial dentures.

ONE COMPLETE DENTURE

Jaw registrations for one complete denture opposing an arch of natural teeth (or one including bridgework or partial denture) emphasize the problem of maintaining retention of the denture base while making the registration. They present the problem of obtaining an accurate, hard cast of the opposing teeth and the need to preserve their occlusal surfaces while developing the occlusion. The following procedures are suggested in an attempt to meet the difficulties which are often encountered.

Teeth preparation

The natural teeth should be inspected with a view to emphasizing the fossae and marginal ridges so that intercuspal occlusion can provide the features of tripod contact for the supporting cusps and overjet and overlap for the guiding cusps. This may require reshaping of old fillings or flat surfaces on pontic teeth. It need not be pointed out that once the impression has been made the teeth on the cast cannot be altered.

Impression and cast

Plaster is always reliable but seldom preferred. As one revered teacher (Silberhorn) at Northwestern University used to say: 'Plaster don't bend'. The difficulties of using plaster for this type of impression can be minimized by recording only the occlusal surfaces and by waxing out undercuts in case the plaster does reach into embrasures or under pontic teeth. Plaster will permit a low-fusing metal cast to be made which is preferable to the hardest stone. Alternative materials are well known and emphasis is placed on accurate retention within the tray of the alginate, reversible hydrocolloid or rubber. If a partial denture is worn it must be accurately seated when the impression is made. This presents the problem of movement not being recognized, especially if the material reaches beyond the denture border. It is therefore doubly desirable that the impression material does not reach beyond the greatest convexity of the teeth.

Base and occlusal rim

The permanent base should be used for the jaw registration for reasons given in the previous section and the occlusal rim should be made of hard compound. This can be trimmed and grooved to accept the registration material.

Jaw registration

The OVD is decided and registered into the compound softened on its occlusal surface. This surface is then cut away and grooved to a depth of 3–4 mm. with the exception of two stops. The relationship is re-registered using the same hand-holding method (p. 160) and the material of choice. The lightest contact into the softest material (with the quickest set) at the retruded position are the objectives. If the 'stops' do not show through the record the OVD will be slightly increased and the closure can be completed on the articulator provided a facebow transfer has been made. If more than the 'stops' show it is likely that the base has moved and the registration should be remade.

Setting the teeth

Care in achieving accurate occlusal relationships may require cast-metal occlusal surfaces for the posterior teeth. If this luxury cannot be afforded the choice of posterior teeth should be made on a basis of well-shaped cusps and fossae. It can be an advantage to process only two posterior teeth when first completing the denture in order to ensure accurate closure and function. The occlusion between first molars can be seen more accurately from the mesial aspect when the bicuspids are not present. They can be processed later. The articulation scheme will depend on what is permitted by the opposing teeth.

Remount

One complete denture almost always requires a remount. It is hoped that minimal adjustments are necessary since only the denture teeth can be adjusted. The registration is even more difficult when processed teeth are present since any contact between opposing teeth will result in movement of the base. Plaster is always preferable provided it sets quickly after contact with the teeth. With this material timing and an accurate knowledge of the setting time will minimize the time required to hold the dentures. A fixative for the base is permitted, even advised.

Comment

Whether the denture in question is upper or lower the difficulties are the same and can be overcome by the closest attention to details of jaw and tooth relationships.

IMMEDIATE COMPLETE DENTURES

The choice of intercuspal position when making immediate complete dentures lies between the existing IP (if opposing teeth are present) and the retruded IP. The existing IP may have been changed many times by adaptation as teeth have been extracted and the remaining teeth have moved and have lost their occlusal shapes. The patient may have learned to adapt gradually and comfortably enough to his diminishing dentition but the sudden change to a complete denture may make demands on his neuromuscular function of which it is not capable. It is advisable, therefore, to *return to the retruded IP*. This may require some rehabilitation of muscles which, in the elderly patient, may prove difficult. Instruction on pulling the jaw back when eating and closing and encouragement on the long-term advantages of having a stable position for swallowing will reward the co-operative patient. The retruded arc closure is there to be used and, once learned, will produce a comfortable occlusion, one which can be forgotten. However, dentists are often reluctant to take this risk and two shaky bicuspids are seen as an easy solution to the problem of jaw registration. This approach is often supplemented by reducing the number of teeth on the immediate dentures so that the tongue and cheeks can more easily adapt to the altered environment. This may provide comfort, if not efficiency, for many of these unfortunate patients whose declining dentitions have caused nothing short of misery for many years. This solution does imply that the immediate dentures are temporary and that permanent successors will be supplied when the mouth has fully healed. This presents further problems of adaptation and the case for *permanent immediate dentures* is pleaded, based on accurate jaw and tooth relationships and artificial tooth positions which copy their natural predecessors.

Permanent immediate dentures

Without attempting to describe the methods for making such dentures nor the surgical preparation of the mouth to receive them two principles are advocated.

1. *All but the incisor and canine teeth are removed* before making the dentures. The objectives are to remove posterior occlusion and to allow the buccal residual ridges to recover for the reception of permanent bases. This principle is extended to include the removal of the lower incisor teeth if the patient will tolerate this loss for a limited period. In this way the mandible and its musculature will be released from adaptive contacts and, if the patient is well instructed, they can learn retruded movements. If the patient has been wearing a partial lower denture replacing the posterior teeth this can be extended to a temporary complete denture but it should be worn as an adornment and only when necessary. The chief disadvantage here is the difficulty of replacing the lower incisor teeth in the position of their natural predecessors when the permanent denture is made. However, records can be made to provide guidance for this procedure.

2. *The registration of the mandibular IP is made on the retruded arc of closure*. This well-worn theme is worth repeating if only to prevent the problems that may arise from reproducing a potentially harmful IP. Many elderly patients want only carpet slippers for teeth; comfortable, loose-fitting, easily removable covers for their gums to be worn occasionally when eating and when their grandchildren come to tea. But even these, never-to-be-despised, dentures require

teeth in the neutral zone and an appearance which does not shock. If, in addition, they can have an occlusion which does not cause endless nibbling and lifting they can often be worn out of doors. In the making of immediate complete dentures this is worth remembering.

If these dentures are made on posterior residual ridges which are unlikely to undergo further change their anterior supporting (fitting) surfaces can be rebased following the post-surgical changes. This rebasing procedure does not cover the posterior supporting surfaces of the dentures and remounting should not be necessary. If spare dentures are required it is preferable to duplicate than to remake (Thomson, 1967).

The procedures for registration, mounting and developing occlusion for immediate dentures are no different from those already described. Impression and laboratory procedures have to be adapted to include the records and replacements of the existing teeth but the practice of occlusion is based on principles which, it is hoped, are well established.

PARTIAL DENTURES

The application of the principles of occlusion to partial dentures may be complicated by two factors, namely, a displaced IP of the existing natural teeth and the differing movements of natural and denture teeth during occlusal function. The IP of the mandible may be incorrect in terms of retruded arc closure and an occlusal analysis is always worth while in order to assess if it should be corrected. If allowed to persist the additional adaptive demands made by the denture on muscles, joints or teeth may lead to a disorder. On the other hand, the policy of letting well alone is always tempting and the decision on pretreatment occlusal adjustment is never easy but is worth consideration. The forces of occlusion acting jointly on the periodontia of the teeth and the mucosa of the residual ridges usually result in a greater displacement of the denture bases than of the natural teeth. This results in two potentially damaging forces. Firstly, the residual ridges may resorb in response to masticatory and parafunctional movements and will cause a change of supporting tissue outline, particularly in the buccal segments. This may result in a more prominent mylohyoid ridge and be a cause of denture sore in the lower arch. It will also predispose to a support problem if and when a complete lower denture has to be made. Secondly, there will be an added pull by the retainers (attached to the denture bases or metal framework) on the abutment teeth. This differing response of teeth and mucosa also makes for difficulties in the registration of jaw relationships.

Difficulties

In order to provide good occlusal function by partial dentures the following difficulties may be encountered and attempts should be made to overcome them before the final impressions are made:

1. The existing intercuspal position may be causing a disturbance and potential disorder. These include cusp interferences on closure to IP and during articular movements. If necessary, corrections should be made before making the denture.

2. Altered occlusal curve by exfoliation of unopposed teeth. A decision may have to be made to reduce the height of such teeth by occlusal adjustment or by crowning at a reduced level.

3. High caries incidence and periodontally disturbed abutment teeth. These may have to be crowned and splinted to sound adjacent teeth. This treatment may also apply to teeth whose occlusal surfaces have been worn and are required for improved function.

4. Differing responses of mucosa and teeth in the registration of jaw relationships.

5. Method of making the jaw registration and the materials used in order to obviate (4).

6. Laboratory errors. Most of these can be resolved by correct design of the denture and its return to casts mounted on an adjustable articulator.

In order to assess and deal with these difficulties before the dentures are made an analysis and treatment plan should be carried out.

Analysis and treatment plan

Analysis prior to partial dentures should be comprehensive (Chapter 9) and a planning session with the technician essential. X-rays and hand-held casts should be available for decisions on corrections to the occlusal curve, the acceptance (or not) of the habitual IP and articulation, the removal or treatment of any doubtful teeth (especially those selected as abutments), the type of teeth to be used which will provide the best function with the opposing natural teeth, and the method to be used in transferring the jaw relationships. In addition, the technician will want to discuss the design of any cast framework which may be required, and the preparation of any teeth for occlusal rests and retention areas. The plan may therefore call for extractions, root canal and periodontal therapy, inlays and crowns, splinting of teeth, occlusal adjustment and a further consultation with the patient if any of these radical measures are advised. Bicuspids are not satisfactory abutment teeth and consideration should be given to extracting those with inadequate bone support or to splinting two bicuspids by soldered crowns. With the exception of the canine an abutment tooth for a partial denture should have two roots and this can be achieved by two bicuspids joined together. If occlusal adjustment is advised in order to correct a potentially harmful intercuspal position of the mandible a retruded arc mounting of models on an adjustable articulator will be necessary.

Procedures

Before the final impressions are made, the jaw relationships registered, and the teeth set (the last two of which are the subject of this text), the following procedures are carried out if required by the treatment plan: extractions, root canal and periodontal therapy, preparation of the abutment teeth including crowns splinted to adjacent teeth (as for lower bicuspids), and occlusal adjustment if required (*see* Chapter 12).

IP JAW REGISTRATION

The IP having been determined by the existing teeth, it is recommended that the registration be made with the existing teeth lightly touching in this position. A facebow transfer of the upper cast to an adjustable articulator is followed by a choice of three methods for mounting the lower to the upper cast.

1. *Hand placement* of the lower cast against the upper provided that there is a triangle of contact between teeth of opposing arches. The requirement is that the angles inside the triangular tripod be as close as possible to 60°. This will

provide a stable equilateral triangle of contacts with little chance of the casts tipping. Opposing molar–central–molar would be stable while canine–canine–bicuspid would not. All plaster bubbles must be removed and a reminder about the problems arising from the two phases of contact (p. 69) is given.

2. *Trial bases*. Fast-cure acrylic bases (joined preferably by a lingual bar connector) with compound occlusal rims are advised especially where there are free-ending saddles. The rim is reduced by 3–4 mm. from contact in IP and the registration made using the material best suited to the dentist, while the existing opposing natural teeth maintain light contact. The material should have the properties, previously mentioned, of minimal viscosity, rapid set and minimal dimensional change after setting. The bases must not move during the registration and must fit the mouth as accurately as the cast. The use of the casting seated on the teeth for this registration is not advised since the casting is seldom fully seated at this stage nor is it comfortable (exception: *see* (3)).

In making the registration care should be taken to ensure that the lightest contact is made between the registration material and the opposing natural teeth and simultaneously with the natural tooth contact (*Fig.* 90*b*). If this contact is made before that of the opposing natural teeth, especially if softened wax is being used, setting of the wax may take place before the teeth meet. This will result in the mounted casts being further apart on the articulator than the opposing arches are in the mouth. An increased OVD ('high bite') will be the result. Alternatively, and if wax is used, the force of closure may induce strains in the wax which will cause it to expand on removal from the mouth with the same result. It may not be enough for the technician to ensure that the plaster teeth engage the wax at the same time as the opposing plaster teeth since the base will not move on the plaster residual ridge as it does in the mouth. It is a complex problem. The use of plaster or zinc-oxide–eugenol paste will help to solve this aspect of the problem but both these materials take time to set when movements of the jaw or base can take place and inaccuracy on the articulator result. An alternative method of registration is that of pre-natural tooth contact in the mouth. The completion of closure is made on the articulator. Accuracy of this closure will depend on the facebow transfer producing the same closure on the articulator as occurred in the mouth.

The converse of this problem is the registration made with the material barely in contact or where the base has been raised, either by the dentist's fingers or the patient's tongue. The effect of this error on the mounted casts will be to bring them closer together than in the mouth. The completed denture teeth will then be short of occlusion in the mouth. Neither of these inaccuracies can be seen on the finished denture even if mounted on the articulator and the technicians should not be blamed.

Another situation which can cause inaccuracy in registration is that of opposing free-end saddles (*Fig.* 90*c*). The chief difficulty is that of ensuring contact between the trial bases and the residual ridges while the registration is being made. A fixative is advised and careful holding of opposing bases as illustrated for complete dentures (p. 160) is advised. These problems are made more difficult where there are only natural teeth opposing artificial teeth in dentures being made for both arches (*Fig.* 90*a*). Jaw registrations have then to be made as for complete dentures with the added difficulty of natural teeth dislodging the occlusal rims. Several attempts should be made to ensure even contact between the teeth and opposing compound rims of the correct

OVD. The rims are reduced in height to allow for the registration material but keeping one tooth in contact with the rim on each buccal segment to act as a stop. After registration, the contact areas should be inspected to ensure even penetration and contact by the 'stop' teeth.

3. *Casting and base only*. An alternative method where a casting is being used is for the patient to wear the casting with the final processed base added (but

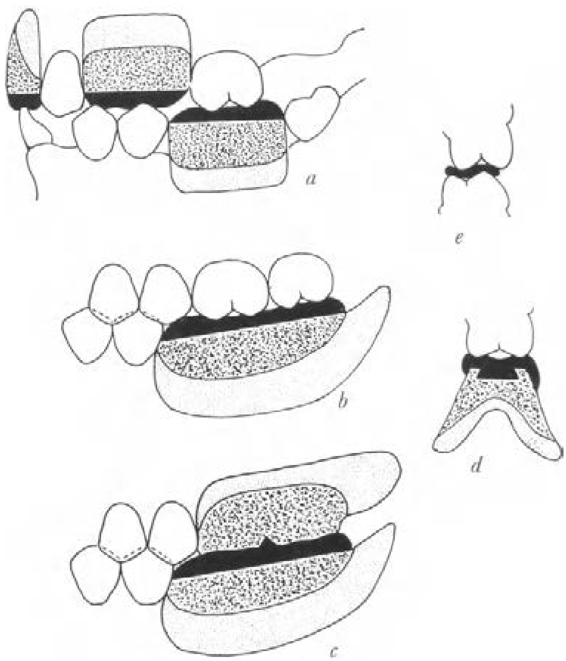


Fig. 90. Jaw registration for partial dentures. *a*, No opposing teeth. Pre-register position on anterior stop if possible. *b*, Natural teeth opposing base. *c*, Two free-end saddles. *d*, Undercut occlusal rim to carry plaster. *e*, Warning: if register pre-contact use face-bow transfer.

not the posterior teeth) for a few days. This will permit the casting fully to seat itself on the teeth after which the registration can be made as in the previous section but using the casting and processed base. Alternatively, immediate fast-cure plastic has been successfully used for securing teeth to the base in the mouth while the patient maintains light contact in IP.

PROTRUSIVE REGISTRATION

The registration of protrusive and lateral positions now follows if an articulation scheme is planned. This will be determined by the incisal guidance and articulation scheme of the existing natural incisor and canine teeth. If these teeth are being replaced articulator adjustment to the positional records is made as for complete dentures.

SETTING THE TEETH

The factors involved are *tooth positions*, the *number of teeth* to be used, *the shape and material* of the occlusal surfaces, the development of the *occlusion and articulation*, and the *return to the articulator* after processing in order to assess and correct any previous errors.

1. *Tooth positions* will usually be determined by adjacent and opposing teeth but it may be helpful, in case of doubt, to place soft, easily displaced, wax on the base at the try-in stage. A few swallows will displace the wax until the position determined by equal and opposite muscle force is achieved.

2. *The number of teeth* should be minimal compatible with adequate function and the prevention of any drift of opposing teeth. The patient may complain at this thrift but he can be assured of additional teeth if necessary and if requested.

3. *Plastic will wear more quickly than porcelain* but a decision on this choice can be reversed if one type proves unsatisfactory. If there is a difficult occlusal relationship to resolve the waxing and casting of a thin gold occlusal surface can be made and processed to the denture. The principle of tripod contact between well-shaped supporting cusps with adequate overjet and overlap by the guiding cusps applies. The *articulation* of the teeth will be determined by the requirements of the standing teeth.

4. *Processing errors.* The return of the processed denture to the master cast mounted on the articulator is always advisable. Processing errors in occlusion can be seen and adjusted and the dentist cannot blame the technician for 'high' or 'low' bite. It should be possible to estimate the cause of occlusal errors more easily when processing errors can be excluded.

Stress breakers

The use of these appliances is arguable since the displacement of the saddle on closure is determined by a hinge which does not necessarily conform to the direction of force caused by the opposing teeth. None the less, they may provide a useful method of distributing the forces of occlusion between the base and the connector or framework, depending on the design used. Tooth positions on the affected base may have to be altered from time to time as the base moves or the supporting residual ridge resorbs.

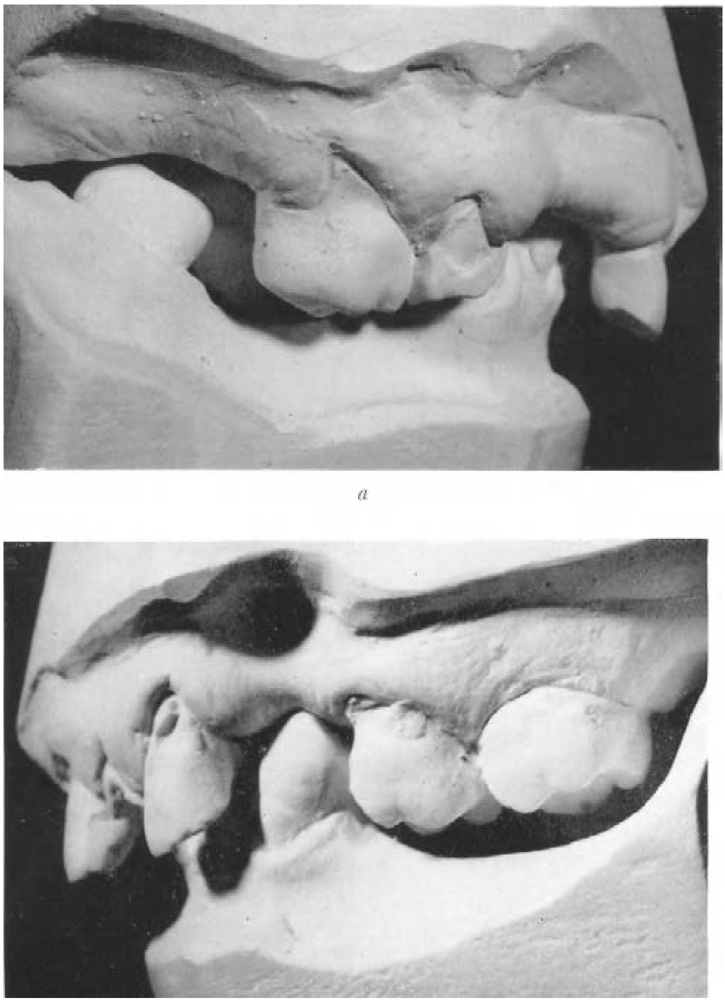
Rebase or new teeth

If the teeth on a saddle are seen to be separating from their opponents on closure and the patient complains of a 'lack of support' the decision to increase either the height of the teeth or the thickness of the base has to be made. If resorption of the ridge has obviously taken place the indication is for rebase. But this should be accompanied by remounting the denture and readjusting the occlusion. If wear of the teeth is the cause remounting is recommended and new teeth added. A change of teeth will make adjustments easier and will be more acceptable to the patient than a new base.

The inexpensive partial denture

As with complete dentures, not every patient can afford these time-consuming procedures and castings, and many dentures without clasps have proved comfortable and functional. Many partial dentures succeed by restoring appearance or by providing a space filler and support for the tongue, but good occlusal relations and tooth positions will help to maintain the low budget denture.

An extension of this theme is the question of the need for a partial denture in the first place. In view of the number of dentures which are worn in the top drawer this is a question which should receive an answer. The replacement of upper molar teeth when only the lower first molars are present is one of many such debatable questions. Lack of support by posterior teeth and the possible effects on the muscles and joints will indicate the need for replacements. On the other hand, many dentitions provide adequate function without this support. The variable factors which may help this decision are the presence of *free-end saddles* and the admission of *parafunctional habits* both of which will prejudice

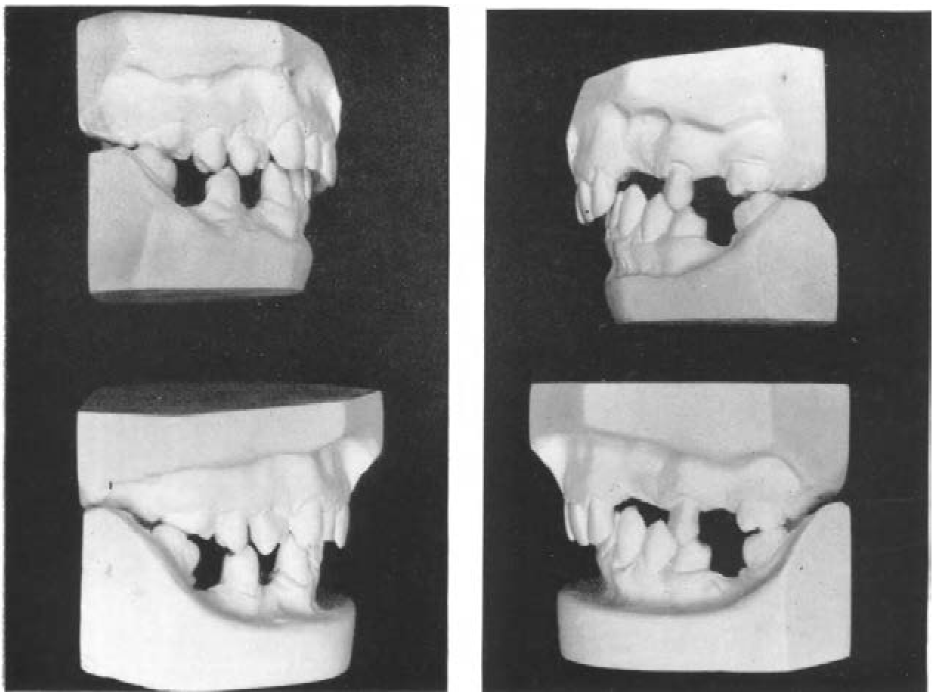


a

b

Fig. 91. Overclosure overlooked. Treatment necessary. *a*, Right side. *b*, Left side.

the success of partial dentures. Front teeth must be replaced and certain functionless teeth restored to function sooner rather than later (*Fig.* 91). If existing isolated teeth are stable and functional, if potential abutment teeth are unstable, and if the patient has neither functional nor appearance complaints then Punch's celebrated advice to those contemplating marriage may not be out of place: 'If in doubt, don't' (*Fig.* 92). The genuine need of the patient remains the justification.



a *b*

Fig. 92. Missing teeth not missed. *a*, Study casts of mouth made at an interval of 11 years. Right side. *Above*, 1962; *Below*, 1973. *b*, Left side. *Above*, 1962; *Below*, 1973.

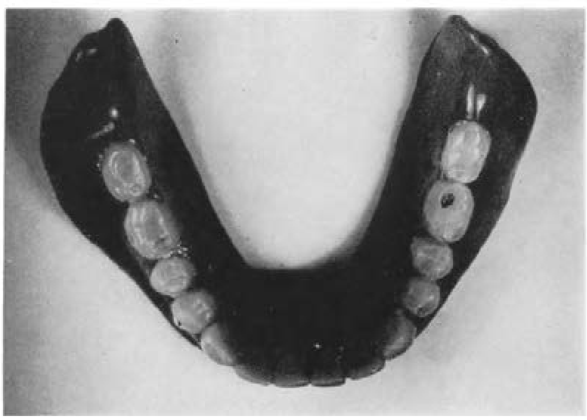
Empirical occlusal adjustment

Many if not most postinsertion occlusal adjustments for both partial and complete dentures are performed on a trial-and-error basis in the mouth. This can prove successful if done with the objective of maintaining cusp–fossa contact at IP. The flattening of cusps and fossae leads to loss of certainty in finding a comfortable occlusion and to adverse forces being directed on the residual ridges and abutment teeth. These forces cause bruising of the mucosa which is often wrongly diagnosed as being caused by overextension of the denture base or by processing errors in the denture bases. The chief difficulty in making occlusal adjustments in the mouth is that of being able to hold the dentures in position while placing the articulating paper between the teeth. The method generally recommended is to hold both upper and lower dentures with the left forefinger and thumb between the posterior segments and so allow the right hand to place the articulating paper. However, this does not leave a hand free to guide the patient on the required arc of closure. If this is necessary, either the assistant can be trained to place the articulating paper or remounting is advised. Disclosing paste may reveal an area of heavy contact on the supporting surface which is confirmed by a bruise on the mucosa and a premature contact on the denture (*Fig.* 93).

Occlusal adjustments in the mouth require the certainty of stable bases and the assurance that the correct jaw closure is being used. Articulating paper should be thin and cut into strips the length and breadth of the posterior segment being tested. Alternatively, typewriting ribbon can be used. Three colours are advised: one for IP, one for working side contacts and the third for balancing contacts. Premature contacts in IP will penetrate the paper and leave a clear punched-out mark on the teeth. Sliding contacts leave a blurred mark. The fossa mark should be removed leaving the supporting cusp untouched. The triangular ridge in the fossa should retain its ridged surface if

a

b



c

Fig. 93. *a*, Bruise on mucosa as result of premature contact. *b*, Confirmed by displacement of disclosing paste. *c*, Associated penetrating contact of articulating paper.

possible and tripod contact is thus maintained. Lateral and protrusive articular movements may then be adjusted using the incoming movements, if possible, since these correspond more closely to the functional pathways used. These will be blurred marks.

Comment

Good occlusal function in partial and complete dentures is a service that will cure many complaints. It will reduce to a minimum the persistent nibbling activities which are often caused by cusp interferences and which, in turn, cause pain and loss of stability. Good occlusal function reduces parafunction and allows occlusion to be minimal and therefore optimal.

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Chapter 12

Occlusal adjustment of the natural teeth

THE objectives in restorative or corrective measures concerned with the occlusion of the teeth are to provide even contact in IP, equal bilateral contact on retruded closure (usually on one molar tooth on each side), and to prevent cusp interferences during mastication and empty-mouth articular movements. These objectives will help to provide efficient and comfortable occlusal function and to make patients unaware of their teeth.

Cusp interferences in the natural dentition are defined as contacts between opposing teeth which interfere with the established closing or chewing movements of the mandible and with bilateral contact on the retruded axis. They can cause disturbances to occlusal function. Cusp interferences can take place during mastication, swallowing and empty-mouth parafunction. They can be corrected by occlusal adjustment. This is a procedure which occupies a controversial place in the treatment of occlusal dysfunction because it is irreversible. It often forms part of the treatment plan prior to the making of partial dentures or bridgework and it is a recognized procedure in the treatment of the mandibular dysfunction syndrome where displacing activities of the mandible have been diagnosed. Much occlusal adjustment of the natural dentition is carried out empirically and this can be helpful in reducing supra-contacts on fillings and forces on mobile or periodontally infected teeth provided certain principles are observed. On the other hand, disorders of the masticatory system can be caused by the indiscriminate removal or reduction of cusps in the emergency treatment of some of these conditions.

Occlusal adjustment is defined as a planned removal of selected occlusal areas of the teeth in order to restore good occlusal function. Its objectives are to provide a stable intercuspal position of the mandible and to remove interferences to and from IP in functional and parafunctional movements. The older term, 'selective grinding', is more realistic but this is the age of the euphemism. It cannot be too strongly emphasized that these procedures are irreversible and no amount of secondary dentine will restore a lost occlusal shape.

Indications

1. The mandibular dysfunction syndrome (MDS) where there is a lateral deflexion to IP from retruded occlusion.

2. Preparatory treatment for fixed and removable prostheses where displacing activities on closure have been diagnosed.

3. Postorthodontic treatment in adults, with limited application for adolescents.

4. Postperiodontal treatment.
5. Improvement of appearance of incisor and canine teeth.
6. As part of a plan in the treatment of mobility and migration.
7. As emergency treatment of tooth extrusion following periodontal abscess or of injury to opposing mucosa in cases of overclosure.

It will be noted that the first four require a plan for the development of stable IP and free articulation and that the remainder are localized measures.

Contra-indications

1. Severe overclosure and displacement except as part of the prosthetic plan.
2. On sensitive, worn and adolescent teeth, with some exceptions for the last.
3. Patients who are preoccupied with their teeth and for whom the mouth and teeth have become an outlet for irrelevant muscle activity.

Plan

As with all procedures in the treatment of occlusal disturbances a plan is essential and this should be based on an analysis of habitual and retruded occlusion in the mouth and on stone plaster casts transferred to an adjustable articulator. A retruded condyle axis transfer for the upper cast is used and a precontact interocclusal record on the retruded arc to mount the lower cast in relation to the upper. This is necessary in order to assess the extent to which tooth positions have moved away from the reproducible path determined by the muscles. It is recommended that this mounting be checked by the split-cast method outlined on p. 186. The existing retruded contact, habitual IP and canine guidance can then be assessed.

The retruded occlusion in the patient should now be compared with the retruded occlusion on the articulator and the decision made either to develop intercuspal occlusion on the retruded arc or to restore bilateral retruded occlusion with a forward glide to habitual IP freed from interferences. The plan should also include removal of articular interferences to and from IP. It can be argued that all patients should be endowed with such an improved occlusal scheme as a preventive measure against the MDS or harmful forces on the periodontal tissues. Without symptoms or obvious signs of disorder these measures should be undertaken with great circumspection. The spectre of iatrogenic disturbances should be clearly seen.

Adjustments on casts

The removal of tooth surfaces is now carried out on the stone plaster teeth with a sharp knife. These adjustments are noted in order of cutting and the occlusion checked after each cut. This is continued until the plan for adjustment has been completed. These adjustments will be subsequently carried out in the mouth but several objectives and cautions are suggested.

1. Develop bilateral retruded occlusion and permit a forward glide to habitual IP without interferences.
2. Prevention of gliding to IP is indicated in MDS cases where the lateral pterygoid muscles are painful or tender and it is decided that stretching of these muscles in IP is desirable. However, this may not be possible without reconstruction of some of the occlusal surfaces.
3. Remove cusp interferences in lateral and protrusive articular movements to and from IP.

4. Provide group contact between upper and lower incisors on protrusion.

5. Remove all balancing side-contacts as a preventive against potentially harmful tilting contacts during function or parafunction.

6. Develop occlusal contacts as closely as possible to the long axes of the roots in the posterior teeth.

7. Avoid occlusion on ridge inclines which may cause tooth reposition. In other words, develop tripod contact between supporting cusps and opposing fossae. Where this is not possible make the fossa flat so as to make the tips of supporting cusps contact at right-angles to a flat surface.

8. Avoid loss of OVD.

9. Reduce the effects of the plunger cusp without disturbing intercuspal occlusion.

10. Avoid cross-tooth and cross-arch balance as a preventive against parafunctional habits.

11. Retain or restore the essential shapes of cusps and ridges.

It will be noted that these objectives do not include any of the articulation schemes suggested as requirements for reconstruction of the natural dentition or for complete dentures. There should be minimal alteration to the existing articulation scheme in the natural dentition.

Adjustment on the teeth

It is now necessary to trim the teeth as determined by the cuts made on the plaster teeth. Before proceeding with these adjustments the mandible should be trained to open and close on the retruded arc without the help of the dentist. And, before this training is instituted, the dentist must be satisfied that the masticatory muscles are free from stiffness and pain and that the mandible can move on its retruded axis without joint noises. The patient is made to *feel* the mandible moving on its retruded axis. This can be achieved in many ways. Gentle force on the lower incisor teeth by the operator's thumb or forefinger as the patient is advised to 'Open and close on to my fingernail' (*see Fig.* 67, p. 158). A tongue spatula can then be provided and the patient is asked to close on to it and to 'Pull the chin back as far as possible'. Other instructions can include 'Push the chin forward, hold it there, and then pull it right back' or 'Push the upper teeth forward'. It is important that the teeth do not touch during these movements so that the patient concentrates on the retruded axis (hinge) closure and not on the teeth touching. Once the movement has been practised and can be repeated, the patient is allowed to withdraw the spatula and to 'close with the same movement and stop when the teeth touch'. This should be the retruded occlusal position (or occlusion on the RCA). On being asked to 'Close all your teeth' the articular movement to IP can then be seen and it should copy the same movement on the articulator.

Trimming procedures should begin only when the patient can repeat this movement on request.

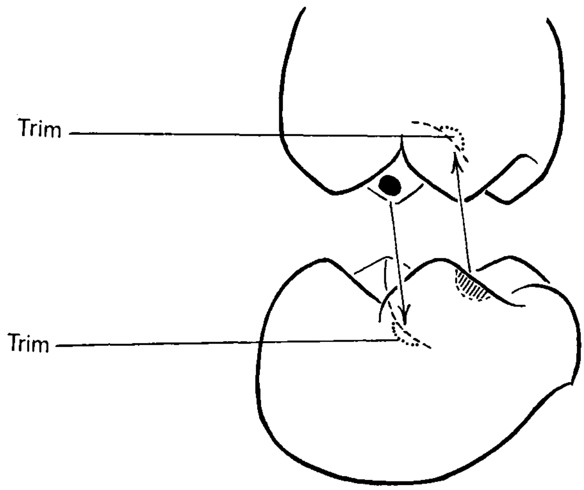
Procedures

FOR INTERFERENCES TO RETRUDED OCCLUSION

Schuyler's (1935) functional principle provides the first guidance for trimming; if a cusp does not make premature contact in lateral and protrusive articulation trim the fossa opposing the cusp. If it does make contact in these movements trim the cusp.

It is rare that a cusp has to be reshaped for this reason in the natural dentition but if it is necessary trim around the cusp tip, reducing it gradually, and so maintain its shape. It is difficult to provide tripod or even perpendicular contact between a flat cusp and opposing fossa.

The fossae. Trim the involved inclines facing the fossae (the triangular or oblique ridges) so as to provide a tripod seating, where possible, for the supporting cusps (buccal lower, lingual upper). Trim the mesial facing inner inclines of the upper fossa ridges or distal facing inner inclines of the lower. If the converse the mandible will move forwards (*Fig.* 94).



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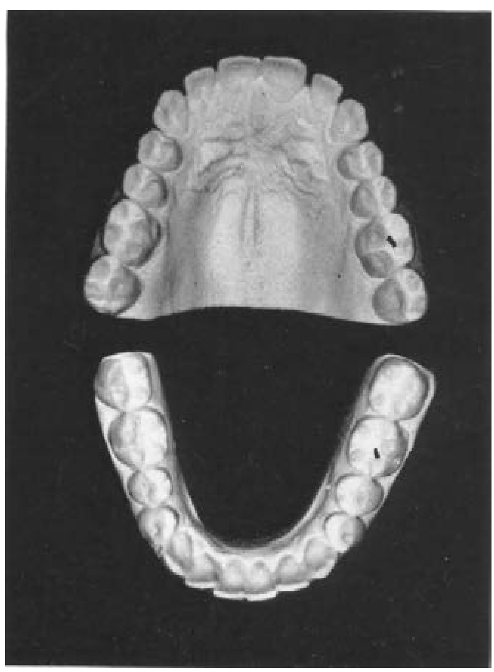

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Fig. 94. Occlusal adjustment in the fossa to provide a more retruded IP. Mesial upper or distal lower. *a*, Diagram. MU or DL. *b*, Casts. MU or DL.

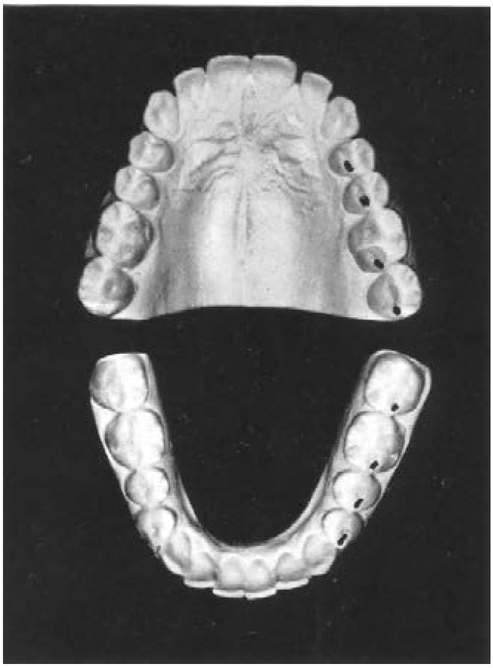


Fig. 95. For interference to retruded occlusion on marginal ridges, trim opposing mesial lower distal upper.

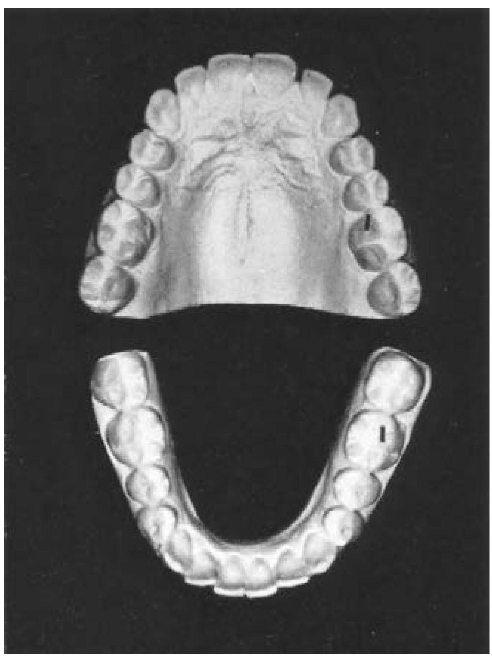
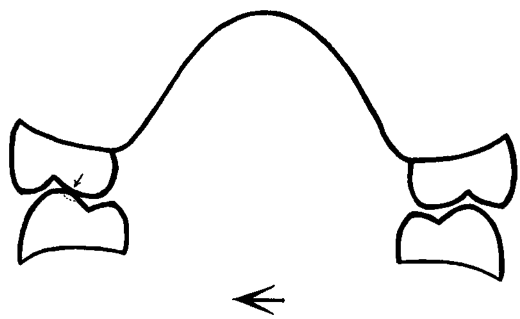


Fig. 96. To prevent forward glide to IP, trim mesial upper and distal lower supporting cusp ridges. MU DL. Same principle as in *Fig.* 94.

Marginal ridge areas. The buccal cusps of the lower bicuspids and mesiobuccal cusps of the lower molars occlude in the upper marginal ridge areas. Similarly the lingual cusps of the upper bicuspids and the distolingual cusps of the upper molars occlude in the opposing lower marginal ridge areas. Rather than disturb the marginal ridges the *mesial facing lower supporting cusp ridges* may be trimmed,



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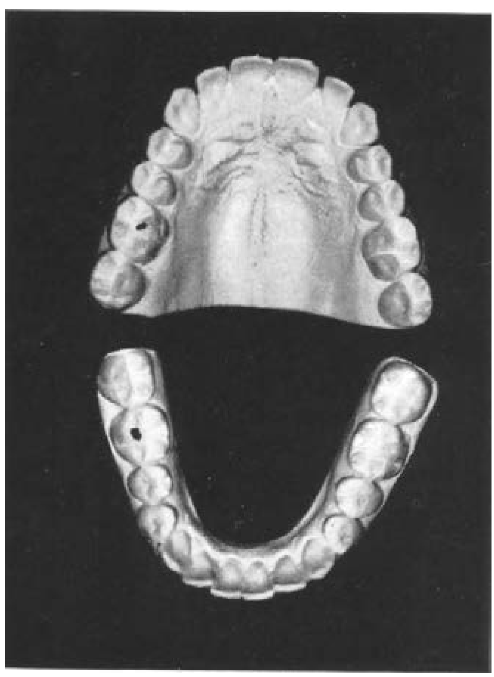

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Fig. 97. Occlusal adjustment to correct lateral displacement on side to which mandible moves. Distal inner of lingual upper or mesial inner of buccal lower. *a*, Diagram. Trim MI of BL. *b*, Casts. DI of LU or MI of BL.

if necessary, or the *distal facing upper supporting cusp ridges* (*Fig.* 95). The supporting cusp tips may extend buccally (or lingually) beyond the marginal ridges into the embrasure areas and may make premature contact in retruded closure (Ramfjord and Ash, 1966). These may be reduced slightly in height and while this may permit a slide into habitual IP the interference will have been removed, and it is hoped that other intercuspal contacts will maintain the retruded IP.

Food channels for food disposal should be ground on the lingual end of the upper marginal ridges and the buccal end of the lower to avoid the plunger cusp action.

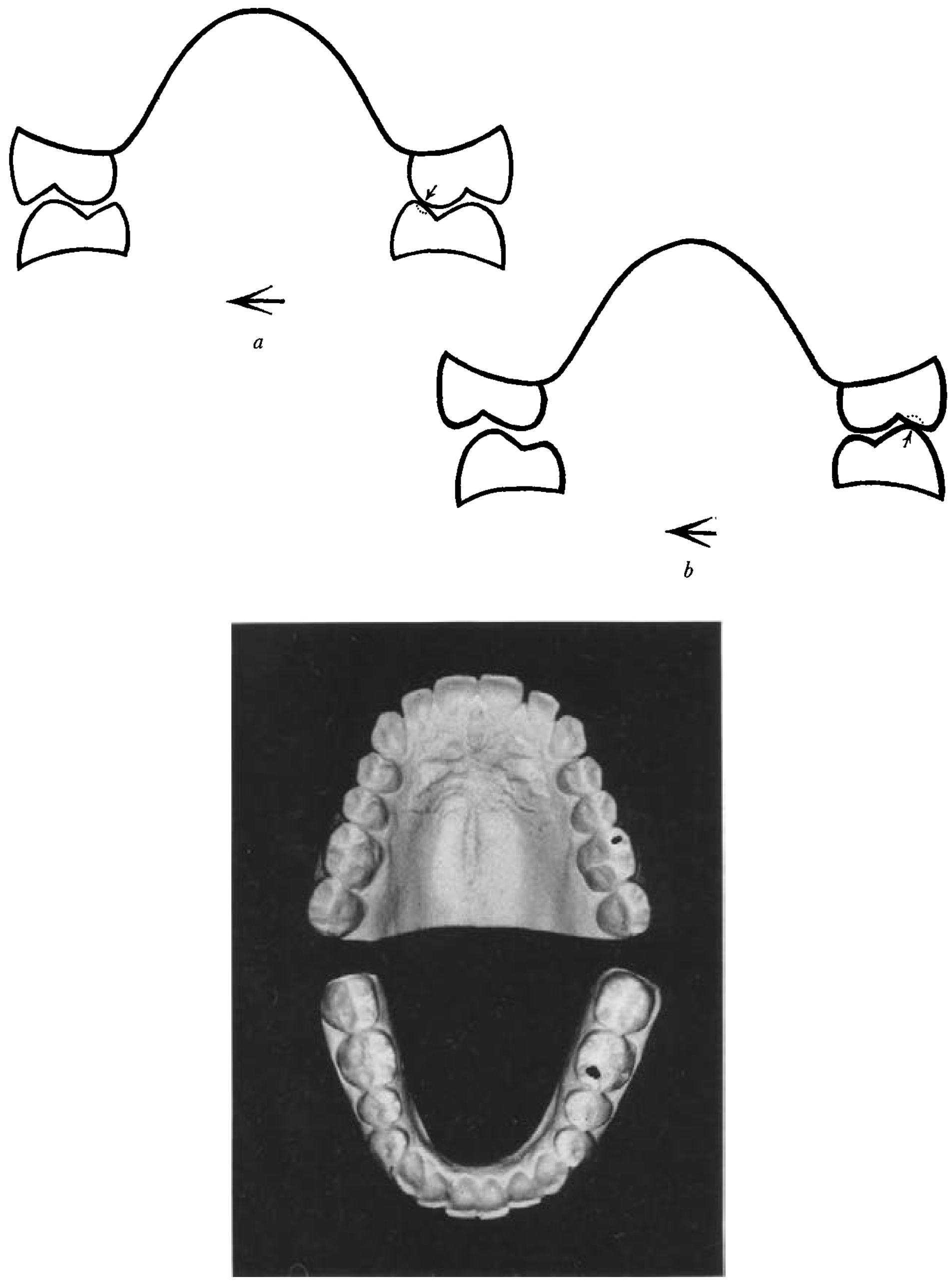

Fig. 98. Occlusal adjustment to correct lateral displacement on side from which mandible moves. Buccal upper or lingual lower. *a*, Diagram. LL. *b*, Diagram. BU. *c*, Casts. BU or LL.

FOR INTERFERENCES WHICH PRODUCE A FORWARD GLIDE INTO HABITUAL IP

These may have to be reduced when the IP has to be repositioned more distally or to a retruded IP. Here, trim the *mesial inclines of the upper cusp ridges* involved and the *distal inclines of the lower cusp ridges*. Thus: MU DL (*Fig.* 96). This will have the effect of moving the upper cusps distally and the lower cusps mesially. The cusp ridges will then permit a more distal IP.

FOR INTERFERENCES WHICH PRODUCE A LATERAL GLIDE INTO HABITUAL IP

This is the correction which can prove most helpful in the MDS.

1. The side to which the mandible slides is trimmed on the *balancing inclines*, namely, the *mesial inner inclines of the buccal lower cusps* or the *distal inner inclines of the lingual upper cusps*. Thus: MI of BL or DI of LU. Trimming is done diagonally to conform to the balancing movement of the lower cusps (*Fig.* 97). This occurs when an initial contact on one side results in a glide to that side.

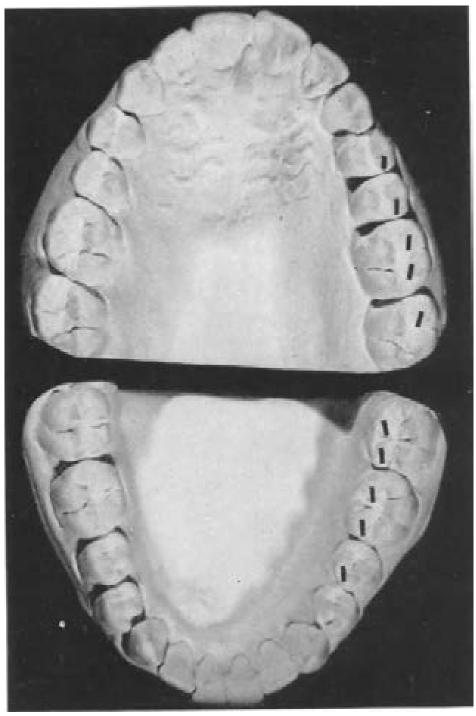

Fig. 99. To reduce interferences in working side articulation, trim buccal upper, lingual lower (BU LL).

2. The side from which the glide takes place is trimmed on the *inner inclines of the buccal upper* and *lingual lower cusps* (*Fig.* 98). However, the buccal surfaces of the lower buccal cusps can be trimmed in this situation.

FOR INTERFERENCES IN WORKING AND PROTRUSIVE ARTICULATION

Warning: do not reduce the supporting cusps or the IP will be reduced for that tooth.

1. On the working side in lateral articulation: trim the *buccal upper* or *lower lingual* cusp ridges (*Fig.* 99). Thus: BU LL. In the upper: trim the distal cusp ridges on the inner surfaces. In the lower: trim the mesial cusp ridges on the inner surfaces.

2. For protrusion: as for lateral articulation.

3. Incisors and canines in all articulations: where interferences have to be removed the *lingual surfaces of the uppers* should be trimmed in order to avoid loss of contact in IP. The incisal edges may be trimmed to provide group contact on protruded occlusion.

FOR INTERFERENCES ON THE BALANCING SIDE IN LATERAL ARTICULATION

These occur between the buccal lower and lingual upper supporting cusps and great care has to be taken to avoid loss of contact in IP. However, as it is the inner facing triangular ridges which are involved it is generally possible to make the trimming without removing the tips of the cusps. Trimming is performed on the *mesial facing inner inclines* of the *buccal lower triangular ridges* or on the *distal inner inclines* of the *lingual upper triangular ridges*. This will be a diagonal trimming following the path of the opposing inner-facing cusp ridge (as in *Fig.* 97).

Emphasis is laid on the need for adherence to order for noting each tooth surface trimmed on the casts and for following this order in the mouth. Short cuts always seem possible but they can lead to complaints of 'loss of support for that tooth', or 'I was never aware of my teeth before' or 'and now my front teeth keep clashing'. Suicidal feelings have been reported 'since my teeth were ground'. These treatment procedures, therefore, should be approached with caution.

Articulating paper

Thin waxed paper or typewriter ribbon is used for trimming the casts and each noted cut is checked in the mouth with the articulating paper before trimming the tooth. The successful use of paper or ribbon depends on the following requirements: the paper or ribbon should be thin and cut to the length and width of the quadrant being examined; it should be held in place with tweezers while the patient closes 'with the jaw pulled back'; the teeth should be dried to prevent smearing of the marks; there should only be one mark provided there is one cusp interference; the paper will be punctured and the hole should be visible if the paper is held up to the light; if ribbon is used it will not be punctured.

There will usually be marks on both opposing teeth where firm contact has been made. If paper is used (with wax on both sides) the sharper tooth surface (cusp, cusp ridge or triangular ridge) will show a well-defined spot. The flatter opposing surface will show a ring. If ribbon is used there will be spots on both opposing tooth surfaces. The teeth should be cleaned after each contact before proceeding to the next registration. This will remove any blurred marks on adjacent teeth caused by the paper or ribbon rubbing against the teeth. Wet tooth surfaces will also tend to leave blurred marks. The principle of trimming one contact at a time will reduce the need for different colours of paper or ribbon but the use of three colours mentioned in the previous chapter will maintain the discipline of emphasizing the difference between IP, working and balancing interferences.

Instruments

Stones and rubber polishing wheels used are illustrated in *Fig.* 100 and water cooling is always advised. The tapered fissure stone (diamond or carborundum) in a slow-running handpiece is the tool of choice for trimming the triangular ridges and the knife-edge stone for carving fissures, reshaping marginal ridges and deepening fossae. For incisor and canine trimming vulco-carborundum or

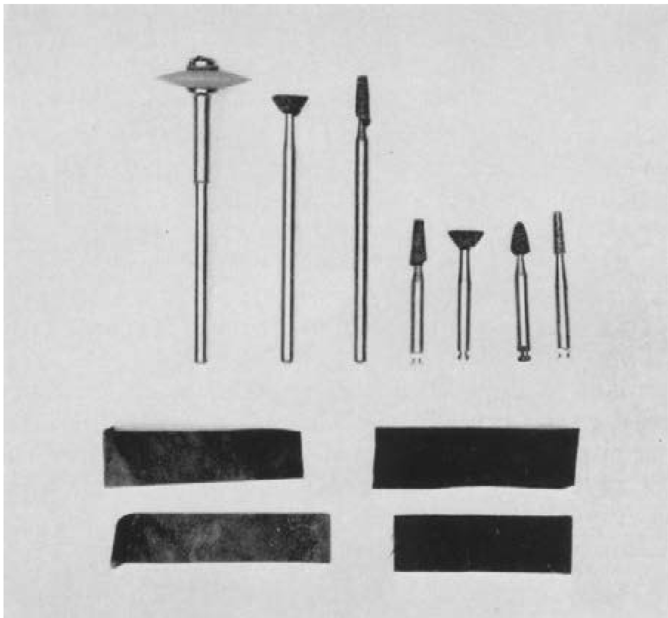

Fig. 100. Instruments, articulating paper and ribbon.

sandpaper discs are used. Polishing is done with rubber discs and polishing paste. Carborundum 'chew-in' paste gives an overall finish but it can be argued that if all surfaces are ground the OVD may be reduced. This claim may be exaggerated but is worth consideration.

The foregoing principles, objectives and methods represent the orthodox teaching on occlusal adjustment and derive originally from Schuyler (1935) and later developed by Lauritzen (1951), Beyron (1954), Jankelson (1960) and Ramjford and Ash (1966) and many other proponents of occlusal equilibration. In the hands of painstaking dentists they represent a method of promoting good occlusal function where the need is genuine. Principles and objectives must precede the dental stone. Otherwise the first case encountered may be a 'cross-bite' or a Class II with missing teeth. Distortions will follow a haphazard or rule-of-thumb approach.

Methods more simple

The plea for simplicity and speed should always be heard and there are careful and comprehensive outlines in the literature which make this form of treatment seem more simple, particularly where it is desirable to retain the habitual IP. Silverman (1962) and Ross (1970) in books with the title *Occlusion* perform the procedures in the mouth, using good diagnostic methods and Glickman in his textbook (1972) has a simple classification of tooth surfaces to be trimmed with particular reference to the treatment of periodontal lesions. Shore (1952) uses an 'auto-positioner' which is an upper appliance designed to increase the OVD minimally and leaves the mandible free to find its own horizontal position. After wearing the appliance for a few days, the OVD is gradually reduced until the teeth make contact whereupon the premature contacts are trimmed as they appear. For the graduate student and practitioner these texts will repay study before embarking on the practice of equilibration by occlusal adjustment.

Jankelson (1960) attempts to identify cusp interferences to IP by using the tap-tap technique or a stretch and relax method of adopting retruded closure. Cusp interferences are revealed by means of a specialized occlusal wax which reveals light contacts as perforations (*Fig.* 68, p. 159). These are subsequently marked on the teeth with a wax pencil and trimmed with stones. Singer (1966) uses a 'chewing detector' for covering the teeth, which reveals parafunctional contacts. The detector takes the form of a varnish and the teeth have to be specially treated before application. The patient is limited to a liquid diet until the next visit. It is used, therefore, for examining tooth contacts between meals and overnight. Occlusal adjustment at the chairside follows.

Localized occlusal adjustment

There are several disturbances and disorders which can be adjusted directly in the mouth without recourse to mounted casts, although a clear objective and awareness of potential harm are always necessary. These conditions are: mobility and migration, extrusion following periodontal abscess, extrusion of incisors in mandibular overclosure causing ulceration of opposing mucosa, extrusion of the unopposed last molar tooth, appearance defects on anterior teeth and supra-contacts on recent restorations.

Mobility and migration are treated (*see* Chapter 13) according to a plan. Careful but minimal removal of the occlusal force is usually necessary at the outset to relieve the aggravating factor in these conditions.

Periodontal abscess can be relieved of its pain by removing the occlusal force. On the assumption that the tooth is going to be successfully treated adjustment should be performed with a view to future cusp–fossa relationship. Where possible the fossa should be reduced.

Overclosed incisors should be minimally reduced in order to relieve the injury being caused. This can only be a temporary measure since the affected teeth will continue to erupt and be repositioned. A treatment plan should be made to stabilize such teeth and correct the OVD if necessary (p. 236).

The unopposed last molar is a common cause of displacing activity and the MDS, and its extraction is usually advised. Immediate treatment is to remove the deflecting surface of the extruded tooth (*see Fig.* 59*d*, *e*, p. 130).

Appearance defects of incisor and canine teeth (upper and lower) can often be improved by small adjustments to their incisal edges. Caution is advised to prevent over-shortening which may disturb lip posture and cause speech defects. The patient should be warned of the dangers which also include reducing removal of unsupported enamel in large Class III fillings and penetration of the dentine. Better to accept a small improvement than to regret an irreplaceable loss.

Supra-contacts on crowns and fillings should be reduced with a view to maintaining cusp–fossa relationships. The temptation to reduce a supporting cusp should be resisted. Loss of support following such 'treatment' has been seen to cause the frustrations of reduced function and undoubted joint–facial pain. Occlusal adjustment of amalgam fillings can include the development of triangular and marginal ridges which will help to develop tripod contact, relieve interferences and improve function.

Comment

As has been said, this form of treatment is irreversible and the effects of it, incorrectly applied, can lead to disorders of muscle activity, undue awareness of the teeth and hypersensitivity of the dental pulps. These effects can be prevented by correct diagnosis, a plan based on an objective clearly visualized and a procedure carefully performed. Short cuts and indiscriminate or inspirational removal of occlusal surfaces are to be avoided. Occlusal adjustment following orthodontic treatment is prescribed cautiously and not until retainers have been worn for a prescribed length of time. In adolescents the greatest care should obviously be taken. Following periodontal therapy, the development of habitual IP is usually the objective together with freedom from interferences in functional and parafunctional excursions. In protrusion group contact between incisors is a preventive measure against uneven forces being directed against healing tissues. Occlusal adjustment is yet another example of the need for co-operation between specialties in both hospital and general practice.

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Chapter 13

The treatment of disturbances and disorders

THE decision to treat disturbances before they become disorders is not an easy one to make. Many mouths, particularly in middle age, show signs of secondary malocclusion and the effects vary widely between healthy adaptation and breakdown of the dentition. Mobility and migration of the teeth are often arrested by stable repositioning. Parafunction and attrition of the occlusal surfaces can sometimes be controlled by stern warnings to, and co-operation by, the patient. Cusp interferences and displacing activities can result in adaptation by healthy muscles unaffected by parafunction. Mandibular overclosure is often normal in many Class II patients especially if there is no loss of teeth. Knowledge of the tissues and their behaviour, experience, and an awareness of the need for treatment may provide a better basis for treatment than ability, enthusiasm and optimism, to say nothing of the power of persuasion by patient or dentist. On the other hand, disorders represent a pathological response to disturbances and when the patient complains of pain in the teeth or face, when teeth are drifting and the periodontia is diseased, when gums are being ulcerated by opposing teeth or food stagnation the time has come to treat.

Treatment for the following disorders will be discussed and described:

Mandibular overclosure.
The mandibular dysfunction syndrome (MDS).
Progressive wear of the occlusal surfaces.
Mobility and migration.
Pulp necrosis.
Gingival ulceration from food stagnation.
Developmental anomalies.

MANDIBULAR OVERCLOSURE

Treatment of mandibular overclosure has to be based on an accurate assessment of the occlusal vertical dimension in relation to rest position and the disorders which may be caused by it (p. 139). The cautionary conclusion made by Bergström (1950) to his study on the reproduction of the dental articulation is worth quoting: 'We do not know if and to what degree we can prevail upon joints and muscles to adapt themselves to new central positions, heights of bites and movements, but everyone probably agrees that our possibilities in this respect are very limited.' None the less, there are occasions when it is necessary to restore rather than to raise, to correct rather than to open the occlusal vertical dimension. Thus the terms 'raising the bite' and 'bite raising appliance (BRA!)'

are discounted since they suggest an indiscriminate alteration rather than a planned restoration.

Plan

The plan will be based on an analysis and diagnosis of the signs, symptoms, rest position and interocclusal distance of the masticatory system. Preliminary treatment should include minimal removal of injurious incisor contacts on opposing mucosa, rehabilitation of painful muscles (*see* next section), the institution of good hygiene, and decisions to deal with problems of mobile teeth and altered occlusal curves. A decision will have to be made on the use of fixed restorations or removable appliances for the permanent restoration of the OVD. A bite guard temporarily to restore the OVD is always recommended. The patient should be advised that the muscles will have to adapt to changes of chewing level and that this may not be easy for him. However, if the planned OVD is correct the change will prove comfortable and more efficient.

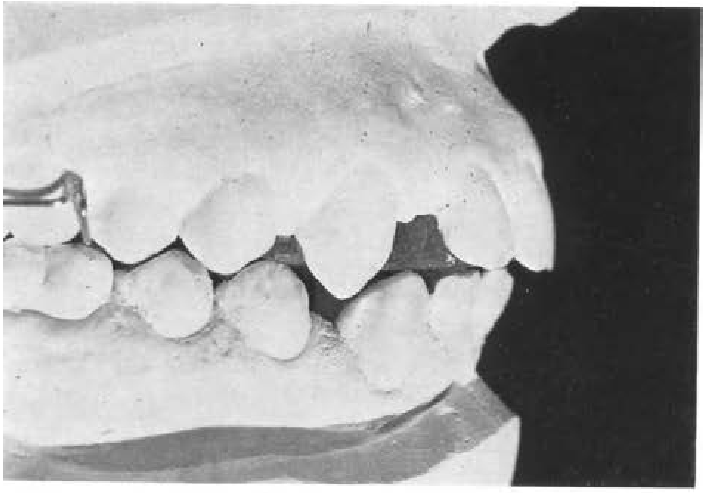
FIXED RESTORATIONS OR REMOVABLE APPLIANCES

This decision is usually easy to make since the decision to restore lost OVD cannot be so assured as to risk the costly and irreversible crown and bridge-work required. Even if the patient resists the idea of wearing a removable appliance he should be prevailed upon to wear one as an interim measure in case the alteration is not, in the event, tolerated. A removable appliance for this purpose will cover the supporting cusps of the teeth and can be called an onlay denture, and metal is preferred to plastic for reasons which will be explained. However, a temporary plastic appliance is advised as a primary measure and this takes the form of a bite guard. Fixed restorations can follow if the need and the demand are justified.

The bite guard

This is the term given to an acrylic resin appliance which covers the upper incisor and canine teeth only and is retained by Adams's cribs on two posterior teeth, preferably molars, one on each side. A bite plane is made behind the upper incisors and canines to engage the tips of the lower incisors and canines and should be flat in order to allow the mandible free movement in the horizontal plane. Where the bite guard is being used only to assess tolerance of the muscles the incisor teeth need not be covered. Where incisor parafunction is being prevented or porcelain crowns protected, the incisors and canines should be covered. This assumes that the overlap and overjet will permit it. Casts of the upper and lower arches are made and the upper cast is transferred to an adjustable articulator with a facebow record. The lower cast is mounted to the lower member of the articulator with the teeth in the existing intercuspal occlusion. The vertical dimension is increased to the estimated correct level by raising the incisal pin. The appliance is formed in wax and processed in acrylic resin. It is supplied to the patient for wear at all times possible during the day and night (*Fig.* 101).

Speech and mastication will obviously be difficult but the patient should be advised that it is a trial appliance and that the objective is to discover the most comfortable level for the teeth to meet. Adjustments in level can be made either by removal from the bite plane or by additions to it in fast-cure acrylic.



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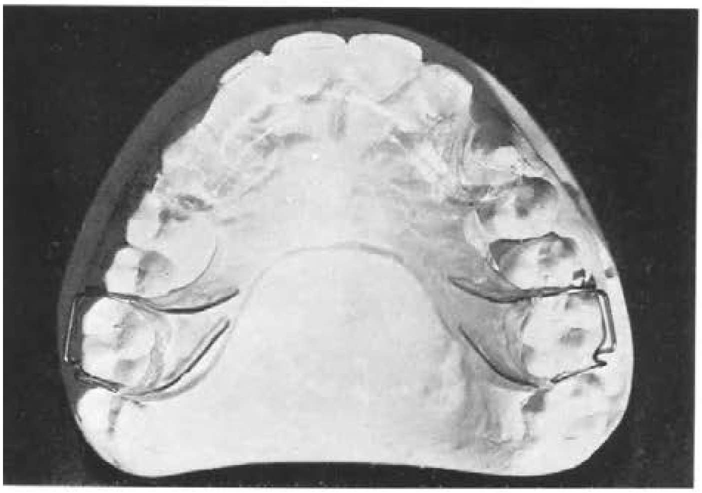

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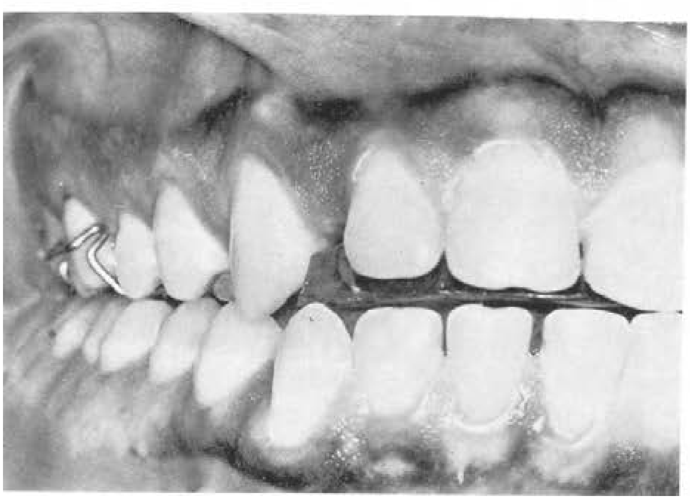

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Fig. 101. The bite guard. *a*, Processed appliance on mounted cast. *b*, Appliance on cast with bite plane behind incisor and canine teeth and avoiding gingival margins where possible. *c*, In place.

The flat plane should be maintained, however, in order that the most comfortable horizontal position can also be determined by the patient. In this respect the patient is advised that the most efficient horizontal position for the teeth in closure is with the mandible as far back as possible and to practise this posture as often as possible, thus attempting to have the patient open and close on the retruded axis. The bite guard is used for this reason in treatment of the mandibular dysfunction syndrome where it provides rehabilitation for the muscles.

COMMENTS

It will be noted that the mounting of the lower cast was made at the existing IP and that no wax record was used, thus possibly transferring a displaced mandibular position. The flat bite plane, however, permits the mandible to adopt its own horizontal position.

The bite guard will remove all occlusal stimuli which may have been causing displacing activities and any consequent hyperactivity of the muscles. It will therefore provide a cure for any muscle pain caused by this activity and confirm the diagnosis of the dysfunction syndrome. It can thus be called a *diagnostic bite guard.*

The bite guard will also provide an inhibition to any clenching or grinding habits, particularly during sleep. The symptom of jaw stiffness on waking usually subsides if the appliance is worn conscientiously while asleep. The condition of click is often reduced after wearing this appliance thus suggesting that the overclosed or altered IP has been causative.

The disclusion of the posterior teeth by the bite guard allowing the muscle force of mandibular closure to be directed on the lower incisors and canines will tend to depress these teeth rather than cause the posteriors to erupt. This is difficult to measure or prove and the statement is made on a basis of experience and on the assumption that it is more likely for teeth to depress under force than to erupt through lack of it.

Why not a posterior bite guard? Many acrylic resin bite guards are made to cover the posterior teeth. Since the posterior teeth are going to be covered in the eventual treatment why not use the principle as a temporary measure? The answer lies in the importance of allowing the mandible to find its correct horizontal relationship to the maxilla. This can be found only with the bite guard already described. It is used as a diagnostic appliance. Posterior bite guards are clumsy and tend to fix the teeth in one occlusal position. Even if they have flat surfaces and permit lateral gliding the posterior teeth are not freed from contact and mandibular activity is often increased.

The permanent appliance (the onlay denture)

This should not be delayed for more than a month for reasons made in the comment regarding depression or raising of the teeth. It now becomes necessary to cover one or other of the arches in order to restore intercuspal occlusion at a level determined by the bite guard. Two principles of design are advised:

1. The coverage of the posterior teeth should be limited to the supporting cusps thus reducing the possibilities for food stagnation and subsequent decalcification (*Fig.* 102).

2. All teeth should be restored to function to prevent unequal depression and eruption between posterior and anterior teeth. Thus, if the lower arch is

chosen the incisors and canines should either be covered or the appliance should have support arms (mesial and distal rests) on these teeth. An exception to this principle is the assurance that the anterior teeth will make gliding contacts with each other or with the food bolus in function. Tongue posture may be helpful in this respect. Another exception is an edge-to-edge incisor occlusion with lack of development of the posterior dento-alveolar tissues. In such a

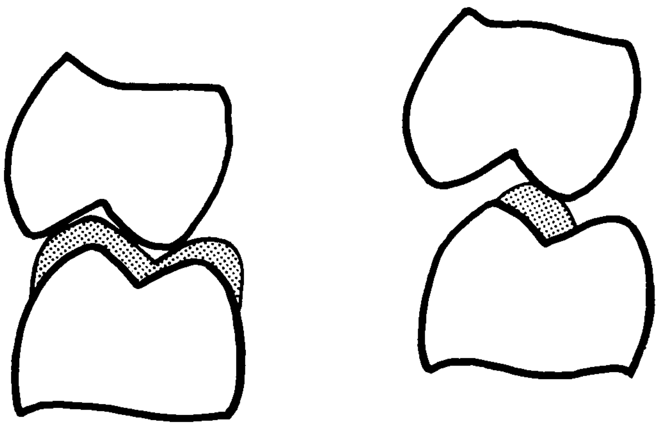


Fig. 102. Diagram. Onlay denture. *a*, Incorrect. *b*, Coverage limited to supporting cusps.

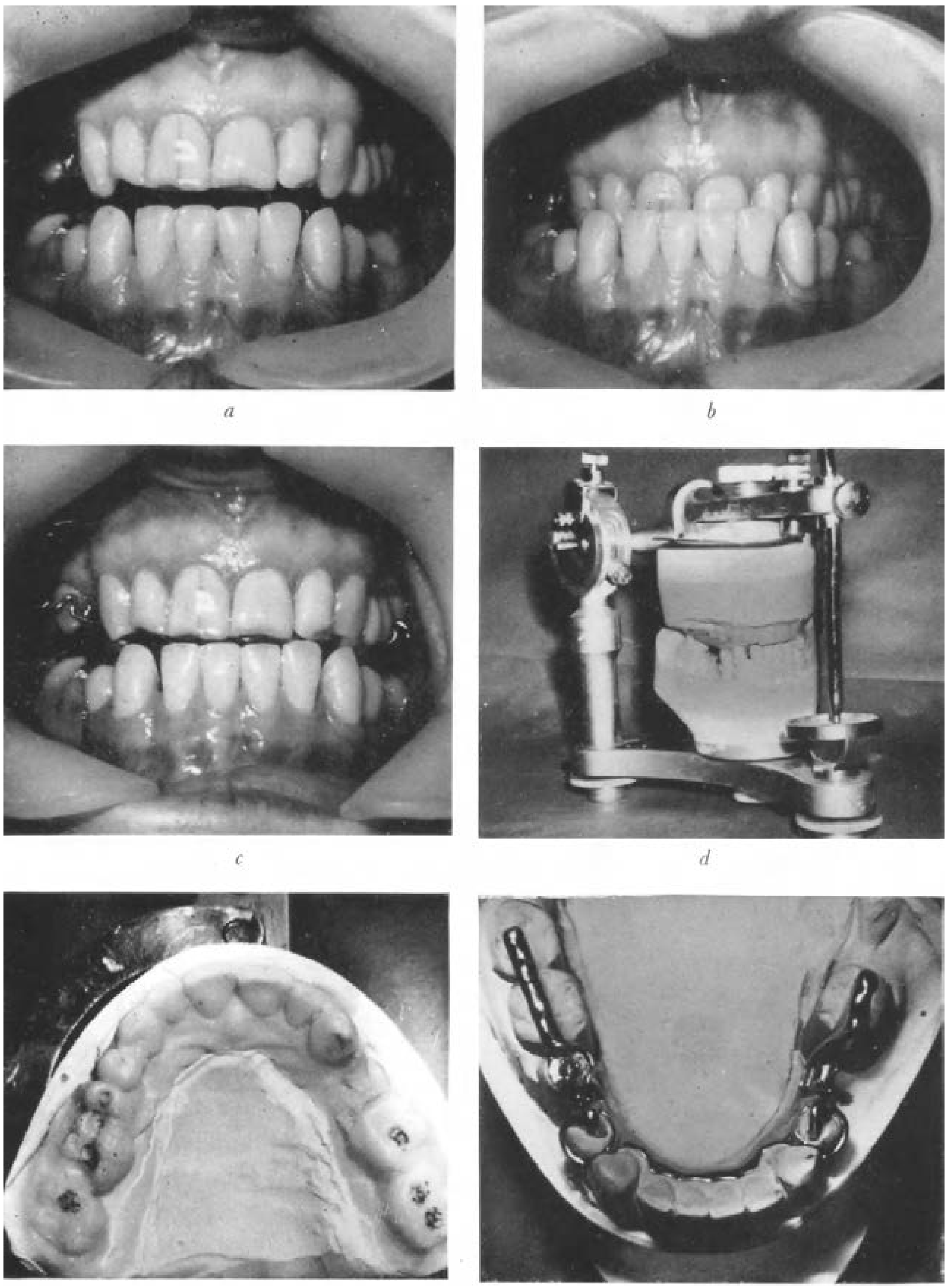
patient there is usually a forwards and upwards displacing activity to IP (pseudo-Class III) and the onlay denture serves to restore the posterior occlusion at the level determined by the anterior occlusion (*Fig.* 103).

CHOICE OF ARCH

This is usually determined by the site and number of missing teeth. Overclosure is usually associated with missing lower teeth and narrowing of the lower arch with consequent overclosure. In such a case the lower arch is chosen. Patients usually adapt more easily to lower onlay dentures and the factor may be gravity. However, the problem of the free standing lower anterior teeth mentioned above remains and has to be solved without disturbing the appearance of the lower teeth. If the upper arch is chosen this problem is solved by incorporating a bite plane behind the incisor teeth. Two appliances should be avoided and individual circumstances will determine the choice.

REGISTRATION AND TRANSFER

Accurate casts of the arches should be available before these records are made so that they can be fitted on the casts and mounted at once. An arbitrary face-bow transfer is made for mounting the upper cast. The actual retruded axis is not required since the vertical level of closure will be determined by the bite guard as will the horizontal position of the mandible. An adjustable articulator is necessary, however, in order to introduce freedom from interferences in protrusive and lateral movements. The interocclusal registration is made with the bite guard in place and with the anterior lower teeth lightly in contact with the bite plane. The mandible should be withdrawn backwards as far as is comfortably possible. The registration material should have the requirements of low viscosity, rapid set and dimensional stability on removal. Two or three thicknesses of wax, depending on the space between the upper and lower segments, is still the medium of choice. Two rectangular blocks, one on each side, are placed on the lower segments while the cheeks are retracted by the assistant. The patient is asked to close on the back teeth on the arc previously practised. This method has the occasional disadvantage of seeing the wax blocks topple as the jaw closes. Quick-setting stone plaster may be preferred or a wafer of wax crossing the arch held against the upper teeth by the left forefinger and



a *b* *c* *d* *e* *f*

g

Fig. 103. Mandibular overclosure with anterior displacement. *a*, Rest position. *b*, Overclosure at IP. *c*, Bite guard. *d*, Mounted casts (upper made in acrylic resin). *e*, Marks for contact of opposing supporting cusps. *f*, Metal onlay denture. *g*, Denture in place at restored OVD.

thumb (*see Fig.* 71, p. 166). The resultant record should be transferred to the lower cast as quickly as possible and the mounting completed. A protrusive positional record will allow the condyle adjustment to be made.

WAXING

This is directed at making contact between the supporting cusps of the segments being restored (buccal lower or lingual upper where a normal overjet exists) and the opposing central fossae. These areas on the opposing teeth should be marked by the dentist (*Fig.* 103*e*) and the technician advised to build the wax up in cones to contact these areas with a tripod of contact on the triangular ridges forming the central fossae if this is feasible. The practice of closing the opposing teeth on to a mound of soft wax and carving away the excess should be avoided. This will make the supporting cusps of the onlay denture an exact fit of the opposing fossae or ridges. This fixes the intercuspal occlusion too rigidly and tends to prevent free articular movements. The tripod contact with cusp tip free of contact provides a stable IP and presents a smooth occlusal surface for the avoidance of interfering articular movements.

Other requirements in the design of the onlay denture are emphasized:

1. Limitation of coverage to the supporting cusps already mentioned.
2. Adequate retention arms extending from the onlays.
3. A rigid connector bar to join the two onlay segments.
4. Coverage or mesiodistal rests on the anterior teeth.
5. Sandblasting of the onlay segments so that any premature contacts in function can be readily seen. This procedure will also reduce the shine of the appliance and make it less conspicuous.

The lower onlay denture is illustrated in *Fig.* 103 where it has proved successful in curing MDS pain (3 years). An upper appliance to engage the lower incisors is illustrated in *Fig.* 104, where ulceration of the mucosa was combined with overclosure. A lower onlay appliance was also necessary. These were worn for 12 years when periodontal breakdown prevailed.

CHOICE OF METAL

The gold and chrome-cobalt alloys are the current alternatives. The widespread use and success of the chrome-cobalt alloys is impressive but the installation costs of the necessary equipment are high. The gold alloys have qualities which make them even more suitable for onlay dentures. Their surface hardness is less than in chrome cobalt and less likely to cause wear on the opposing teeth

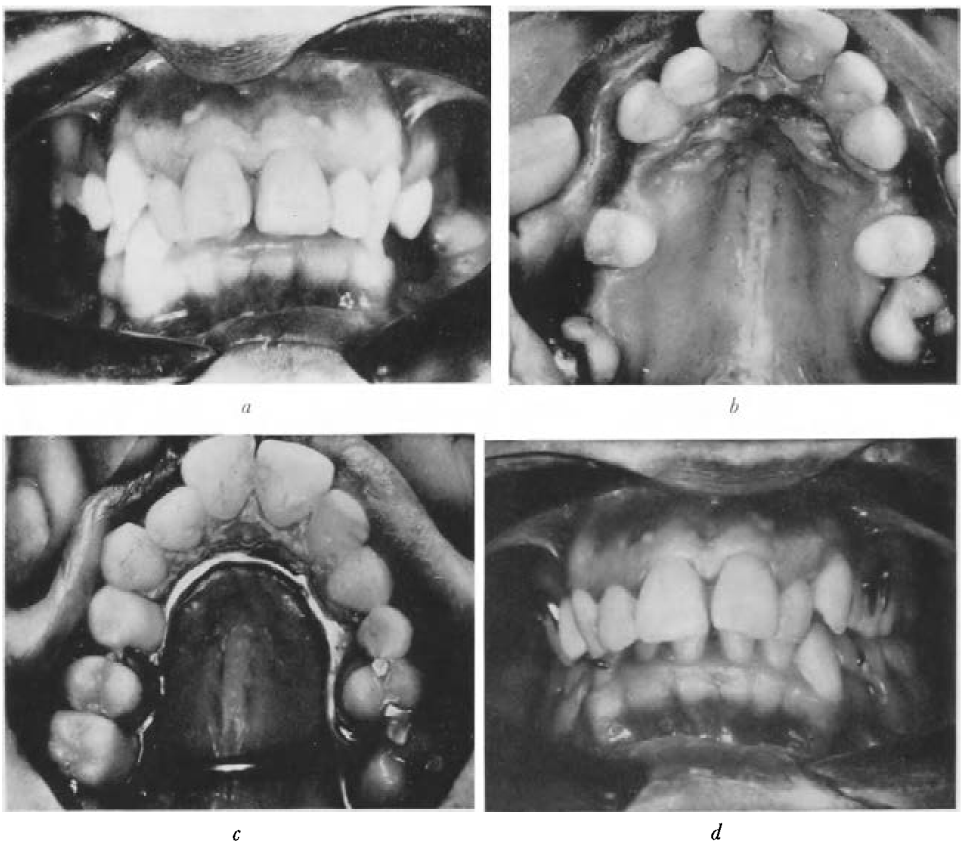


Fig. 104. Mandibular overclosure with ulceration of upper mucosa. *a*, IP. *b*, Ulcerated mucosa. *c*, Upper denture with bar to engage lower incisors. *d*, Upper and lower (onlay) dentures in place with mandible in corrected IP.

although the control of clenching and grinding will reduce this as a factor. For laboratories not equipped with the chrome-cobalt equipment gold is still a worthy material and its added cost has to be measured against the cost of equipment and the work of the technician which transcends both these factors.

Why not plastic? Acrylic resin has provided many onlay dentures but, whereas they are easily made and adjusted, they wear and break and cannot be considered permanent. Also, for purposes of strength, they have to be made to cover the whole occlusal surface of each tooth. This not only promotes greater food stagnation but is more bulky than desirable. One use of plastic, however, is as a pattern prior to casting in metal. The onlay surfaces can be made in resin according to the principles laid down for waxing and joined temporarily by the connector eventually to be incorporated in the denture. The denture can then be worn in the mouth for a short period and the occlusal surfaces adjusted. The appliance is subsequently cast and soldered to the connector. Care should be taken to ensure that the resin used will not leave a residue when burnt out prior to casting.

INSTRUCTIONS TO PATIENTS

There are three instructions which apply to all wearers of dental appliances:

1. Simultaneous bilateral mastication on the posterior quadrants. 'Chew with the chin back and equally on both sides at once.'

2. Avoidance of parafunctional contacts and movements. 'Keep the teeth parted except when eating. The teeth should touch only when swallowing.' 'Try not to fiddle with the appliance.'

3. Strict hygiene before and after meals. 'It is good prevention to eat with clean teeth.' Explain film (or plaque). 'Clean the teeth and appliance after meals.' This may be too strict a discipline for many patients but the opportunities to encourage preventive hygiene should never be missed. Nowhere does it apply more stringently than when wearing removable onlay appliances.

THE MANDIBULAR DYSFUNCTION SYNDROME (MDS)

The symptoms, clinical features and suggested pathology of this syndrome have been described and discussed in Chapter 8. Treatment is based on a combination of muscle rehabilitation and restorative procedures to promote good occlusal function where this is considered necessary.

Consultation

This was described in Chapter 9 and in the Glossary an itemized form of examination is presented. There will seldom be difficulty in discovering the complaint in patients with pain or a noisy joint since they may have been referred for treatment from their doctor or dentist. However, this may not be so and while the harmful effects of suggestion are well known an open question such as 'Are your mouth and jaw comfortable?' may reveal a disorder which the patient had not realized might be a dental problem. The questionnaire for these patients should be extended to include a more precise description of the pain and its site, when it happens, and how long the effect, when it began and how, and the association of any stiffness of the jaw on waking. The possibilities of any chronic infective or degenerative conditions should be excluded and the patient referred to his doctor if there is any doubt. In the case of joint click questions should include the degree of opening when the click occurs, if there is any associated pain and, most important, if it can be avoided and how. Emotional stress and the parafunctional habits, the effect of cold or damp weather, and the association of any minor illnesses should be included with a view to reassuring the patient that these factors could be causative and are treatable. A good rapport with the patient is essential since the first stage in treatment is enlightened reassurance. Consequently, the patient must have confidence that this is possible.

Examination, analysis and diagnosis

Some of the inquiries made in Chapter 9 are repeated for purposes of continuity with the treatment measures to be outlined. The teeth are examined for causes of unilateral function and displacing activities. Recent treatment measures are questioned together with incidence of any injury or exaggerated activity of the mandible.

X-rays of both joints (with the mandible open and closed) will be helpful to reassure both patient and dentist that nothing serious is wrong, and a radiologist's report is desirable. Any suspicion of bony disturbances (or fractures) will require referral. Observations from the radiologist may suggest a reduction in joint space and limitation of movement as factors which may require correction, but usually the report is 'normal joint space'.

Analysis of the occlusion, articulation and facets of wear may reveal disturbances which will require treatment. The path of closure from rest position to IP and the retruded arc closure are examined for displacements to habitual IP. Palpation of the tender areas which are almost always unilateral is made and these include the origins of the lateral pterygoid muscles inside the mouth (the pterygoid sign) as well as the areas around the condyle. The ramus and submental areas are also palpated for masseter and digastric tenderness. The most common site of tenderness is immediately in front of the condyle (insertion of lateral pterygoid) and this, together with deviation to the affected side, generally confirms the diagnosis. Synovitis and rheumatoid arthritis may have to be excluded but they are generally bilateral. Other conditions for differential diagnosis include osteoarthritis, trigeminal neuralgia, migraine, pain of dental origin, sinus disturbances and pain of central origin. Impressions and a facebow record are then made for diagnostic as well as for treatment purposes.

Treatment

Treatment begins at the consultation with the establishment of rapport and confidence. As Newton (1969) points out, the success of these treatment measures may be attributable as much to the association with a sympathetic dentist as to the physical measures employed. A preliminary diagnosis can usually be made during the first visit and the following treatment measures are prescribed.

EXPLANATION AND REASSURANCE

On the basis of a preliminary diagnosis of muscle dysfunction, the explanation of 'aching muscles' can be given with the assurance that even if there are pathological problems the muscles will always be involved. The admission of unilateral chewing by the patient permits the analogy of 'chewing with a limp' to be used. Clenching or grinding habits suggest the explanation that abuse of muscles leads to fatigue or injury of the muscles themselves. This type of explanation is also justified to explain 'click' where an occlusal alteration or abuse of muscle function has led to an alteration of the condyle position on closure. On opening the mouth the condyle then moves on a different path. The ridge on the top of the condyle momentarily jams against the tissue (it can forgivably be called 'cartilage') between the bones of jaw and skull. Sometimes it becomes stuck and 'your jaw gets fixed'. On this basis the patient can justifiably be reassured and instructions given to rehabilitate the muscles.

MUSCLE REHABILITATION

This takes three forms: instructions for correct function; avoidance of parafunction; prescribed movements.

Corrective function consists of advising the patient to chew on both sides simultaneously, 'not one side then the other but both at once'. At the same time, the patient is told to 'chew gently with the chin back and the back of the head up'. This produces equal contraction of the bilaterally acting muscles and encourages the lateral pterygoids to stretch. It will also help to relieve any localized spasm and to stretch any scar tissue in muscles which have suffered torn fibres. Raising the back of the head will relieve tension in the neck muscles. Replacement of lost teeth may be necessary to support this function. Advice to 'wet the food thoroughly in the floor of the mouth before beginning to chew' will also help to reduce the force necessary to masticate.

Secondly, advice is given to avoid any clenching or grinding of the teeth. The patient is told: 'This is a common outlet for various forms of emotional stress, such as trying to drive in a traffic jam, when it produces fatigue of your muscles, even cramp.' Counter-advice can consist of placing the tongue between the teeth, clenching the fists or even bad language, but better still is to relax and let go of the immediate problem. This is always easier said than done and it should be accompanied by the more positive advice of: 'Remember that the natural position for your jaw is with the teeth parted.' It is a common misconception that the teeth should be touching when not in use and the concept of resting posture is never of greater value than in the treatment of this syndrome.

Thirdly, corrective movements are described and these are to open and close the mandible while the chin is pulled back as far as possible: 'Direct your chin downwards and backwards, towards your neck, but within the limits of pain or click. No more than an inch.' It is important to emphasize that this is a movement and not an exercise since the performance of an exercise tends to promote strain. The objective is for the patient to open and close on the retruded arc, to keep the menisci from moving forwards in the glenoid fossae and to avoid all lateral movements. Additional advice to 'touch the teeth lightly when closing, behind your usual closed position' will be helpful. This seldom fails to cure a click, albeit temporarily, and gives the patient assurance that he can cure himself.

In cases where there is difficulty in maintaining a lip seal or where the patient has persisted in posturing the mandible forwards for appearance reasons he should be advised to allow the mandible to adopt a comfortable rest position at all times when the mandible is not in function. The effort required to maintain an unnatural posture may cause fatigue and may aggravate an existing muscle injury. Pulling on a cigarette or cigar has been known to produce pain in the joint region in such a patient. Kissing is also well known as a painful attendant on pleasure. These are, perhaps, minor aggravants of an established syndrome but their correction is advised.

THE BITE GUARD

If parafunctional habits, as evidenced by jaw stiffness on waking, have been acknowledged the wearing of an upper bite guard while asleep will help in correcting this activity and is often curative of the stiffness, pain and click. The manufacture of the bite guard has been described (p. 236) and the casts and facebow record made at the first visit are used for this purpose if the bite guard is to be prescribed. Emphasis is laid on the requirements of a flat plane to engage the lower incisors and a cover for the incisor teeth, if this is possible, in order to prevent front-tooth parafunction. Patients do not take readily to wearing these appliances overnight and they are often rejected while asleep. Perseverance is usually rewarded in the majority of cases. The bite guard can be worn through the day if stress and parafunction are anticipated, as when driving. The objective of the bite guard in the treatment of MDS is frequent, gentle, passive stretching of the affected muscles.

REPLACEMENTS

At the second visit the first question is always open, leaving the patient to tell the story. The entry on his notes is 'better', 'worse' or 'same'. When the complaints are still those of pain and lack of support a further analysis is made with a view to correcting a displaced IP or simply to replace missing teeth. Before teeth replacements are planned, however, occlusal adjustments are carried out if necessary. Partial dentures or bridgework are then made with emphasis on the occlusal factors described in Chapters 10 and 11. The adoption of and adaptation to replacements is another hurdle to cross but, if accurately made, the added support which these prostheses give to function are worth perseverance by both patient and dentist. Onlay dentures to restore lost OVD in cases of mandibular overclosure may be prescribed at this stage but not until their need has been assured by the success of the bite guard.

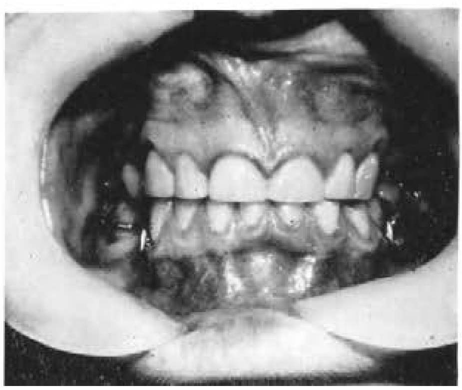
Treatment by a combination of lower onlay appliance and anterior crowns is illustrated in *Fig.* 105. This was carried out at the Eastman Dental Hospital over a period of years. The upper crowns were made (David Atkinson) after the onlay denture had proved successful in relieving the joint pain for 18 months. The lower crowns (Brian Parkins) followed 4 years later when it was obvious that the attrition was deteriorating. There was one recurrence of the pain which occurred when the onlay denture was damaged and could not be worn. The pain recurred almost at once and before the lower crowns were made. This suggested that the overclosure was causative. The patient is still attending for supervision of the treatment measures after 7 years.

FURTHER REHABILITATION

At this and all subsequent visits emphasis is laid on the need to continue the rehabilitation measures. If difficulties are being experienced in performing the movements an additional composite movement may help to emphasize the importance of involving all the muscles which support the head, shoulders and back. This movement consists of rolling the shoulders forwards and then upwards and at the same time sinking the head. From this crouched position the shoulders are gently lowered, the arms stretched downwards and forwards and the palms of the hands rotated till they face forwards. During this movement the head is gently raised as if pulled by a string from a point above the external occipital protuberance. Emphasis is on 'gently' since jerk and strain should be avoided. This movement is carried out on rising in the morning and at any time when stress is experienced. It can be practised with benefit while walking and, in order to keep shoulder-joints open, the little fingers should brush the thighs as the arms swing. The shoulder-rolling and head-raising movements can provide a helpful release from feelings of strain while driving and will prove indirectly beneficial to the jaw musculature. It is important to emphasize that all movements should be free from force or strain and that all anti-gravity movements and postures should be momentary and always changing. Stasis

a

b



c

Fig. 105. Mandibular overclosure with associated attrition and MDS. *a*, Rest position. *b*, Overclosure at IP. *c*, Completed treatment to date (*see* text).

causes fatigue. These measures derive from McLurg Anderson's studies of *Human Kinetics* (1951).

DRUG THERAPY

Although the administration of drugs and local anaesthetics (which follow) does not constitute occlusal therapy these agents provide a useful aid to treatment where muscle spasm and pain require immediate attention. Pain and spasm in muscles have been treated by analgesics, tranquillizers and muscle relaxants with varying degrees of success. Recurrence following withdrawal of the drug has been reported in almost all cases of muscle spasm where the cause has not been treated. On the other hand, drugs can provide a helpful adjunct to treatment. Of the analgesics *mefenamic acid* (Ponstan) and *pentazocine hydrochloride* (Fortral) have been widely used. The tranquillizers which have been used in MDS are *meprobamate* (Miltown) and *chlordiazepoxide* (Librium). Lenman (1961) reports that *meprobamate* has proved the most successful single relaxant drug but it does produce drowsiness. The muscle relaxants used include *mephenesin* (Myanesin), *orphenedrine citrate* (Norflex), *chlormezanone* with *paracetamol* (Lobak), *methocarbamol* (Robaxin) and *diazepam* (Valium). *Methocarbamol* proved effective in controlling spasm in three series of orthopaedic and neurological cases independently investigated by Carpenter (1958), Forsyth (1958) and O'Doherty and Shields (1958), but this drug does increase anxiety. The best muscle relaxant is still reckoned to be *curare* (tubocurarine chloride) but its use is not indicated in MDS since it has to be given parenterally and its use is usually confined to achieving relaxation during general anaesthesia. *Diazepam* combines tranquillizing and muscle relaxant effects with few contra-indications. Patients have been seen who have been taking *diazepam* successfully but who 'would like to stop taking pills'. Withdrawal of the drug, however, has resulted in a recurrence of the syndrome. Without treating the dysfunction no drug has yet been successful.

LOCAL ANAESTHESIA

Schwartz (1959) advocated the use of *ethyl chloride* spray as a surface anaesthetic for the relief of pain which permitted the function of the affected muscles to be restored. With the patient protecting his eyes and nostrils and the operator supporting the patient's chin with one hand, the spray is directed over the mandibular joint region, downwards over the masseter muscle and upwards over the temporalis. A slow sweeping movement is used with the nozzle directed at an acute angle from the face and about 2 feet from it. Care is taken not to frost the skin or hair and to withdraw the spray if pain is experienced. Pain will indicate spasm and the muscle should be palpated and gently stretched. If successful in relieving the pain retruded arc movements should be performed to institute muscle rehabilitation and used before eating or when the pain recurs. Ethyl chloride has a penetrating effect and is useful as a diagnostic as well as a therapeutic measure. Additional warnings on the use of ethyl chloride include the avoidance of any flame (gas jet) since it is inflammable and of inhaling the vapour since it is a general anaesthetic and cardiac depressant.

The infiltration of local anaesthetics into painful muscles was also advocated by Schwartz (1954) and a useful chapter on this subject is contributed by Kutscher and others (1968) in *Facial Pain and Mandibular Dysfunction* edited by Schwartz and Chayes.

These methods of reducing muscular pain are considered as an adjunct to the rehabilitation measures previously described.

MDS in complete dentures

The incidence of patients wearing complete dentures in this syndrome (Thomson, 1959, 1962, 1971) has been 10 per cent of the patients treated. In most of these cases the dentures were satisfactory as such but the OVD was incorrect. Overclosure and increased OVD were equally observed. Restoration to a level 2–3 mm. above rest position was helpful in the majority of patients treated.

Reduction to the correct OVD is best performed by transfer of the dentures to an adjustable articulator using a facebow transfer and precontact record on the retruded arc, albeit registered below the level of rest position. The amount of closure can be assessed by reference to a measurement of the OVD with the dentures in place compared with the RVD with the lower dentures out and the mandible in rest position. Occlusal adjustment is then carried out by the methods described in the Glossary. (p. 267).

Restoration of lost OVD (overclosure) can be performed temporarily in the mouth by adding a roll of rapid-setting acrylic resin to each lower posterior segment and having the patient close on the retruded arc to a predetermined occlusal level. The upper posterior segments should be covered with tin foil secured temporarily by adhesive. The acrylic resin can be shaped into supporting cusps and the dentures will prove usable until a more permanent restoration of the correct OVD is possible.

RELAPSES AND FAILURE

The failure rate, using these treatment measures, has proved low (Thomson, 1959, 1971) but relapses have occurred and are usually associated with parafunctional habits, injury (unexpectedly tough food), the loss or breakage of an appliance or lapse of rehabilitation measures. None the less, failures occur and referral to specialist departments for heat and galvanic therapy has proved helpful although it is often from these departments that referrals come. Further diagnostic investigations may be necessary.

PROGRESSIVE WEAR OF THE OCCLUSAL SURFACES

Whether this disorder is called abrasion or attrition, parafunctional grinding habits are usually a precipitating cause. Attrition may be aggravated by the chewing of tough foods and, when the dentine is exposed, lodgements of food will cause further loss of tooth tissue and can be blamed for turning this disturbance into a disorder. In many patients the condition suffers from watchful therapy or from no therapy since many of these patients are caries-free and do not attend the dentist. Advice on treatment has to be aimed at prevention and, where possible, any penetration of dentine should be restored by a filling. Amalgam has proved its worth over the years but the composite fillings are now proving a stable replacement for lost enamel and dentine. When this condition advances beyond the stage of small dentine replacements into flattened, tooth surfaces, with reverse Monson curves, there is often no choice between palliative and reconstruction therapy.

Reconstruction therapy can prove a massive task (Chapter 11) and should not be undertaken without a full realization of the time and cost involved. It can, however, be performed in units. For example, the four first molars can be restored and subsequently other groups of four teeth. If lost OVD has to be restored an interim appliance for the remaining teeth may be necessary in order to share the load of occlusion and prevent depression of the restored teeth. Onlay dentures by themselves have not proved satisfactory.

This disturbance can affect young adults and the emphasis on prevention cannot be too strongly made. The avoidance of grinding habits supported by the use of bite guards if necessary is advised. Strict hygiene of the occlusal surfaces (with a soft toothbrush) and care in the eating of carbohydrates and citrus fruits are measures which should be enforced. No patient is too young to embark on a programme of preventing this long-term destructive disturbance and likely disorder.

MOBILITY AND MIGRATION

The part played by occlusal disturbances in the disorders of mobility and migration is probably one of aggravation and represents a deterioration of what is essentially a periodontal or orthodontic problem. None the less, an assessment of occlusal function is essential in the treatment planning and in the after-care following treatment.

Mobility of a tooth or teeth can be caused by occlusal forces but if the cause is removed the affected teeth will recover their stability provided there is no gingival or periodontal lesion. Mobility is generally caused by a loss of periodontal support and is aggravated by occlusal forces either in IP, if there is any extrusion of the affected tooth, or during lateral movements when the affected tooth causes an interference. This presupposes a gingival lesion with subsequent loss of periodontal tissue and alveolar bone. Mobility without migration also implies the condition of jiggling whereby the tooth is moved by an occlusal or muscle force and is restored to its original position when these forces are removed (p. 138). It is therefore necessary to make a habit analysis of the circumoral and tongue muscles in addition to the factors of occlusion and periodontal loss before planning treatment.

Treatment consists, firstly, of assessing the periodontal condition and arresting it if this is possible and, secondly, of removing the aggravating causes. When the periodontal treatment has been completed the occlusion and articulation are reassessed. Occlusal adjustment is performed to remove interferences in closure to habitual IP and during articular movements. If habitual IP has become displaced forwards or laterally from retruded occlusion in excess of what is considered normal for the patient (possibly as a result of the periodontal condition), then consideration should be given to restoring IP on the retruded arc (Chapter 12). The removal of premature contacts caused by tooth extrusion will accompany the periodontal treatments. Tongue and lip habits have to be pointed out to the patient and efforts made to control them. This alone has proved successful in treating mobility, there being no treatment like self-treatment. But it is often too much to expect and if an irritant (a mobile tooth) is present it can seldom be left alone. Thus, incisor teeth may have to be shortened and irritant edges smoothed. In general the objectives are periodontal health, teeth in good alignment and an IP in good relationship to the rest position.

Migration of a tooth or teeth exists when they have become repositioned and may still be on the move. The commonest example is the drift of the lower second molar following the loss of the first. Of more concern to the patient, and by no means uncommon, is the forward drift of upper incisors. This is difficult to treat because in many cases the lower incisors have followed them. Lip and tongue adjustments to these altered tooth positions can result in aggravation of the condition as when the lower lip gets behind these upper incisors in order to restore the oral seal but tends to promote the drift. The phenomenon of adaptation was never better illustrated but less welcome. As with mobility, migration of incisor teeth generally begins with a periodontal lesion which reduces the stability of the tooth and renders it liable to movement by unopposed forces. There are exceptions and these include the case of lip seal in the young adult maintained by voluntary effort which is relaxed in later years. This permits the tongue in function to push the incisors forward until they reach a position of stability with the weaker lip muscles. In the case of tilted lower second molars following the loss of first molars there is seldom a periodontal lesion since the mesial gingival margin is more accessible to hygiene and therefore tends to remain inact. Here again the tooth will drift until it reaches a stable position although not in orthodox occlusal function.

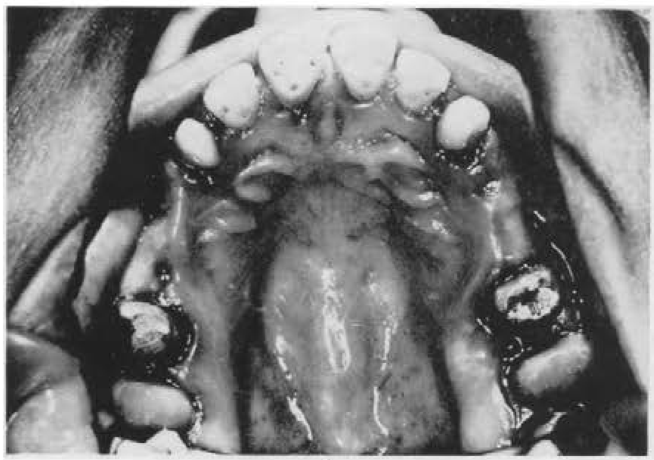
Treatment of migration is difficult and debatable. It is difficult because of the adaptive drift of adjacent and opposing teeth and debatable because the teeth may have moved into stable positions. If the condition is progressive treatment is directed at arresting the migration or restoring the original tooth positions if this is possible. Treatment consists firstly of measures to restore periodontal health and its maintenance. Then follows orthodontic treatment, if this has been prescribed, which includes retention. Retention will generally require more than a removable appliance worn at night and may call for permanent fixed or removable splinting of the affected teeth. Whether or not orthodontic treatment has been performed, adjustment of the occlusion is performed in order to promote bilateral IP and freedom from interferences into IP. Such interferences will tend to promote recurrence of the migration. Unilateral function will tend to cause drift diagonally across the arch (Thielemann's phenomenon, 1956). Finally, a reassessment of the circumoral and tongue muscle behaviour is made with a view to keeping the teeth stable within the pattern of activity and to preventing habits, both muscular and occlusal.

Splinting was mentioned as a treatment measure to retain orthodontically moved teeth and it can be used to support periodontally involved mobile teeth. Without periodontal treatment splinting will only delay the inevitable loss of severely affected teeth but it can be a successful supporting measure. In cases of post-orthodontic retention in adults, and where there is a tendency for recurrence, the front teeth should not only be splinted together, preferably by cemented restorations, but this splint should be joined to the posterior segments (*Fig.* 106).

PULP NECROSIS

This can be the result of prolonged, intermittent occlusal force between two teeth and can be said to be a genuine effect of occlusal trauma. Such a case was illustrated in *Fig.* 63 (p. 139) where the patient acknowledged such a habit and had no memory of other accident to the tooth. Treatment is by root-canal therapy and prevention of recurrence which may require the services of a bite

a



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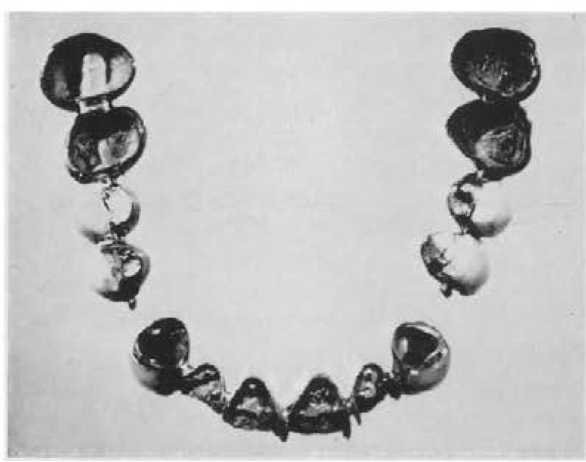

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Fig. 106. Splinting for migration after orthodontic and periodontal treatment.
a, Preparations begun and temporary partial denture in place. *b*, Teeth prepared. *c*, Splint and bridgework. *d*, Work in place. *e*, IP.

guard especially if the habit occurs during sleep. Occlusal adjustment may be necessary if, in protruded occlusion, this is the only contact.

GINGIVAL ULCERATION FROM FOOD STAGNATION

Gum bleeding in association with food stagnation suggests ulceration of the interdental epithelium and faulty contact points. The causes and effects of this disorder have been described in Chapter 8. This may have been the result of incorrectly restored Class II fillings or crowns. In the case of replacing a faulty filling the emphasis is not only on ensuring a 'tight' contact area, but on embrasure shape, on the placement and shape of the marginal ridge above the contact point, on food spillways from the marginal ridge, and on the approximal shape below the contact point. These requirements are best appreciated by looking in a young, caries-free mouth, both clinically and radiographically.

a

b

c

Fig. 107. Anterior open bite associated with MDS. *a*, IP pre-treatment. *b*, Lower onlay denture. Symptoms relieved but appliance clumsy. *c*, IP following surgical correction of mandible by Lester Kay at Eastman Dental Hospital.

The embrasure shape should conform to the norm for that tooth and its neighbour. The marginal ridge should be above and central to the contact area thus allowing the ridge to be a masticating tool and allowing the food to slide into the embrasure area. A food channel across the ridge into the embrasure area exists on the lingual aspects of the upper posterior teeth and buccal of lower. The shape of the approximal surfaces below the contact areas is more concave than convex thus permitting access for woodstick hygiene. The approach to interdental health is one of prevention. This disorder can be cured and its recurrence prevented provided the teeth are close enough to restore the features mentioned.

The plunger cusp is a common cause and aggravating factor of food stagnation and even of tooth separation. It is, however, often seen as the effect of an incorrectly restored contact area, where the marginal ridge has been lowered and the embrasure widened with the result that the opposing supporting cusp loses effective contact and tilts into the space, thus causing the plunger action. It then becomes difficult to treat since, in order to restore the correct relationship, the cusp has to be tilted back and it would be an understatement to say that this presents difficulties. Reducing the cusp size is the regrettable conclusion unless the affected marginal ridge can be reshaped with especial skill.

When the posterior teeth are so separated that 'top heavy' restorations would be necessary to restore the contact point it may be justifiable to make the space even wider so that food is easily removed. Alternatively, a bridge with sanitary pontic is indicated.

DEVELOPMENTAL ANOMALIES

As was said in Chapter 8, developmental anomalies are disturbances which seldom cause disorders. When, however, the reduced area of occlusion is associated with a parafunctional habit in cases of anterior 'open bite' and where there are displacing activities in posterior 'open bite', pain from fatigue or muscle injury in the masticatory muscles may develop and require treatment. The treatment objectives are to prevent the habits and to correct the displacements. In the case of the former, bite guards are large and adaptation to them is difficult. Surgery by mandibular resection has proved beneficial in these cases where the MDS has proved untreatable by conservative or restorative measures (*Fig.* 107*c*). For the latter, appliances to correct posterior open bite are often welcome for purposes of mastication but not always well tolerated (*Fig.* 107*b*). Design of these appliances is determined by requirements and the principles outlined for appliances to correct overclosure apply in these cases. Adaptation and tolerance to these appliances may have to be of a high order since cusp heights are increased and the appliances are bulky. But the needs of the masticatory system may demand this form of treatment.

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Chapter 14

Summary and an exhortation

FROM the one-time kingdom of Fife came the proverb: 'Mony a mickle maks a muckle.' This can be translated, in a positive sense, as: *Petit à petit l'oiseau fait son nid,* from the other member of the Auld Alliance. More applicable to this text it can be interpreted as: 'Constant dripping wears away the stone'. In more scientific terms this is understood as the cumulative effect, and can be applied to the life and hard times of the teeth in relationship to each other. The mastication of food by contemporary man may decay his teeth if the oral bacterial flora are pathogenic for caries but it will seldom wear them away. The occlusion and articulation of opposing teeth in the empty mouth will, over the years, do this for him and the effects are cumulative. The occlusal surfaces of the teeth do not repair themselves and their relationships to each other are, therefore, continually changing. The effects may cause few complaints and give the dental profession little apparent concern. Adaptation to change and ageing is a feature of all tissues but this is not unlimited. In the case of the tissues of the masticatory system the borders between change, disturbance and disorder are guarded by the dentist and his skill often lies in protecting them against disorder by advice and sometimes by treatment.

In their studies of occlusion and practices to achieve good occlusal function dentists have come a long way from Angle's assertion that the key to occlusion is the relative positions of the first molars. This static solution to the problems of malocclusion still has its place as a sign to be noted on the way to a comfortable and efficient relationship between the teeth in the empty mouth. But the movements and positions of the mandible in relation to the maxilla during the varied functions of the masticatory system require a wider range of explanations than are supplied by two molar teeth on each side of the mouth. These movements and positions depend on the muscles which move the mandible, the joints which permit the movements and the shapes of the teeth which control the occlusal function in both the empty mouth and the one filled with food, in both good function and bad. These tissues are interdependent and the stimuli from their functions elicit responses and impulses in the central nervous system which, in turn, governs their functions and health but can lead to disturbances of the tissues.

Teeth wear, tip, become carious, lose their support and are removed. To these declining features can be added restorations which do not always contribute to good function. At each and every stage of change the muscles adapt and maintain the best possible occlusal function but they may tire, become injured or respond with varying degrees of spasm. Meanwhile, the flexible joints provide the movements required but they, too, are subject to unfavourable paths of movement resulting in varying degrees of dysfunction.

To diagnose and treat these disturbances of function and their consequent disorders dentists are required to watch, advise and treat when necessary. No advice to limit occlusal activities in the mouth is premature. All proposed treatment to prevent or cure is subject to the possibilities of harm and every dentist is his own specialist in watchful therapy while taking care to avoid supervised neglect. But some specialists are more specialized than others, and patients are sometimes warned that when they choose a specialist they may be choosing a diagnosis and treatment plan. It has been said of astro-physicists that they are often in error but never in doubt and this gentle gibe might apply to specialists in occlusion. Treatment of occlusal disorders is best carried out by more minds than one, by groups of dentists with specialized skills and each with knowledge, integrity and a clear appraisal of what is genuinely required for each patient. Practitioners of occlusal problems are often imbued with enthusiasm but this admirable quality is best tempered with a sense of clinical justice.

The studies and practices of occlusion are often criticized for the emphasis placed on the use of articulators, some too complex and some too simple. The articulator will only transfer to the laboratory bench what the dentist wants to transfer and each instrument provides no more than a mechanical copy, not always accurately, of a series of mandibular movements and positions governed by neuromuscular function. And the more this complex function is understood the greater is the need to employ accuracy. The more limited the possibilities of accurate transfer to and from the articulator the more adjustment will be required in the mouth. Many restorations have been flattened and their occlusal function lost by too much correction in the mouth. Perhaps as many are left with interferences when too little correction is made.

The practitioners of occlusal problems are often unjustly criticized for confining their procedures to reconstruction and grinding the teeth. Such procedures are often the last resort for neglected dentitions and further neglect may involve untreatable disorders and dismay. To rehabilitate a disturbance is preferable to the reconstruction of a disordered dentition. Rehabilitation has been defined in this text as the restoration of muscle and joint function, but in orthopaedic circles it has been referred to as the progressive withdrawal of facilities. The application of this sane but severe definition for the dentist is to treat his crippled patient with the minimum of appliances compatible with adequate function. Reconstruction procedures are for the extreme case and most dentitions will survive a life of adequate function with regular preventive care and advice.

The treatment of most disturbances of occlusion are for the most part carried out without alterations to the existing intercuspal position of the mandible. Such treatments include the amalgam fillings, the crown, bridge and various combinations of multiple restorations where the occlusal or proximal surfaces of the teeth require improved shapes but where the existing IP does not require alteration. The objectives are to achieve intercuspal occlusion without deflexions of teeth or mandible and to abolish articular interferences during mastication or in the empty mouth. When a change of IP is required, however, there can only be one position for intercuspal occlusion and this is on the retruded arc at a level 3 mm. above that of rest position. Here there will be stability and reproducibility of the intercuspal position. For those who like a quickly spoken objective, IP at RC is easily said. But it requires qualification since RC (retruded contact or retruded occlusion) exists at a level slightly below the optimal vertical level for IP. To reach the retruded IP requires effort and the intention is to limit intercuspal occlusion to the act of swallowing. The effort also provides the beneficial stretching of the lateral pterygoid muscles. At all other times and during all other functions do not let the teeth touch.

These principles apply to the occlusal adjustment of the natural teeth with the restated warning that the teeth once adjusted (ground) will not repair themselves. While giving great benefit, occlusal adjustment can lead to iatrogenic disorders of a most distressing nature. Careful planning with a clear objective is encouraged. The suggestion that a generalized reduction of cusp height be carried out as a prophylactic measure (Berry and Poole, 1974) is challenged. This proposal is based on observations that occlusal wear was a constant feature of mammals and early man with its association with low caries incidence. It is true that the refined diet of contemporary man has reduced the wear on his teeth and that this diet and absence of occlusal wear have contributed to the disease of caries. With care, however, man can now retain his teeth as they were evolved and so benefit from more efficient mastication, a reduced need to occlude his teeth and a secure intercuspal position for his mandible when required. Perhaps mutations will, in time, provide him with cuspless teeth but, until that time comes, it would seem that to make the best use of these unworn tissues is preferable to a haphazard attempt to copy past abuses in spite of environmental hazards. Survival depends on the optimal adaptation of function to form.

There will continue to be debate over the best IP for complete dentures. To make elderly patients thrust backwards every time they want to occlude may seem a harsh and unrealistic discipline and it will be argued that they will slide forwards to a more comfortable and habitual position in any event. So why not allow the more comfortable IP within the parcel of movement? Or at least give them a 'long centric' to slide there? Or flat cusps? The answer lies in the difficulty of transferring to an articulator any other mandibular position than one on the retruded arc. The registrations of all other positions are liable to adaptation by neuromuscular response to bases, occlusal rims, fingers and thumbs. No two will be the same. Somehow the denture patient must be given one secure position at which to occlude his teeth; he must be allowed freedom to articulate his teeth without interferences; and only then can he be realistically advised to leave his teeth alone.

Let us return briefly to the robin and see it pick up the seed without touching the path. Let our patients chew their food without touching their teeth. Let us dentists make this possible by providing the best possible occlusion, with cusps and fossae making secure contact in one reliable position and freed from interferences in getting there. Let our patients be freed from the aimless, endless and exhausting search for a stable occlusion by giving them one. Let them have an occlusion which they can forget.

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Glossary

TERMS AND DEFINITIONS

Anterior segment articulation takes place when the incisors or canines alone take part in lateral and protrusive articular movements.

Arbitrary retruded axis. See Retruded condyle axis.

Articulation. The contact that exists between the teeth of opposing arches while the mandible is moving.

Articular movements are the mandibular movements while two or more opposing teeth are in contact.

Balanced articulation is simultaneous contact between teeth of two or three opposing segments during an articular movement.

Free articulation is the absence of cusp interferences to lateral and protrusive articular movements.

Balancing side. The side from which the mandible moves in lateral articular movement or unilateral mastication. It is the side opposite to the working side. Alternative term: non-working side.

Bennett angle. The angle between the medially translating condyle and the median sagittal plane.

Bennett movement. The bodily lateral component in the rotation of the working side-condyle as the mandible makes a lateral movement. Alternative term: lateral shift.

Border movements. See Envelope of motion.

Canine guidance. See Guidances.

Centric occlusion. See Intercuspal occlusion.

Centric relation. See Retruded relation.

Condyle guidance. See Guidances.

Cross-arch balance. Simultaneous contact between opposing teeth of working and balancing sides as the mandible makes a lateral articular movement.

Cross-tooth balance. Simultaneous contact between opposing buccal and lingual cusp ridges on the working side of an articular lateral movement.

Cusp. The apex of cusp and triangular ridges of a tooth.

Cusp angle. The angle made by the slope of a cusp ridge or triangular ridge with the plane of occlusion.

Cusp interference. The premature or initial contact which takes place between two opposing teeth in a functional or parafunctional movement (*see* p. 132).

Cusp ridge. See Ridges.

Disclusion. The separation of all posterior tooth contacts when the mandible moves away from intercuspal position and articulation is maintained between the opposing anterior segments (anterior segment articulation).

Displacing activity. The reflex movement made by the mandible when a lower tooth encounters an initial cusp contact on an upper tooth.

Envelope of motion.

Horizontal. The outline traced by a point between the lower central incisors as the mandible moves laterally to the left, forwards, laterally to the right and backwards as far as it can go in these directions. This envelope is usually traced with a central bearing device which keeps the teeth parted but it can also be traced during articular movements in these directions. Alternative term: horizontal border movements. *See* Chapter 4.

Vertical. The outline traced by a point between the lower central incisors as the mandible moves in the median sagittal plane through all possible tooth contacts from retruded to fully protruded position and then downwards, upwards and backwards as far as the mandible can go in these directions. Alternative term: vertical border movements.

See also Space parcel.

Fischer angle. The angle made between the paths of the medially and protrusively translating condyle.

Gothic arch. The outline made by a stylus attached to the maxilla on a tracing plate attached to the mandible with the teeth parted, as the mandible makes retruded lateral movements from one side to the other. The apex of the arch represents the retruded relation of mandible to maxilla and this outline corresponds to the posterior half of the horizontal envelope of motion.

Guidances. The influence on mandibular movement created by the occlusal surfaces of the teeth or condyle paths.

Canine. The guidance provided by the lingual surfaces of the upper canines in lateral articular movements.

Condyle. The guidance provided by the paths of the translating (medially or laterally) condyles.

Cuspal. The guidances provided by the cusp ridges of opposing posterior teeth.

Incisal. The guidance provided by the lingual surfaces of the upper incisor teeth as the lower incisal edges make contact with them in protrusive articular movements.

Guiding cusps. The buccal upper and lingual lower cusps of the posterior teeth. The surfaces which provide the guidance are the inner facing triangular ridges and their slopes. The lingual surfaces of the upper incisors and canines are guiding surfaces.

Horizontal overjet. The horizontal distance between the labio-incisal edge of an upper incisor and the labial surface of the opposing lower incisor when the teeth are in intercuspal occlusion. This overjet also applies to posterior teeth.

Intercuspal occlusion (IO). The contact between the greatest number of opposing teeth (usually cusps and opposing fossae or marginal ridges) while the mandible is stationary. Alternative term: centric occlusion.

Intercuspal position (IP). The position of the mandible when the teeth are in intercuspal occlusion. Alternative terms: centric position or muscular position if the mandible has closed in a reflex pattern from rest position.

Habitual intercuspal position. IP following a displacing activity from rest position. Alternative term: tooth position. In this text, however, all intercuspal positions are considered habitual when they are not on the retruded arc of closure.

Retruded intercuspal position. The position of the mandible when it is in retruded relation to the maxilla and the teeth are in intercuspal occlusion.

Interocclusal distance (IOD). The distance between the upper and lower teeth when the mandible is in rest position. Alternative term: freeway space.

Marginal ridge. See Ridges.

Oblique ridge. See Ridges.

Occlusal table. The area on a tooth bounded by the mesial and distal marginal ridges and the buccal and lingual cusps.

Occlusal vertical dimension (OVD). The vertical distance between points marked on the nose and chin when the teeth are in intercuspal occlusion.

Occlusion. Any contact between the teeth of opposing arches. The term is usually qualified as by intercuspal, retruded, lateral, protruded (*see* Chapter 1).

Plane of occlusion. The imaginary surface that touches the incisal edges and cusps of the lower teeth. It is a curved surface and, when in the sagittal plane, is called the compensating curve (or curve of Spee). When continued distally it is said to run through the condyle (curve of Monson). When viewed in the coronal plane it is called Monson's curve and these two aspects together combine to make Monson's sphere (*see* Chapter 5).

Parafunction. Disordered function (*Oxford English Dictionary*, 1971). In the masticatory system it implies clenching or grinding habits between the teeth in the empty mouth or between the teeth and various outside agencies such as pens, hair-grips, finger-nails. Alternative term: bruxism.

Plane of orientation. The flat surface which touches the cusps of the lower canines and the distobuccal cusps of the lower second molars.

Rest position. The position adopted by the mandible when the muscles between mandible and maxilla are in minimal contraction. Alternative terms: resting posture, endogenous posture.

Habitual posture The position adopted by the mandible when the requirements of lip seal cause the mandible to move away from rest position.

Rest vertical dimension (RVD). The vertical distance between mandible and maxilla when the mandible is in rest position. This is usually measured between marks on the nose and chin.

Retruded arc. The arc of opening and closing made by the mandible while it is rotating on the retruded condyle axis.

Retruded condyle axis (RCA). The imaginary axis which runs through both condyle regions when the condyles are in retruded (most superior and posterior) relation to the maxilla. Alternative term: terminal hinge axis or hinge axis.

Arbitrary retruded axis. The imaginary axis running between points marked on the skin over the condyles each one 12 mm. in front of the tragus of the ear and on a line between it and the external canthus of the eye. Alternative term: arbitrary hinge axis.

Retruded intercuspal position. See Intercuspal position.

Retruded relation. The relationship between mandible and maxilla when the condyles are most superiorly and posteriorly placed in their respective glenoid fossae. Alternative term: centric relation.

Ridges. The crests of tooth slopes which run from cusps on a posterior tooth and are contiguous with other ridges or end in central fossae (*see Fig.* 8, p. 26).

Cusp ridges run mesially or distally from a cusp to marginal ridge or contiguous cusp ridge.

Marginal ridges are contiguous with the cusp ridges and form the mesial and distal margins of the posterior teeth. The slopes from ridges run towards the central fossae and contact areas respectively.

Oblique ridges run from the mesiolingual cusps of all upper first molars (and some second molars) and join the distobuccal triangular ridges. They may be continuous or be separated by a fissure.

Transverse ridges run across the tooth between the buccal and lingual cusps as in the lower first bicuspid or they may join two other ridges.

Triangular ridges run from the cusps to the central fossae of all posterior teeth except the lower first bicuspid.

Rotation centres. The imaginary vertical, coronal–horizontal and sagittal–horizontal axes of rotation which run through both condyle regions and about which the mandible rotates in order to provide three dimensional movement (Chapters 5 and 7).

Space parcel. The volume occupied by the median vertical and horizontal envelopes of motion at all levels of jaw separation. This is depicted by a point between the two lower central incisors and represents the circumductory (or border) movements of the mandible in three dimensions of that point. *See* Chapters 5 and 7.

Supporting cusps. The lingual upper and buccal lower cusps of the posterior teeth. These cusps and their ridges occlude in opposing central fossae (where they are wholly enclosed within the opposing occlusal table) or marginal ridge areas. The incisal edges of the lower incisors and canines act as supporting cusps. Alternative terms: centric holding cusps or stamp cusps.

Tripod contact. The contact between three surfaces of a supporting cusp and an opposing central fossa or marginal ridge area. The cusp itself does not make contact with the fossa or ridge surface.

Vertical overlap. The vertical distance between the incisal edges of opposing incisor teeth when the teeth are in intercuspal occlusion.

Working side. The side to which the mandible moves in lateral articular movement or in unilateral mastication. It is the side opposite the balancing side.

Appendix

CRITERIA FOR GOOD OCCLUSION

1. Two complete arches of teeth with secure contact points and occlusal surface contours adequate for function required.
2. Root shape and alignment adequate to resist occlusal forces.
3. Rest position stable with adequate lip seal.
4. An interocclusal distance of 2–4 mm. between rest position and intercuspal position.
5. Simultaneous and bilateral intercuspal occlusion between all teeth of upper and lower arches at intercuspal position. No deflective contacts.
6. Simultaneous and bilateral occlusion on the retruded arc between one or more opposing posterior teeth.
7. Cusp–fossa and cusp–ridge occlusion having tripod contacts where possible.
8. Each tooth returns to its original position on removal of the occlusal force.
9. Articulation between retruded and intercuspal position free from any interferences causing lateral deflexion.
10. Stable vertical overlap and horizontal overjet.
11. Empty-mouth articular movements free from deflective contacts.

CRITERIA FOR GOOD OCCLUSAL FUNCTION

1. Simultaneous bilateral mastication.
2. Light contact in intercuspal position while swallowing.
3. Incoming and outgoing chewing movements free from working or balancing side deflective contacts.
4. No adaptive lip or chin movements on swallowing.
5. No clenching or grinding (parafunctional) movements.
6. No joint noises in mastication or wide opening.
7. No deviation of mandible on wide opening.
8. No tooth contacts in speech or facial expression.
9. Pleasing appearance.

TEN-POINT TEST FOR OCCLUSAL FUNCTION

1. Patient's assessment of function and parafunction.
2. Stability of rest position and lip competence.
3. The interocclusal distance and any cusp interference from rest position.
4. The incisor midlines and any altered tooth inclinations.
5. Palpation and sounds of intercuspal occlusion on firm closure.

6. Length and direction of slide from retruded to intercuspal occlusion.
7. Wear facets as indicators of parafunction.
8. Articulation movements to and from IP.
9. Maximum active opening of mandible: deviation and noises.
10. Palpation of joints and muscles.

MANDIBULAR DYSFUNCTION SYNDROME

I. Information required from patients and suggested form of questionnaire

1. SOCIAL
   Name, age, sex, occupation, marital status (and children), source of referral.

2. CURRENT SYMPTOMS OR NATURE OF COMPLAINT
   Patient's own description and site of pain is desirable and the open question is preferred to the closed one.
   Such questions are helpful:
   a. Tell me about the problem, discomfort.
   b. Can you point to the place where it starts?
   c. How would you describe the pain (if pain is mentioned)? Note adjectives used: e.g. 'dull', 'neuralgia', or 'burning', etc.
   d. What area is covered by the pain?
   e. Any complaints while eating? Hard chewing? Laughing? Yawning?
   f. How widely can you open your mouth? Make a measurement with, say, Willis gauge.
   g. Do you notice anything about your jaw when you wake up? If so, describe. (Information required regarding any stiffness.)
   h. Do you notice any noises in your jaw? If so, describe.

3. HISTORY OF PAIN OR DISTURBANCE AND NATURE OF ONSET
   a. How long have you had it?
   b. Tell me how it first began.
   c. Do you remember if it began suddenly or gradually?
   Information required as to any accident or unusual activity of the jaw such as prolonged opening, or side opening at onset, without suggesting this to the patient.

4. PROGRESS OF PAIN AND/OR JOINT NOISES
   a. Has it subsided and recurred without apparent cause?
   b. Has it kept you awake?
   c. Do you take pills? What are they? Are they effective?
   d. Does the weather affect it? Cold day? Damp day?
   e. Have you been treated for it before? What was the treatment? Was it successful?
   f. Is it getting better or worse?

5. EMOTION AS FACTOR
   Assess by tactful straightforward questions:
   a. Are you easily upset at present? Pressed for time? Too much to do?
   b. Have you noticed that you get the pain when you are upset?

c. Do you clench or grind your teeth when you are pressed for time or concentrating or when you are preoccupied?
d. Does the pain make you grind your teeth?
e. Does the pain go away while you are free from worry? On holiday?

6. WEATHER
Does the weather seem to affect your pain?
Cold, damp, heat?

7. PAST MEDICAL HISTORY
Questions directed towards assessing systemic causes:
a. Do you have pain or stiffness in any other joints?
b. Treatment for other joint conditions?
c. Headaches? Colds? Sinus affections?
d. Are you under treatment for anything at present, or recently?

8. DENTAL HISTORY AND CURRENT FUNCTION
Questions directed towards discovering any recent injury to joint, cause of alteration to tooth relationship or wear on teeth.
a. Recent extraction dates? Any jaw injury at the time or subsequently?
b. Injuries: fall, blow, wide yawn or laugh?
c. Denture history, if any.
d. Orthodontics.
e. Clenching and grinding habit? Do you keep your teeth together?
f. Side preferred in function? Tough foods? Food traps?

9. CLINICAL EXAMINATION
a. Missing teeth.
b. Wear on the teeth.
c. Closure analysis from rest position:
Assess displacing activity due to cusp interference and which tooth causative?
Light tapping—fremitus?
d. Retruded closure analysis: forward or lateral displacement.
e. Wide-open analysis.
Deviation.
Limit of opening: measure by Willis gauge.
Palpation } assess noises and pain incidence.
Auscultation }

10. DIFFERENTIAL DIAGNOSIS
Exclude:
a. Rheumatoid arthritis.
b. Osteo-arthritis.
c. Trigeminal neuralgia.
d. Facial pain of dental origin.
e. Migraine or headache of systemic origin.
f. C.N.S. disturbance.
g. Sinus disturbance.
h. Specific infective arthritis.

11. X-RAY EXAMINATION OF BOTH MANDIBULAR CONDYLES
Take at IP and maximal opening.

Based on radiologist's report, examine:
a. Joint space. Compare sides for increased or decreased space.
b. Extent of opening. Compare spaces.
c. Irregularities of condyle outline. Referral.

II. Some suggestions for treatment

1. Explain and reassure.
   Physical therapy:
   - *a.* Advise bilateral chew.
   - *b.* Avoid chewing and grinding—keep your teeth parted when not in use.
   - *c.* Open movements.
   - *d.* Head, neck and back posture.

   Impressions and records for casts.
2. Note progress: better, same, worse?
   Comments of patient.
   Check on and repeat physical therapy measures.
   Decide if occlusal adjustment necessary:
   - Plan and carry out procedures.
   - Grinding procedures to correct displacing activities.
   - Activity of mandible: (*a*) from rest position; (*b*) on retruded closure.

   Decide if appliance therapy necessary:
   - Bite guard for night wear.
   - Prosthesis to restore lost teeth.
   - Prosthesis to restore lost OVD.

   Impressions and records.
3. Note progress.
   Check on and repeat physical therapy measures.
   Place appliance and advise on use and hygiene.
4. Continue as previously.
   Consider referral if no success.

OCCLUSAL ADJUSTMENT FOR COMPLETE DENTURES

Objectives

I. To restore intercuspal occlusion of the dentures at the retruded horizontal and correct vertical position of mandible.
   Registrations required:
   1. Facebow transfer of arbitrary retruded axis.
   2. Precontact registration on retruded axis.
   3. Confirmation of (2) by a check registration.

   Procedure:
   1. Achieve equal contact on closure by deepening fossae: avoid reduction of cusp height if possible.
   2. If premature contact is greater than half the width or height of one tooth, re-set the teeth.
   3. On incisors and canines remove palatal surfaces of uppers. If incisal edges of lowers require shortening for speech or appearance, shorten lowers.

II. To produce balanced occlusion in the lateral and protrusive positions and free articulation between these contacts.
Registration required.
Pre-contact registration with mandible in 6 mm. of protrusion.
Adjust condyle guidance on articulator. Add 5° for lateral movement.
Procedure:
1. In protrusive movements, relieve distal inclines of buccal upper cusp ridges, mesial inclines of lingual lower cusp ridges. Intercuspal position will be disturbed if lingual upper or buccal lower cusps or cusp ridges are removed. On labial segment remove lingual surface of upper teeth.
2. In lateral movements: on working side remove buccal upper or lingual lower cusp ridges (Bull rule); on balancing side remove lower buccal cusp, inner triangular ridge.

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