OCCLUSION IN COMPLETE DENTURES

C P Owen

Introduction

Occlusion has been described as the most important subject in all the disciplines of dentistry, and for good reason, because the way the teeth come together, and function together, is as important to most of us now as it was to our ancestors, who lived on diets much more difficult to cope with. When, as dentists, we are faced with the problem of replacing occlusal surfaces, either by restorations in natural teeth, or replacement of some or all of the teeth, then a thorough knowledge of the way teeth come together and function together, is essential.

Occlusion has unfortunately also been described as one of the most confusing subjects in all the disciplines of dentistry (mostly by each generation of dental students). Attempts to understand occlusion have ranged from the mechanical, mathematical and geometrical analysis of tooth contact and jaw movement, to the biological and functional analyses based on the behaviour of natural dentitions under different environmental (mostly dietary) conditions. All of these analyses have their place but they need to be brought together into a unified concept, and this is rarely done. However, there *are* rational ways to study occlusion, and studying occlusion in complete dentures is a good starting point, because of the need to place an entire dentition within a system so that the edentulous patient can once again function with the minimum of discomfort and the maximum possible efficiency.

Natural occlusion and artificial occlusion

Development of the occlusion

The evolution and development of the dentition and temporomandibular joint is a useful study in that it gives us clues as to how our present dentition functions.

Mammals evolved from a group of “mammal-like reptiles” about 280 - 190 million years ago. Reptiles cannot bring their upper and lower teeth together and cannot chew; their teeth cannot move because they are ankylosed. But by the time the earliest known mammal had evolved, these now had two sets of dentitions, and the upper and lower teeth could be occluded. The development of a joint that could allow lateral movements, allowed the newly evolved mammalian cheek teeth to come into a definite occlusal relationship. The earliest known mammal had as precise a relationship between upper and lower molars as nearly all known mammals, the upper molars lying just behind the equivalent lower molars.

Diphyodonty (one replacement set, i.e. two dentitions) probably evolved as a result of the increasing efficiency of the dentition created by the use and wear of teeth that would shear against each other. On eruption, the (unworn) teeth do not fit accurately together and so work inefficiently. There is no point in producing a succession of such inefficient dentitions, as every newly erupted molar, because of its high unworn cusps, would have disrupted the smoothly efficient shearing edges which are created by attrition (see Figures 1 and 2).

Figure 1: Early wear of teeth in a gorilla

Figure 2: Early wear of teeth in a human who lived about 10,000 years ago. The wear has produced a sharp edge of enamel on the first molar, which is very efficient for shearing and cutting of coarse food, and the flatter occlusal surface allows for efficient grinding. This person was a coastal-dweller, and lived on a variety of foods, including fish and crustaceans. The other teeth still have enamel occlusal surfaces.

A deciduous dentition also helps to solve the problem of providing a child with a most effective masticatory apparatus appropriate to their needs at that time, and consistent with the space available in the jaws. The potential functional weakness of a transition period is minimised by the sequence of events: when the central incisors are lost, the deciduous lateral incisors and canines can be used to incise food, whilst loss of the deciduous molars does not prevent crushing and grinding because the first permanent molars are already in place.

The allied development of a gomphosis (periodontal ligament type attachment) allows the position of each tooth to be adjusted after eruption, in response to forces produced during chewing, so that it normally ends up in the most efficient position. This adjustment can only take place within very narrow limits, so that it seems that environmental forces provide a fine adjustment for the basic developmental controls that ensure that the jaws, and the teeth within the jaws, develop in the correct relationship.

Features of natural occlusions

In the unworn dentition, which used to occur only soon after the teeth erupted and before they were worn down by the diet, the pathways the teeth take are dependent on the cusps and morphology of the occlusal surfaces of the teeth, as well as on the morphology of the joints. In chewing, the lower teeth move across the uppers, passing through the intercuspal position, usually without stopping. The intercuspal position is used during chewing, swallowing, and during deliberate clenching of the teeth.

During function, the presence of unworn cusps usually results in a separation of the teeth on one side, whilst the teeth contact on the other side of the arch. This is observed most obviously during lateral movements but also occurs in protrusive movements when the anterior teeth contact and the posteriors do not. These occlusal and articulating relationships are those of what has become called “ideal occlusion” by those dentists who have used mechanistic philosophies and explanations, based on observations of how things are rather than on *why* things are. There are those, however, who realise that a *biological* explanation should be sought for the way in which teeth come together and function under different conditions. And it is the different conditions that have caused the problems.

Under the influence of an abrasive diet, the majority of natural dentitions display no malocclusion, largely because of the wear that takes place. However, since the Industrial Revolution and the refinement of foodstuffs and their preparation, human dentitions no longer function as it appears they “should”. The requirement that teeth that are lost be replaced has made the dental profession aware of the difficulties encountered in replacing the complex morphology of an unworn tooth. That requirement made dentists look minutely at the form of each tooth, and more especially at the form of its occluding surface in order to make replacement teeth fit into, and function with, the remaining teeth. It is from this perspective that the concept of “ideal occlusion” has arisen: but it really describes how teeth relate to each other after they have erupted but before they have worn.

Although this lack of wear in the dentition can lead to misunderstandings as to its natural function, the fact remains that we are faced with repairing and replacing teeth within such an unnatural environment. Further, we are faced with complete dentitions that do not function harmoniously in terms of the masticatory system as a whole (which includes muscles and joints). It is, therefore, necessary to understand how unworn dentitions are supposed to function, provided one does not lose sight of the fact that they were in fact meant to wear. Hence concepts such as “protrusive occlusion” and “canine lift” may have no real biological meaning. From the biological point of view there seems little justification for building these concepts into a reconstructed dentition, especially when the materials used are by their nature incapable of wear.

Artificial occlusions

When replacing natural teeth with artificial teeth, it is imperative that the replacements function in harmony with the entire system of jaws, muscles and joints. When teeth are lost, their surrounding bone resorbs, and an alveolar ridge of varying shape and size is left, covered by mucosa of varying quality and thickness. When complete dentures are constructed to fit onto this base of mucosa-covered bone, they remain static only when the jaws remains static. All dentures move in function, and one of the prime aims in the construction of complete dentures, is to ensure that this movement is reduced to the minimum, and can be controlled by the patient to allow for optimal function. One of the most important determinants of these inevitable denture movements, is the way the teeth come together, and how they function together.

If, when the artificial teeth do contact, they do so in the same way as in the unworn natural dentition, then it should be quite obvious that this is likely to induce unwanted movements of the denture base. If only one side contacts, or even if only one pair of teeth contact (as is often the case when canines are the only contact in lateral movements in some natural dentitions) then this will produce a tipping of the denture bases which will be extremely difficult if not impossible for the patient to control (Figure 3).

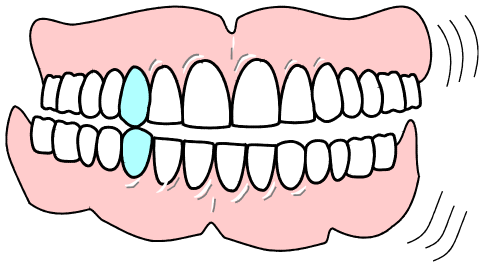


Figure 3: If, when the patient moves to the side during chewing, there are only one or two tooth contacts, then the denture bases will tip up and be very difficult to control. If they do not tip because the ridges and/or the patient's muscle control prevent this, they will still move, but will create pain, discomfort, and ulceration.

But if the tooth contacts caused the denture bases to tip up until the teeth on the other side met, they would then guide the bases into a more stable position with as many teeth contacting as possible. It would therefore be entirely logical to try to achieve that situation in the first place, to limit or prevent these tipping actions by ensuring that as many teeth contact on both sides of the arch (and at the front and the back of each arch) during as many different positions of the jaws during chewing. In other words, an occlusion that balances both sides with each other, and the anterior part with the posterior part.

Interestingly, this "balanced occlusion" is precisely the situation that occurs in the naturally worn natural dentition. But even in unworn natural dentitions, during chewing, where there is an ever decreasing bolus between the teeth, it is possible to identify tooth contacts on both sides of the arch. In addition, numerous studies on occlusal contacts have shown that the position at which all the teeth come together – centric occlusion – is the position most often used during mastication, and is the position at which masticatory forces are greatest. Furthermore, the tooth contacts during swallowing seem to follow a similar pattern to those occurring during mastication – in other words, a slide around, and then into, centric occlusion.

A phrase was coined in the mid '60s to explain the movements of dentures that occurred whatever the occlusal scheme used, which stated "enter bolus, exit balance". The above discussion though, has shown that "balancing" tooth contacts occur even in the natural dentition; the contacts are the result of the great variety of jaw position that occurs around centric occlusion. But in an artificial dentition, with denture bases only really being controlled by muscle activities (albeit to varying degrees), it becomes *imperative* that balancing contacts occur as soon as possible into, around, and out of centric occlusion, so as to minimise any movement of the denture bases.

Normal masticatory function, though, represents only one aspect of the use of complete dentures and artificial teeth. Centric occlusion is the most frequently used position during mastication but also during swallowing, an action that occurs about 1500 times in 24 hours, and so any slide into centric occlusion, the position adopted during swallowing, should be balanced to minimise denture movement and undue forces being exerted on the base. Other actions also take place, that can jeopardise even the most ideal arrangement of denture bases and artificial teeth. For example, it has been shown that the total time the teeth are in contact during masticatory activities in a 24-hour period is about 10 minutes; but *non*-masticatory contacts in the same period can amount to 2-4 hours. If the manner in which the denture teeth come together during these non-masticatory contacts is unstable, then the dentures will move even more, and be even more difficult to control for the patient. These movements will subject the underlying tissues – mucosa and bone – to unnecessary trauma.

The inevitable conclusion all the above evidence points to, is that the occlusal scheme for complete dentures should be one in which there are as many contacts around the arch as possible at all excursive movements away from, and back into, centric occlusion.

Terminology

In an attempt to create some consistency of understanding of prosthodontic terms, the American Academy of Prosthodontics has, over the years, produced a *Glossary of Prosthodontics Terms*, published in the Journal of Prosthetic Dentistry. The seventh edition, published in 1999, contains a variety of terms related to occlusion, and in some cases several alternative definitions of the same terms. These definitions have arisen as a result of various researchers over the years trying to gain a better understanding of jaw movements and the way in which teeth come together. The definitions reflect the various approaches to this understanding, from the mechanistic to the biological and bio-functional. It is the latter approach – a *bio-functional* approach – which is most likely to endure the current rigour of scientific inquiry, and the need for both understanding as well as therapeutic interventions, to be based on sound evidence. Therefore, this section will recommend the use of terminology which it is hoped will allow for a consistent understanding of occlusion and complete dentures, and take into account the different requirements and conditions of complete denture occlusion rather than natural dentition occlusion.

The interpretations of the word occlusion in dentistry, seems to have influenced its earlier non-dental meanings, as even a 1983 edition of Chambers 20th Century Dictionary includes the following: "*occlusion*: *v.i.* to bite or close together (as the teeth); *occlusion:* the bite or mode of meeting of the teeth". The Glossary of Prosthodontic Terms defines occlusion as "the static relationship between the incising or masticatory surfaces of the maxillary or mandibular teeth or tooth analogues". Centric occlusion is defined by the Glossary of Prosthodontic Terms as "the occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximum intercuspal position". Such a definition contains two other terms which then also need to be defined, which can get quite confusing. For example, when one goes on to the term centric relation, there are *seven* definitions of this. In an attempt to unpack and better define these terms, they have been set out in Figure 4 on the following page.

It is useful to distinguish between occlusion and *articulation* because the former refers to a static relationship, whereas the latter term refers to what has been called "occlusion in motion". The definitions in Figure 4 are taken from the seventh edition of the Glossary of Prosthodontic Terms.

Figure 4: Recommended terminology on occlusion and articulation

Occlusion
The static relationship between the incising and masticatory surfaces of the maxillary or mandibular teeth or tooth analogues.

Maximum intercuspation
The complete intercuspation of the opposing teeth, independent of condylar position.

Centric occlusion
The occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with maximum intercuspation.

Centric relation
The most retruded physiological relation of the mandible to the maxillae to and from which the individual can make collateral movements. It is a condition that can exist at various degrees of jaw separation. It occurs around the terminal hinge axis.

Terminal hinge axis: this term is now referred to as the **transverse horizontal axis**
An imaginary line around which the mandible may rotate within the sagittal plane.

Articulation
The contact relationship between the occlusal surfaces of the teeth during function.

Mutually protected articulation
An occlusal scheme in which the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation, and the anterior teeth disengage the posterior teeth in all mandibular excursive movements.

Balanced articulation
The bilateral, simultaneous, anterior and posterior occlusal contact of teeth in centric and eccentric positions.

Anterior protected articulation
A form of mutually protected articulation in which the vertical and horizontal overlap of the anterior teeth disengage the posterior teeth in all mandibular excursive movements.

Lingualised articulation
Does not appear in the Glossary: lingualised occlusion is defined as a form of denture occlusion which articulates the maxillary lingual cusps with the mandibular occlusal surfaces in centric working and non-working mandibular positions.

It can be seen from Figure 4 that the definitions attempt to cover both natural and artificial dentitions, and therefore fall short of good working definitions for complete dentures. For example, the different "articulations" described do not really give a sense of occlusion in motion. Hence the following explanations and definitions are suggested for complete dentures:

Centric relation

When constructing complete dentures, there are only approximate guides available to determine where to place the teeth; two of the most important of these are the vertical and horizontal relationship of the mandible to the maxillae. The mandible, though, exhibits a consistent movement vertically only when it undergoes pure rotation around a horizontal axis, and this can be used to obtain a reproducible mandibular position at a determined vertical dimension. At this occlusal height, the teeth are placed so that the most stable tooth contacts occur in maximum intercuspation.

Therefore a definition of centric relation for complete denture construction needs to take into account the ability of the mandible to obtain a consistent *horizontal* relationship at which the teeth can occlude in a stable manner once the *vertical* height of occlusion has been determined.

Definition: the most retruded physiological relation of the mandible to the maxillae to and from which the individual can make lateral movements; the position is clinically determined when the condyle-disc assemblies articulate in the anterior-superior position against the articular eminences; it is restricted to a reproducible rotary movement about the transverse horizontal axis; it is the position at which maximum intercuspation of the teeth can occur at the determined vertical dimension of occlusion.

Transverse horizontal axis (terminal hinge axis)

Definition: an imaginary line around which the mandible can produce a vertical hinge or rotary movement of approximately 25 mm.

Maximum intercuspation

This term better describes what in natural dentitions is centric occlusion, but for complete dentures, it must include the horizontal and vertical relationships of the mandible to the maxillae. The term can be a little misleading, though, as not all teeth used in complete dentures necessarily have occlusal schemes that generate an interdigitation of cusps – an "intercuspation". However, all teeth, whether with shallow cusps or no cusps, do have a "best fit" arrangement, and it is this that is required in order to produce a stable relationship.

Definition: the static relationships and contacts between the mandibular and maxillary artificial teeth that produce a stable relationship between the incisal and masticatory surfaces, when the mandible is in the centric relation position at the desired vertical dimension of occlusion.

Articulation

As mentioned previously, this term refers to all relationships of the teeth in any position away from that of maximum intercuspation. In complete dentures, the objective is to provide as many simultaneous contacts as possible, and different types of occlusal scheme have been devised to achieve this, hence the different qualifying definitions of the term articulation.

Definition: the contact relationship of the teeth during function when not in the position of maximum intercuspation.

Balanced articulation

Definition: the continuing contacts of as many mandibular and maxillary artificial teeth as possible in all excursive movements away from, and into, the position of maximum intercuspation.

This term can apply to any type of occlusal scheme, using cusped teeth or cuspless teeth, or any combination of these. There seems little point in producing sub-definitions of balanced occlusion, except where they describe specific occlusal schemes (e.g. lingualised articulation/occlusion), and these will therefore be dealt with later.

The biomechanics of functional occlusal contacts

In order to understand how balanced articulation is achieved, the following discussions will be based on the use of cusped artificial teeth; modifications of these arrangements will be dealt with in later sections.

It is assumed that the teeth start by having cusp to fossa relationships that are similar to those of natural teeth, and that they are set in maximum intercuspation to maintain these relationships. This is fairly simple, because the teeth are manufactured to fit together maintaining these cusp-fossa contacts. However, as soon as the mandible moves out of centric relation position, other factors come into play.

Protrusive movements

There are two determinants of mandibular movement in any forward direction, the *incisal guidance angle* and the *sagittal condylar guidance angle*.

The incisal guidance angle (IGA) is formed by the vertical overlap (overbite) between the teeth (Figure 5). It is only dependent on the amount of horizontal overlap (overjet) to the extent that there *is* no guidance until the teeth actually contact. In natural teeth, these dimensions of overbite and overjet are determined by the positions of the teeth; in complete dentures, they are determined by other factors, mainly aesthetics, phonetics, and function. This means they can be controlled by the dentist, within the limitations of the other factors that determine overall tooth position (mainly the imperative to place artificial teeth in the positions occupied by the natural teeth in health).

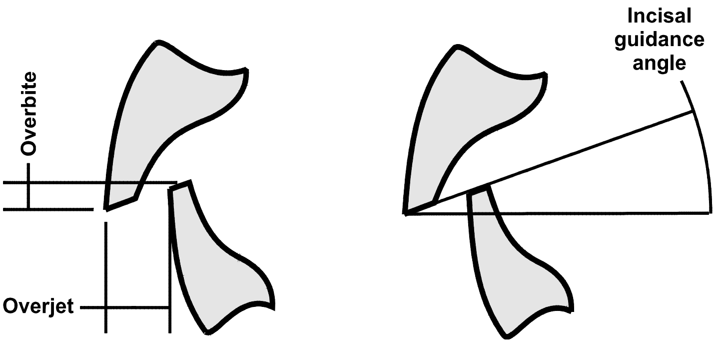


Figure 5: The incisal guidance angle is formed by the amount of vertical overlap or overbite between the teeth, when viewed in the sagittal plane.

The sagittal condylar guidance angle (SCGA) (Figure 6) is not under the control of the dentist at all, and is determined purely by the biomechanics of the joint itself. This is the net result of the condyle-disc assembly passing forwards and downwards, under the influence of the anterior slope of the glenoid fossa. In fact, the condyles do not traverse along a straight-line path as in the diagrams given here, but take a very shaky zig-zagging pathway, the net result of which can be represented by a straight line. The actual pathway has a non-linear shape because of the nature of the joint itself – it is very slippery (about five times more slippery than ice on ice) and yet the condyle has to resist any forces acting at the teeth, in all positions it may occupy within the glenoid fossa.

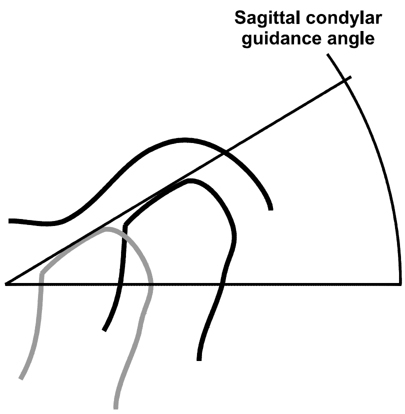


Figure 6: The sagittal condylar guidance angle is the average path taken by the condyle during a forward movement from centric relation position, when viewed in the sagittal plane.

The form of the condyle and fossa means that any forward movement of the mandible is also a downward movement: if record blocks are placed midway between the incisors and condyles on a flat plane, they will separate if the mandible moves forwards (see Figure 7). Similarly, if teeth are placed in place of flat record blocks, again on a flat plane, they will also separate, unless they can be given cusps with inclines that may fit in with the geometry of the path of movement of the mandible.

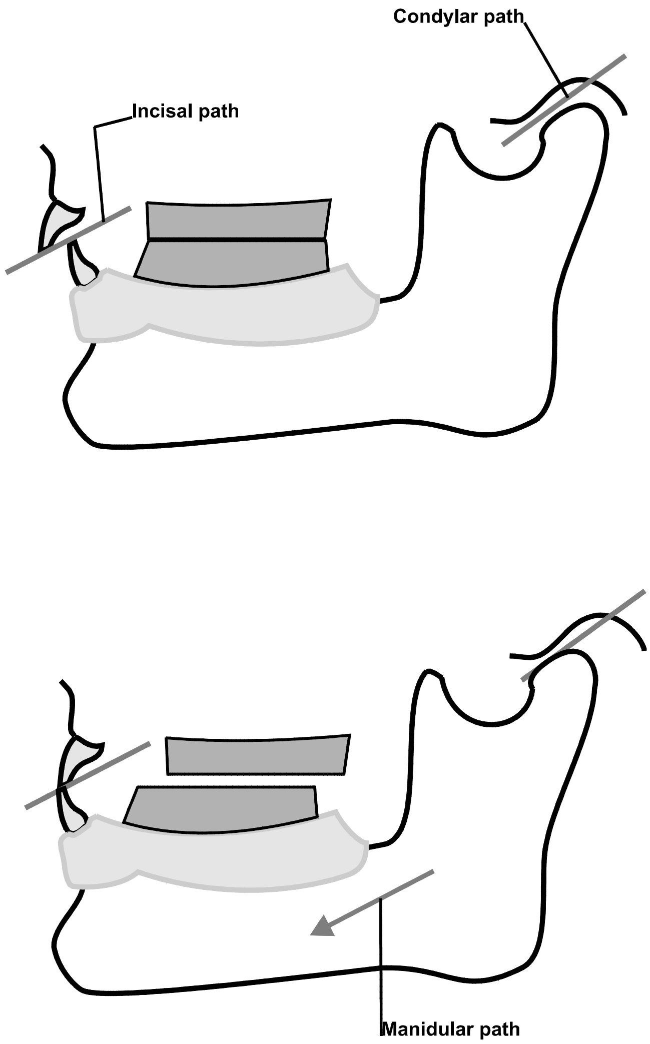


Figure 7: The so-called "Christensen phenomenon", in which the mandibular path in a forwards direction produces a downward displacement of the mandible. This means that record blocks, for instance, set on a flat plane will separate when the mandible moves forwards.

For example, consider Figure 8. The IGA has been given a value of 10° and the SCGA a value of 30°. Teeth have been placed between, with very stylised cusps with angles of 20° (see Figure 9).

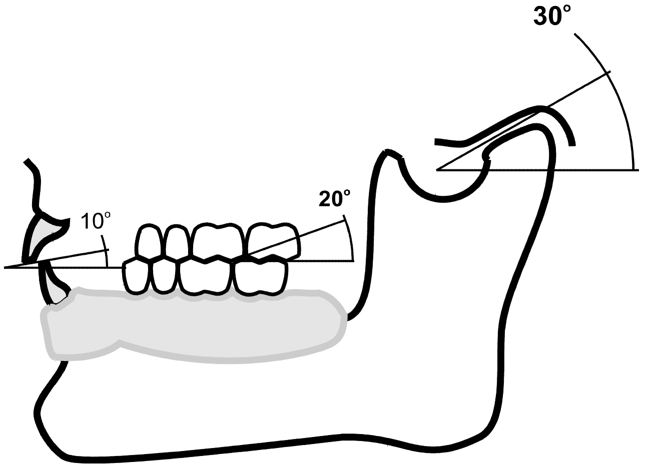


Figure 8: The incisal guidance angle is 10° and the sagittal condylar guidance angle is 30°. Teeth have been placed on a plane, and have 20° cusp angles, as illustrated by the distal cusp of the upper first molar

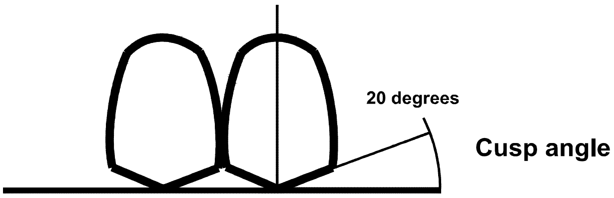


Figure 9: The cusp angle of these teeth is 20° when the teeth are positioned upright against a flat plane.

If now the mandible moves forwards, it will do so on an arc which will be steeper posteriorly, as it is under the influence of the 30° condylar guidance angle, than anteriorly, where it is under the influence of the smaller 10° incisal guidance angle (see Figure 10). As the mandible moves forwards, at a point mid-way between the posterior and anterior determinants of its pathway, the teeth will remain in contact, because they have 20° cusp angles. However, anterior to this mid-point, and posterior to it, the teeth will separate, because the cusp angles need to be closer to 10° anteriorly, and closer to 30° posteriorly (note that the slopes of the cusps that remain in contact are the distal slopes of the uppers and the mesial slopes of the lowers).

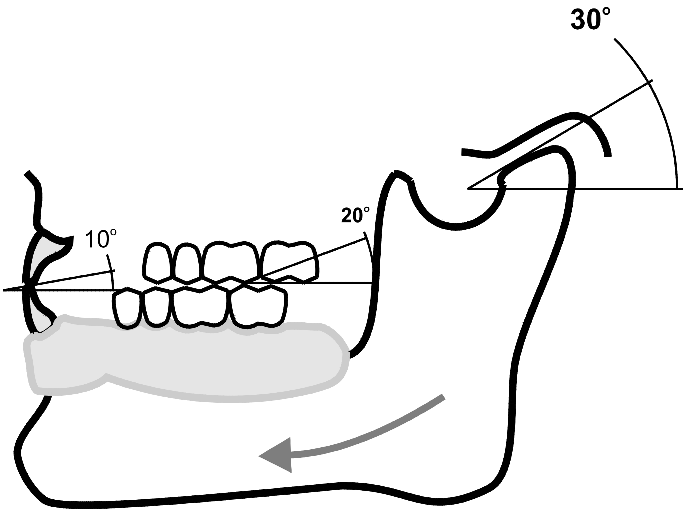


Figure 10: The mandible's path is an arc which is steeper posteriorly than anteriorly. The only teeth that will remain in contact are those mid-way between the 30° movement posteriorly and the 10° movement anteriorly, i.e. whose cusp angles are 20° at the mid-point of the arc (30+10=40; half of 40=20).

So how do the cusp angles of the teeth change? They could of course be ground, but they could also change by changing the axis of the tooth relative to the plane of occlusion. If the tooth is tilted five degrees say, then the *effective* cusp angle will be 25° on one side and 15° on the other, depending on the direction of the tilt (Figure 11).

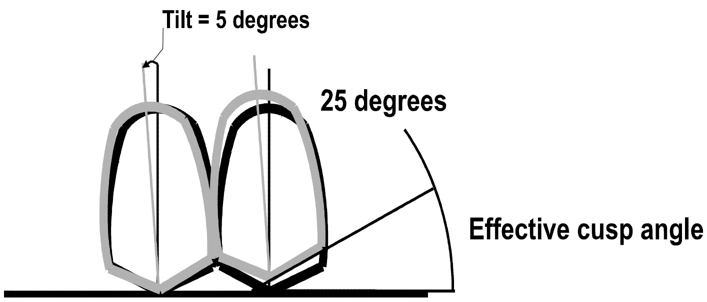


Figure 11: The teeth are tipped five degrees, making the effective cusp angle of the distal slopes 25°, and reducing the mesial slopes to 15° (after Watt and McGregor, 1976).

This tilting of the teeth to correct the cusp angles can now be used to ensure that the teeth remain in contact during a protrusive movement of the mandible. For example, suppose the incisal and condylar guidance angles are such that it is necessary for the effective cusp angles of the distal slopes of the upper cusps (and therefore of the mesial slopes of the lowers also) to be 10° at the first premolars, and 30° at the second molars. If the teeth have an actual cusp angle of 20°, then the premolars must be tilted to *reduce* that angle to 10° at the first premolar, and the second molar must be tilted to *increase* that angle to 30°, as shown in Figure 12.

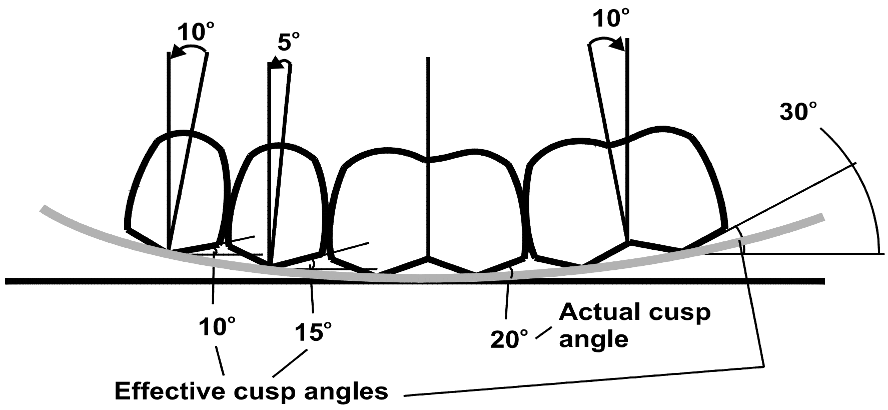


Figure 12: The teeth are tilted to increase or decrease the effective cusp angles to compensate for the arc of the path of the mandible in protrusion (after Watt and McGregor 1976).

If all the cusp tips are connected, it will be found that they now no longer lie on a straight plane, but on a curve: this curve will be in harmony with the arc of movement of the mandible, as it will have compensated for that arc, determined by the incisal and condylar guidance angles. This *compensating curve* will vary, therefore, according to any variation in these determinants of the mandibular pathway, as illustrated in Figure 13.

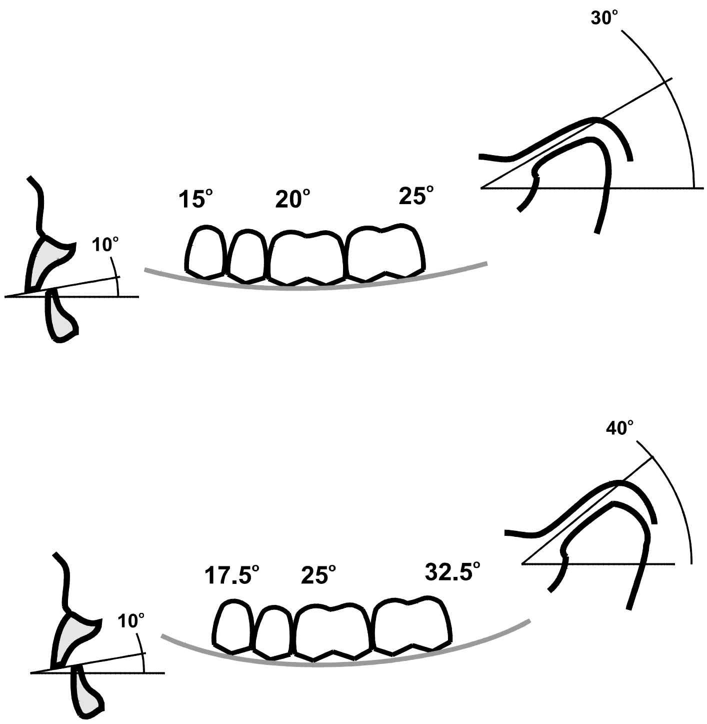


Figure 13: The steepness of the compensating curve varies according to the condylar guidance angle as the incisal guidance angle remains the same. So with a 30° condylar guidance angle, the curve is shallower (upper diagram) than that required for a 40° condylar guidance angle (lower diagram).

Lateral movements

When the mandible moves sideways, the side to which it moves is called the *working* side, and the opposite side of the arch, moving now towards the mid-line is the *nonworking*, or *balancing* side.

Consider a movement of the mandible to the left. As in protrusion, this movement is also not a flat one, but is under the influence of posterior and anterior determinants. The anterior determinant in this case will be any vertical overlap at the corners of the arch, i.e. at the canines. As with the incisal guidance angle, this *canine* guidance angle is under the influence of the operator but subject to the similar constraints of aesthetics, arch form, etc. The posterior determinant is, again, dependent on the anatomy of the joint, as the condyle-disc assembly now comes under the influence of the angulation of the *medial* wall of the glenoid fossa.

Precisely the same principles as followed for protrusive movements can be used to explain the necessary changes in tooth morphology required to ensure tooth contact during lateral mandibular movements. Figure 14 illustrates the problem: the medial condylar guidance angle when viewed from the frontal plane (what used to be called the Bennett angle) is taken to be 40° (for purposes of illustration) and the canine guidance angle, 10°. On the nonworking side a stylised molar is shown with 20° cusp angles. Figure 15 shows which of the slopes of the cusps are involved in order to maintain simultaneous contact on each side of the arch when the mandible moves to the left.

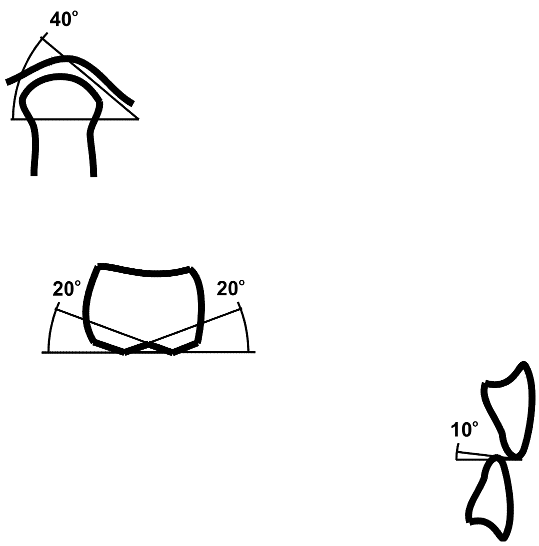


Figure 14: Shows a medial condylar guidance angle of 40°, a canine guidance angle of 10° on the working side and a tooth with 20° cusp angles on the nonworking side.

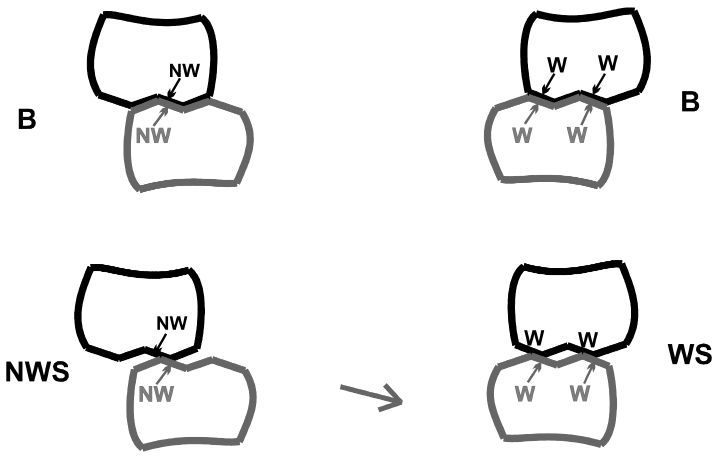


Figure 15: When the mandible moves to the left, the inclines marked **W** must remain in contact on the working side (**WS**) and the inclines marked **NW** must remain in contact on the nonworking side (**NWS**), for balanced articulation.

Consider now just the requirements of the nonworking side cusps, that they remain in contact when the mandible moves to the left. These cusp angles are 20° but if this tooth is placed mid-way between the condylar guidance angle and the canine guidance, then their angle ought to be 25°. Once again, as in protrusion, this can be achieved by tilting the tooth to provide an effective nonworking inclined cusp angle of 25° (Figure 16). If this is done on both sides of the arch, and a line drawn through the cusp tips, another curve is created, this time compensating for the arc of movement of the mandible in a lateral direction.

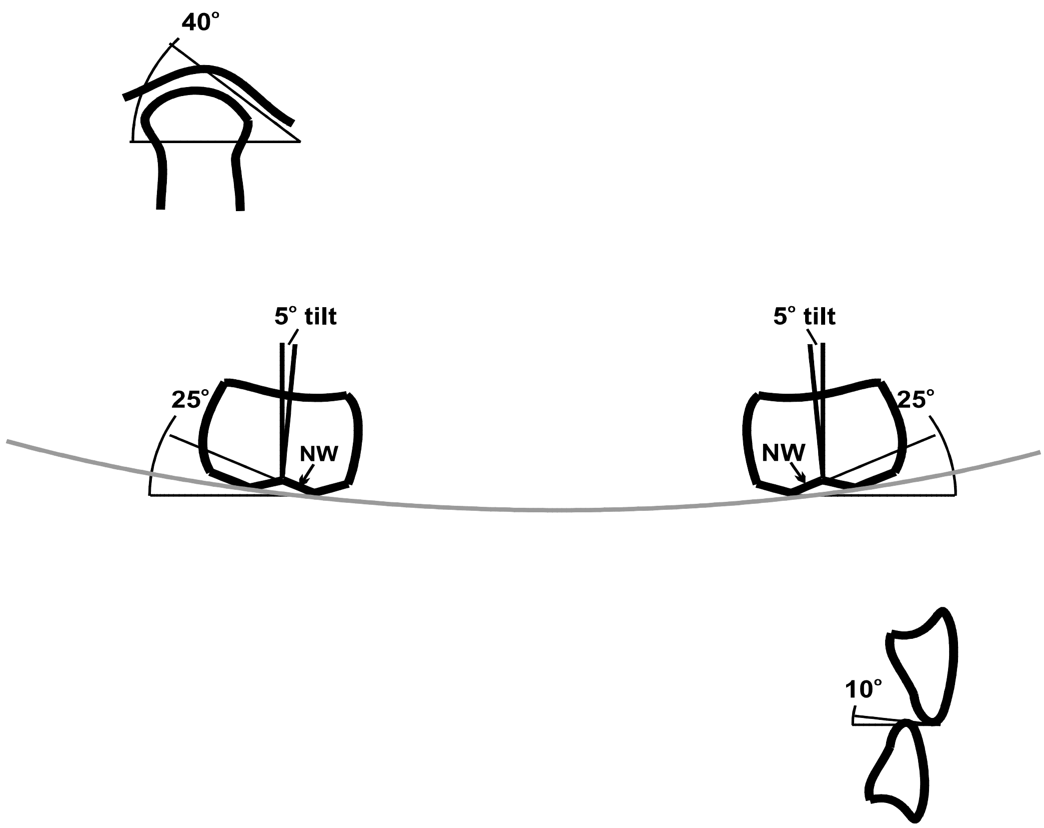


Figure 16: The nonworking inclines (**NW**) have been effectively increased to 25° by tilting the teeth, thus generating a compensating curve when viewed in the frontal plane.

These examples have assumed that the condyle on the working side has no influence on the mandibular movement, but unfortunately this is not so. Although it is often called the "orbiting" condyle because its movement is predominantly one of rotation, it does in fact move sideways, this time under the influence of the slope of the lateral wall of the glenoid fossa. This *lateral* condylar guidance angle will therefore influence the inclinations of the *working side* slopes of the cusps that must remain in contact. For purposes of illustration the predominant cusps involved have been shown in Figure 17, again at a point mid-way between the canine guidance and the condylar guidance. It is evident that the tilt of the tooth will produce the desired nonworking incline angles, but is insufficient in itself to produce the required *working* incline angles, given the angles shown. This clearly has implications for the way in which teeth are set up and adjusted, to achieve a fully balanced articulation.

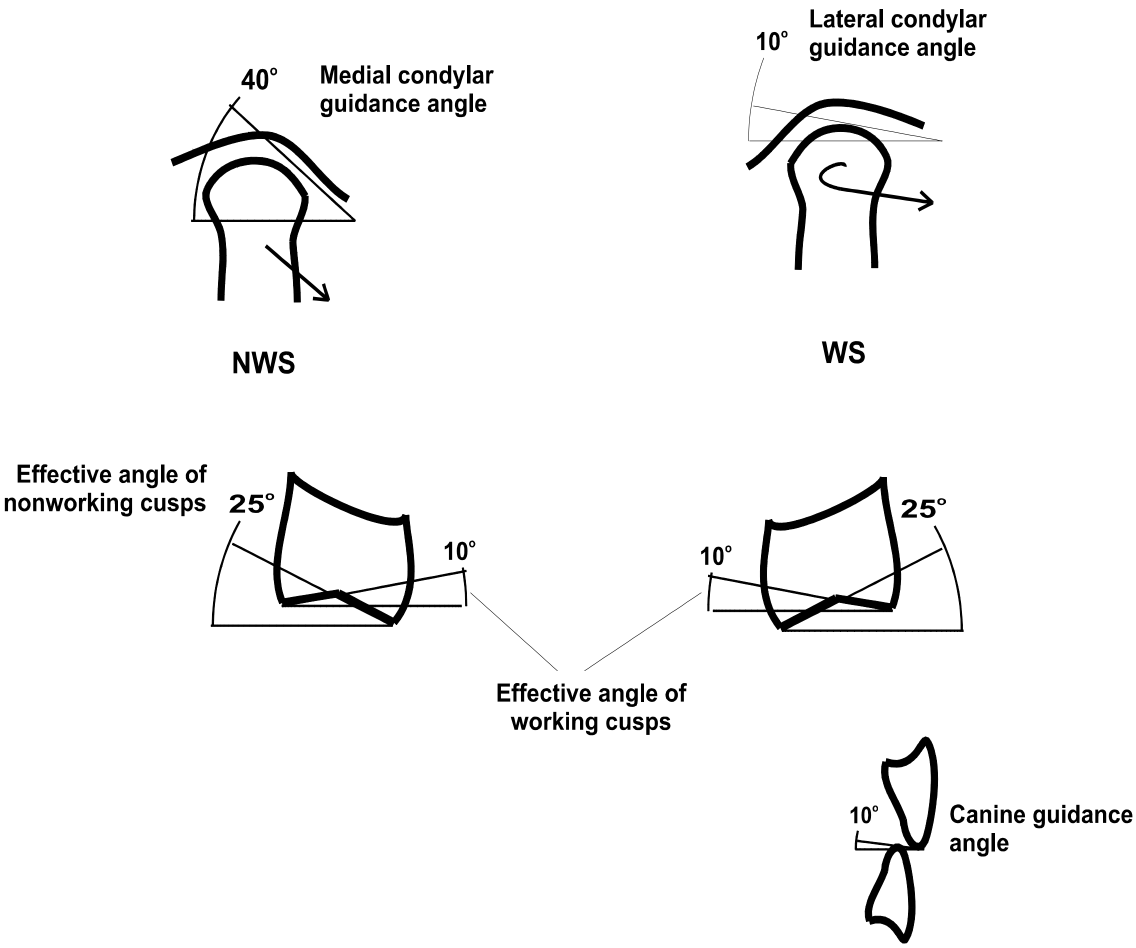


Figure 17: Although the nonworking inclines are in harmony by tilting the tooth to make them 25°, the working inclines need to be adjusted (ground) in order to reduce them to the required 10° to compensate for the lateral condylar guidance angle of 10°. **WS**: working side; **NWS**: nonworking side. (after Watt and McGregor 1976).

Technical aspects of balanced articulation using cusped teeth

The discussion thus far has assumed that the jaws are in a skeletal Class I relationship, and that the tooth arch also conforms to this. Other jaw relationships will be dealt with later.

Cusped artificial teeth are manufactured with varying degrees of cuspal angles, usually 20°, 30°, or 33°. The choice for balanced articulation will of course depend on the determinants already discussed, but it must be realised that some adjustment to the teeth will be inevitable, over and above the positioning of the teeth for the creation of the required effective cusp angles and the compensating curves.

Balanced articulation can be created for many if not for most complete denture cases by using average values for the patient's condylar guidance, and using 20° cusped teeth. Although some studies have shown average values for the condylar guidance to be 35° the so-called “average-value” articulators are set to a value of 30° on each side for the sagittal condylar guidance, and 15° for the medial condylar guidance angle.

Teeth can be set up on this type of articulator using the appropriate compensating curves, and a balanced protrusive articulation will be obtained, as well as an almost balanced lateral movement articulation. The lateral articulation cannot compensate for the working side movements fully: nevertheless, without any physical alterations to the teeth, a remarkable degree of balance can be obtained.

It is recommended that no physical alterations be made at this stage, for two main reasons. First, and most obvious, not all patients conform to the average values of the articulator and so inevitably there will need to be further alterations made and this can only be tested in the mouth. Second, even if there appears to be a close correlation between the set-up on the articulator and that which is observed in the mouth (i.e. the patient's condylar guidance angles are not too different from those of the set-up), there will inevitably be some post-processing changes to the positions of the teeth. For this reason, once the dentures have been processed, they will be re-mounted on the articulator, and now physical alterations can be made to cusp angles, slopes, etc., to compensate for processing errors, and also to achieve a fully balanced articulation.

Clinical aspects of balanced articulation using cusped teeth

As stated above, when setting teeth to average values, there will inevitably be a discrepancy when the articulation is viewed in the mouth. At this stage, a decision must be made as to the degree of discrepancy and its clinical importance.

Clearly the first consideration will be the horizontal and vertical jaw relationships, so that there is maximum intercuspation at a reproducible horizontal position (centric relation) and at the desired occlusal vertical dimension. Then when the patient is guided into excursive movements, the quality of the tooth contacts must be compared to those obtained on the articulator. If there are very obvious discrepancies, then these are most likely to be due to a discrepancy between the patient's condylar guidance angles and those of the articulator. In the clinical setting, a decision must then be made to either accept this, and try to adjust the articulation after the dentures have been processed (i.e. using the mouth as the better articulator), or whether the adjustments required will be too great, and the morphology of the teeth will require far too much adjustment. In this latter case, and ideally for all cases where there *is* an obvious discrepancy between the patient and the articulator, it is preferable to use a semi-adjustable articulator – one that will enable the clinician to relate the maxillae to the mandibular axis, and that will allow for the condylar guidance angles to be adjusted to mimic those of the patient as closely as is practical.

Correcting occlusal errors in balanced articulation using cusped teeth

Once the dentures have been processed, and replaced on the articulator, then the final adjustments can be made to ensure that functional contacts exist during all excursive movements away from maximum intercuspation. Maximum intercuspation is adjusted for first, as this is the most frequent position and must be the most stable, and then lateral and protrusive movements are adjusted. The teeth cannot of course be moved, and so it is important to be aware of the consequences of any tooth adjustments made. This requires an awareness of which aspects of each cusp of each tooth are involved in which functional movements. The most obvious example of this, is the relationship of the cusps and fossae in maximum intercuspation. Figure 18 illustrates teeth with stylised cusps, to show the different slopes of these cusps, in a frontal plane. The cusps intimately involved in this contact are clearly the upper palatal cusps and lower buccal cusps, contacting the central fossae of their opposing teeth.

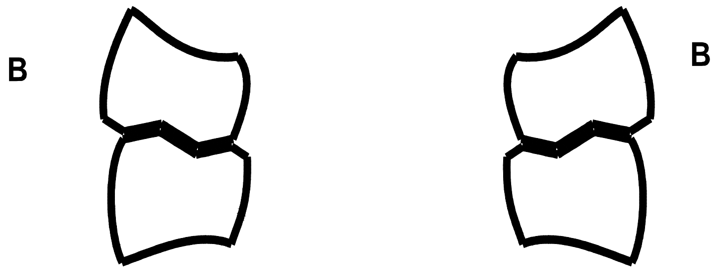


Figure 18: Position of maximum intercuspation showing cusp/fossa relationship of the upper palatal and lower buccal cusps with the central fossae of the opposing teeth. **B**: buccal side

When the mandible moves to the left as shown in Figure 19, the aim is, as shown, to maintain contact between the nonworking side slopes of the cusps as well as the working side slopes. In each case, upper palatal and lower buccal cusps are involved and if these cusps were to be adjusted and shortened as a result, then when the mandible returns to centric relation position, there will no longer be contact between these cusps and their opposing fossae. This then, illustrates the point that when correcting for occlusal errors, other errors must not be introduced.

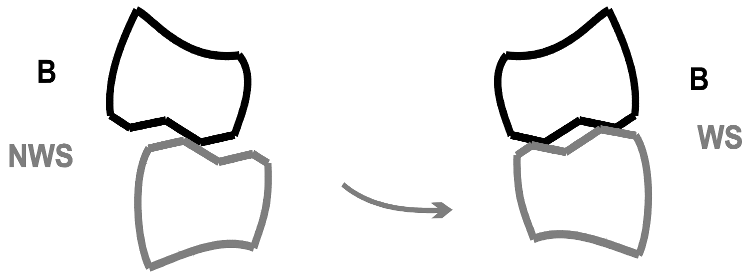


Figure 19: Functional contacts between working side (**WS**) and nonworking side (**NWS**) cusp slopes when the mandible moves to the left. **B**: buccal side.

Correcting for maximum intercuspation

Discrepancies in the static relationship between the teeth in maximum intercuspation are usually due to minor processing errors and corrections must be made to those teeth causing any interference and preventing the achievement of maximum intercuspation for all posterior teeth. There are four types of correction required, one due to a discrepancy in the mesio-distal relationship of the teeth, and the others due to discrepancies in the bucco-lingual relationships.

1. Mesio-distal discrepancy: discrepancies in mesio-distal relationships in maximum intercuspation (as opposed to protrusive interferences) will usually be due to interferences between the mesial slopes of the upper cusps and the distal slopes of the lower cusps. The teeth are adjusted by grinding the appropriate slopes of the cusps involved (Figure 20).

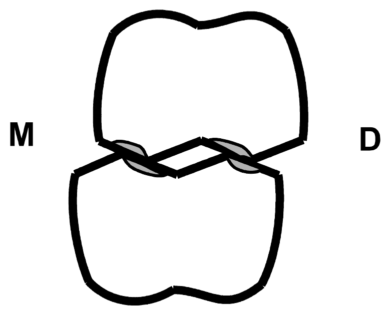
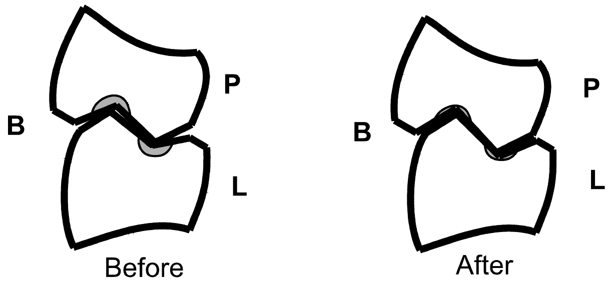


Figure 20: Errors in the mesio-distal relationship between the teeth are corrected by grinding the shaded areas: mesial slopes of the uppers and distal slopes of the lowers. **M**: mesial; **D**: distal.

Mesio-distal discrepancies are also observed dynamically in the mouth, when there is a slide from centric relation position into maximum intercuspation. This results from an incorrect jaw relationship record and will be dealt with later.

2. Cusps appear to be too long: if the interference is because some cusps appear to be the only ones contacting, it appears as if they are too long (Figure 21). The cusps involved are the supporting cusps, so the opposing *fossae* are deepened until an appropriate cusp-fossa relationship is obtained.

Figure 21: Cusps appear to be too long: grind the opposing fossae, not the cusps themselves. **B**: buccal; **P**: palatal; **L**: lingual.



3. Insufficient overjet: the posterior teeth may appear to have insufficient overjet in some places, with the upper and lower teeth seeming to be contacting end-to-end (Figure 22). The interfering slopes must be adjusted, because the effect desired is that of “moving” the cusps into the correct relationship. Hence the buccal cusps effectively are moved inwards, and the palatal and lingual cusps moved outwards, so that the cusp tips contact the central fossae. In the process, the central fossae are widened and the cusps appear to become narrower.

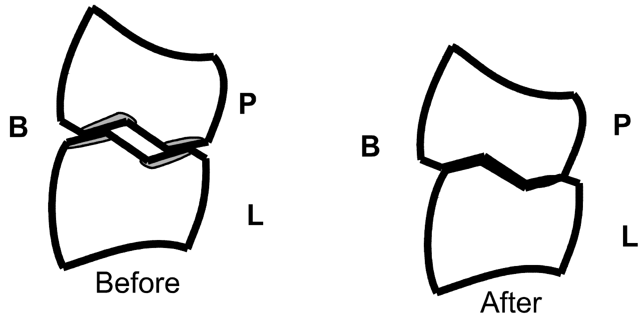
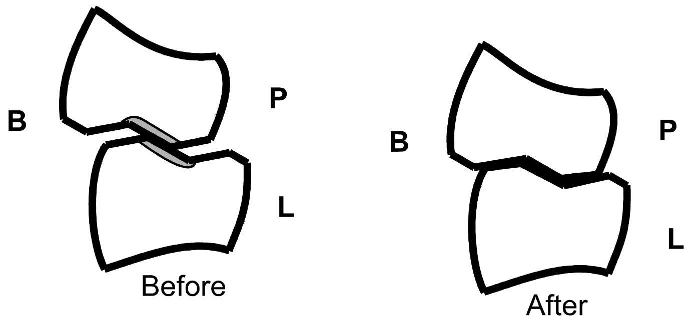


Figure 22: The teeth appear to be placed end-to-end: grind the inclines to move the upper cusps buccally and lower cusps lingually. **B**: buccal; **P**: palatal; **L**: lingual.

4. Overjet too large: the last type of discrepancy in maximum intercuspation is when there now appears to be too great an overjet, with the uppers appearing to be too far buccal to the lowers (Figure 23). Once again, the length of the cusps must not be reduced, so now the inclines are adjusted to effectively move the upper cusps inwards and the lower cusps outwards. The result is again similar, of widening the central fossae and narrowing the offending cusps.

Figure 23: Upper teeth are too far buccal: grind the inclines to move the upper palatal cusp palatally and the lower buccal cusp buccally. **B:** buccal; **P**: palatal; **L**: lingual.



Correcting for lateral excursive movements

When the mandible moves laterally, the aim is to have contact on all working side as well as nonworking side cusp slopes.

1. Working side interferences: working side interferences can either be due to the buccal cusps contacting, or the lingual and palatal cusps contacting, or both, thus preventing any contacts on the nonworking side. Figure 24 shows an interference between the buccal cusps: the lower buccal cusp is a supporting cusp and so should be avoided: the adjustment is made on the upper buccal cusp, from the central fossa to the cusp tip. If this cusp is shortened in the process, it will not affect the maximum intercuspation or any other movement. If the upper palatal and lower lingual cusps are causing the interference (Figure 25), then again the non-supporting cusp should be adjusted, i.e. the lower lingual cusp.

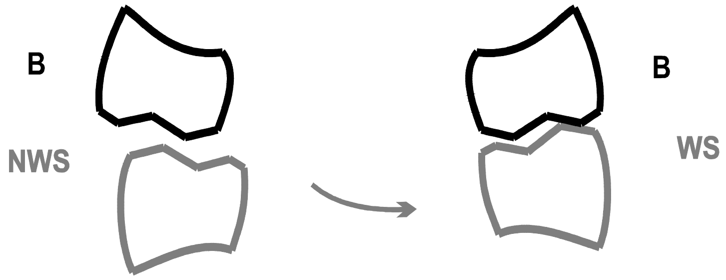


Figure 24: Working-side buccal cusps are preventing contact of any other cusps: grind the incline of the upper buccal cusp from central fossa to cusp tip, *not* the lower buccal cusp, which is a supporting cusp. **B**: buccal side; **WS**: working side; **NWS**: nonworking side.

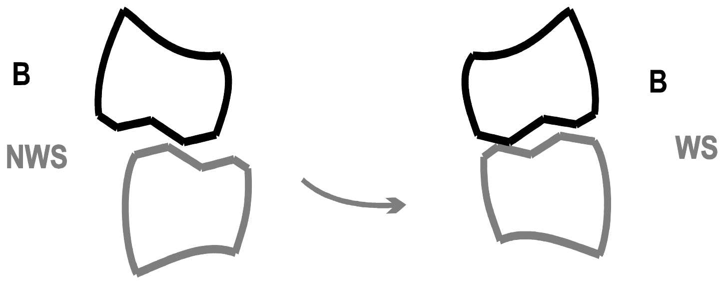


Figure 25: Working side palatal and lingual cusps are causing an interference: grind the inclines of the lower lingual cusp from central fossa to cusp tip *not* the upper palatal cusp, which is a supporting cusp. **B**: buccal side; **WS**: working side; **NWS**: nonworking side.

2. Nonworking side interferences: nonworking side interferences occur between the upper palatal cusp inclines and the inclines of the lower buccal cusps (Figure 26). The problem here, is that *both* these cusps are supporting cusps, and so great care must be taken to preserve as much of the cusp as possible. Therefore those parts of the inclines causing the interference are adjusted, and their relationship in maximum intercuspation constantly checked whilst doing so. If it appears that cusp heights *must* be changed, it is preferable to preserve the upper palatal cusp, and rather adjust the lower.

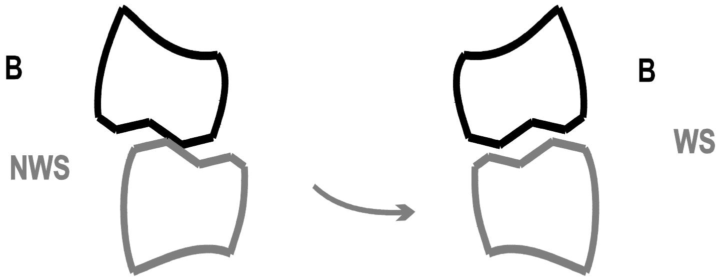


Figure 26: Nonworking side interferences are between inclines of supporting cusps: adjust only those parts of the inclines that contact, preserving the cusps as much as possible, especially the upper palatal cusp. **B**: buccal side; **WS**: working side; **NWS**: nonworking side.

Correcting for protrusive movements

1. Anterior interference: interferences caused at the incisors are either because the incisors have too great an overbite, or there is insufficient compensating curvature to the occlusal plane. Clearly either the upper or lower incisal edges must be adjusted. This usually means the lowers, because presumably the clinician has gone to great lengths to ensure the correct level of the upper incisal edges, for aesthetics and phonetics. Hence the inciso-labial surfaces of the lowers are adjusted (Figure 27).

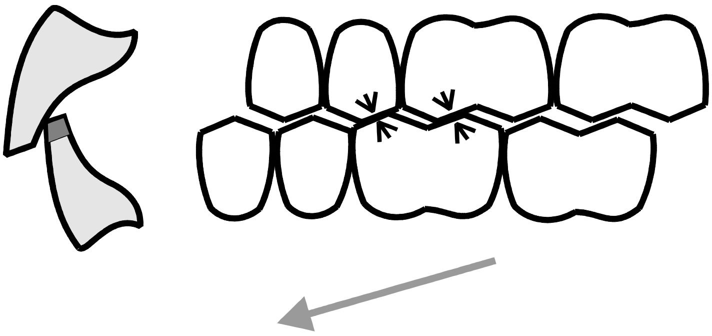


Figure 27: Incisal interferences are adjusted by preferably grinding the lower incisors. Posterior interferences are adjusted by grinding the distal slopes of the upper cusps and the mesial slopes of the lower cusps.

If the problem is due to too shallow a compensating curve, then a decision must be made as to whether this can be corrected by altering cusp angles, or whether to abandon the existing set-up and remount and re-process new teeth with a steeper compensating curve and correct effective cusp angles. If the teeth can be adjusted, then the adjustments required are the same as for a posterior interference to protrusive movements.

2. Posterior interference: posterior interferences to protrusive either cause no contact at the anteriors, or only a few contacts posteriorly (Figure 27). In either case, the offending cuspal inclines must be adjusted: these will be the distal inclines of the upper cusps, thus effectively moving the cusps mesially, and the mesial inclines of the lower cusps, thus effectively moving them distally.

Summary

The correction of occlusal errors can be summarised as in the box below (Figure 28). It is important to understand the consequences of any action that alters the occlusal shape of a tooth *before* adjusting that tooth, so that previous contacts in other positions are not lost. So the process is one of first adjusting for maximum intercuspation and then, *whilst* adjusting for the excursive movements, continually re-checking that maximum intercuspation has not been lost, nor any other contacts in other excursive movements. The results will be an increasingly stable articulation in all reasonable positions of the mandible.

Figure 28: Summary of corrections required after processing (or remounting) the dentures (some of the centric summary refers to text following)

CORRECTING OCCLUSAL ERRORS

CENTRIC

mesio-distal discrepancy (either static, or caused by a slide from centric relation into maximum intercuspation):

–if discrepancy less than width of a cusp:	move mesial inclines of upper buccal cusps distally and distal inclines of lower cusps mesially
–if discrepancy greater than width of a cusp:	remount with a check-bite record
–if discrepancy too great to correct by grinding:	remove posterior teeth, re-take jaw registration, remount and process new teeth in correct positions.

Teeth too long: deepen opposing fossae

Teeth too end to end: grind inclines to move upper cusps buccally and lower cusps lingually
effect: central fossae made broader
upper palatal and lower buccal cusps made narrower

Uppers too far buccal: grind inclines to move upper palatal cusp palatally and lower buccal cusp buccally
effect: central fossae made broader
upper palatal and lower buccal cusps made narrower

LATERAL

Working side: change the incline extending from the central fossa to the upper buccal cusp tip and/or the lower lingual cusp

Nonworking side: reduce the incline on the part of the cusps causing interference: the upper palatal cusp inclines and/or the lower buccal cusp inclines
preserve as much as possible of each interfering cusp**, especially the upper palatal cusp**

PROTRUSIVE

Anteriors: grind inciso-labial surface of lowers in preference to inciso-palatal surface of uppers

Posteriors: move distal inclines of upper cusps mesially and mesial inclines of lower cusps distally

Correcting occlusal errors clinically

The last sentence before the box above should really have finished: “in all positions of the articulator”, for the procedures described have assumed that the articulator is an exact reproduction of the mouth. Clearly this is not the case, and so these procedures need to be repeated, once the dentures are placed in the mouth and all other necessary corrections to the bases have been made.

The first thing to check for will be whether maximum intercuspation coincides with centric relation position, and whether the vertical dimension of occlusion is unchanged. If this latter is practically unchanged and there appear to be only small discrepancies in maximum intercuspation, then these can be adjusted following the same rules as for correcting occlusal errors on the articulator. However, if it is found that there is a large change in the vertical dimension of occlusion, producing an open bite of more than 3 mm, then any adjustments to the teeth to correct this, are going to result in a complete re-shaping of the occlusal surfaces and almost certainly a complete loss of the cuspal anatomy of the teeth. The only recourse is to remove the posterior teeth, re-take the jaw registration, remount on the articulator, and set and process new posterior teeth to the correct occlusal vertical dimension.

If the occlusal vertical dimension *is* correct, then any discrepancy between maximum intercuspation and centric relation position must be corrected. When there is a discrepancy between centric relation and maximum intercuspation the clinician must first consider the size of the error: if it is as a result of an incorrect recording of the centric relation position, then if the discrepancy is no more than the width of a cusp, the dentures must be re-mounted on the articulator using a new jaw relationship record (a “check bite”) and the occlusion corrected on the articulator. If the discrepancy is too great to be adjusted in this way (i.e. more than the width of a cusp), then the posterior teeth must be removed, a new jaw registration record made, the dentures must be remounted, and new teeth processed onto the base.

If the occlusal vertical dimension is correct, and the discrepancy between maximum intercuspation and centric relation position is small, then this will be due to a slide along the mesial slopes of the upper cusps and the distal slopes of the lowers, which can be adjusted in the same manner as described for static mesio-distal relationship errors.

Once maximum intercuspation has been established and made coincident with centric relation, then the excursive movements are adjusted. It is important, though, to keep returning to maximum intercuspation, and especially to ensure a smooth transition between maximum intercuspation and positions in protrusion. This is because even though maximum intercuspation is made coincident with centric relation position, the evidence is that patients actually function a little *anterior* to this, so it is important that this area of 1-2 mm anterior to centric relation also provides for stable intercuspation.

Practical considerations

The above descriptions of the correction of occlusal errors have made no mention of how these contacting interferences are detected. On the articulator, thin articulating paper is used, and different types of error can be detected and adjusted at the same time. For example, once maximum intercuspation has been established, these contacts can be left as a mark on the teeth in one colour, and then excursive contacts can be marked in a different colour; or three different colours could be used, for example red for maximum intercuspation, blue for working side interferences and green for nonworking side interferences. All these contacts can be detected accurately because the bases are firmly attached to a firm plaster model on the articulator.

In the mouth the situation is a little different. Now the denture bases sit on unstable foundations, and occlusal interferences are likely to cause movements of the bases. That is why they must be corrected of course, but the same movements will also affect the *detection* of those interferences. If the patient is asked to tap up and down in centric relation position, and there happens to be a slide into maximum intercuspation, the interferences causing that slide may move the denture bases, so that the bases slide to end up in maximum intercuspation. If articulating paper is placed between the bases, the paper would only record the *end* position of that slide – i.e. maximum intercuspation – and not necessarily the movement into it. The interferences may not then be detected, and the patient will have an unstable occlusion, which will create great discomfort. Therefore great care must be taken when using articulating paper in the mouth, and if there is any doubt as to its efficacy in a given situation, alternative materials must be used. One of the most effective of these is Kerr's ivory disclosing wax. This can be placed, molten, onto the occlusal surfaces of the lower teeth, and when inserted into the mouth provides no resistance to closure: the denture bases can be held firmly to detect the very *first* tooth contacts. When one is sure thereafter that there are no sliding interferences to maximum intercuspation, then articulating paper can be used for the remainder of the occlusal adjustments.

The retrognathic mandible

Introduction

The occlusal scheme thus far described has been that of a fully balanced articulation using cusped teeth, with the assumption that there is a normal horizontal relationship between the mandible and the maxillae. Consideration now needs to be given to those situations where a considerable discrepancy in the horizontal jaw relationship exists. This section will deal with the retrognathic situation, and the next section, with the prognathic situation.

The term most dentists are familiar with in describing these cases, relates to a classification by Angle, of the horizontal relationships of the first molar teeth, which in this case defines a skeletal Class II; most will also be familiar with the two further subdivisions according to the incisal relationships. However, this classification is not necessarily an indication of other skeletal relationships that may affect the problem of having to replace an entire dentition. It is preferable, therefore, to consider a classification of retrognathism which takes into account the problems likely to be encountered prosthodontically. To this end, the skeletal Class II situation can be divided into two broad categories, based on the Frankfort-Mandibular plane angle (FMA). This angle varies according to the relationship of the amount of vertical to posterior growth. The two categories are best illustrated by the two extremes (see Figure 29). A high FMA develops when the anterior components of vertical growth exceed those of condylar growth, and the average FMA is greater than about 26 . The characteristics will be revealed as (Figure 29B):

- — an anterior face height greater than the posterior face height, with a convex profile
- — a steep occlusal plane
- — a high smile line with a short upper lip
- — a high vaulted palate and narrow maxillae
- — a lip seal that is often difficult to obtain without considerable mentalis activity

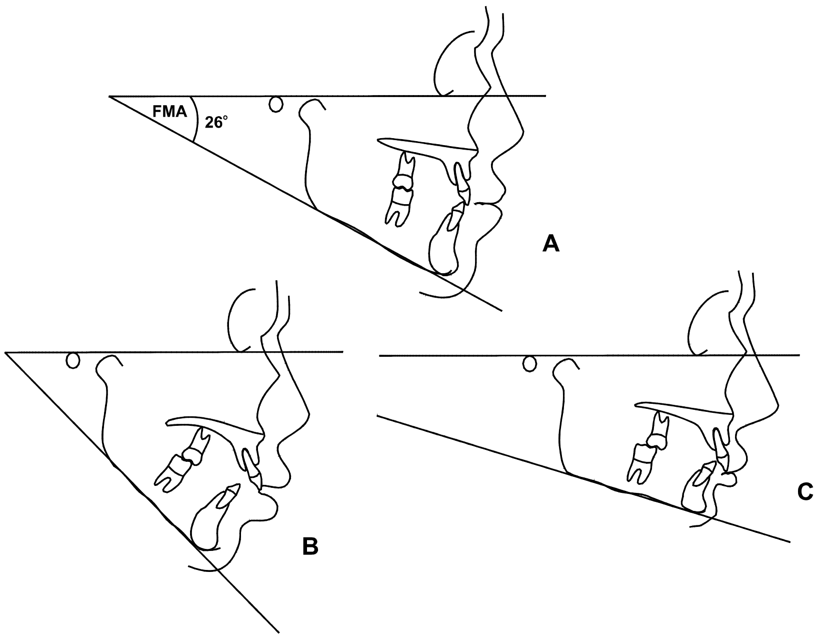


Figure 29: **A**: a normal Frankfort-Mandibular plane angle (**FMA**) of about 26 . **B**: a high FMA case. **C**: a low FMA situation (after Di Pietro and Moergeli, 1976)

The skeletal Class II situation with a low FMA on the other hand, displays opposing characteristics (Figure 29C):

— a hardly discernible discrepancy between anterior and posterior face heights, and less of a convex profile
— a flat occlusal plane
— a long upper lip and low smile line
— a broad flat palate and a wide maxillary arch

The prosthodontic problem

When constructing complete dentures for skeletal Class II patients, a variety of problems arise, because of both the static and functional relationships between upper and lower jaws.

Anteriorly, it is still necessary to replace teeth in the same position as they once occupied, but there can be some allowance for a reduction in overbite, usually by setting the upper teeth a little higher, but in the same antero-posterior relationship. This improves the aesthetics but maintains any overjet, as the lowers must also be set in the same antero-posterior relationship as the natural teeth.

Posteriorly, the different sizes of the arches means that the lower arch appears much shorter than the upper, and there is a narrowing of the arch in the premolar region, because a narrow segment of the lower arch must articulate with a wider part of the upper (see Figure 30).

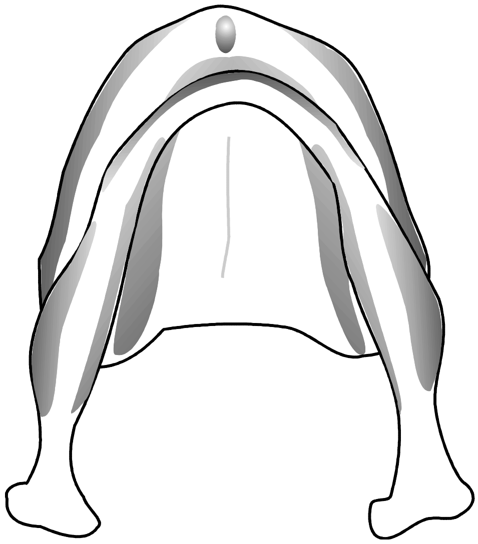


Figure 30: When the upper and lower edentulous arches are superimposed in skeletal Class II cases, it can be seen that a narrow segment of the lower arch must articulate with a wider part of the upper (after Curtis et al, 1988).

Condylar guidance angles also seem to vary with the FMA, being steeper in the high FMA group, with a steep occlusal plane, and this too must be taken into account when setting cusped artificial teeth.

The ridge relationships differ between the high FMA group and the low FMA group. In the low FMA group the edentulous ridges will nearly always be parallel, but in the high FMA group the ridges diverge considerably, and whilst it may be possible to reduce the occlusal vertical dimension to improve this divergence, the ridges will never be parallel to each other. It is important to be aware of this, because after recording the jaw relationship, it may well appear erroneous when the articulated models are viewed.

Functionally, skeletal Class II individuals have an extensive range of motion of the mandible. High FMA cases generally function in a range of positions anterior to centric relation position. They function closest to centric relation position when chewing food requiring more force, but function forwards of this position at rest (to help lip closure and to improve appearance), and when speaking. These variable positions make its difficult to carry out an accurate and consistent jaw registration procedure. More importantly, the occlusal scheme and articulation must provide for these rather extensive ranges of motion. Low FMA cases on the other hand, often have deep overbites with minimal overjet, and the mandible rotates considerably to clear the overbite before it can translate forwards. However, the flatter occlusal plane usually means that lateral excursive movements can be carried out more easily, provided that the overbite, especially at the canines, is not too great. A further problem with these cases, is that the upper arch is often much wider than the lower.

Possible solutions

Anterior tooth placement: in high FMA cases it is likely that the original incisor relationship was that of an Angle’s Class II division 1 situation, with an increased overbite and often a considerably increased overjet. As stated above, the final solution will be to reduce the overbite by setting the upper anteriors a little higher; the solution is *not* to set them back into a Class I relationship as this will cause aesthetic problems by “collapsing” the upper lip and, more importantly, functional problems by limiting the forward movement of the mandible. By definition, a fully balanced articulation means contact at all places in the arch in all positions, and so if this is to be maintained, a solution must be found in cases where the overjet is quite large. If the overjet is not too great, then it can be accepted that at centric relation position there will be no contact on the lower incisors, but these *will* contact the uppers on forward movements of the mandible. However, in cases where the overjet is so great that functional forward movements still do not bring the incisors together, then contact can be created on the palate of the denture. This can be shaped so that the lower incisors maintain contact in protrusion (Figure 31).

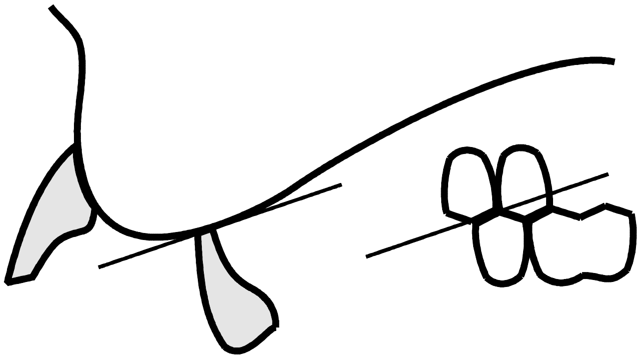


Figure 31: When the overjet is so great that incisor contact is impossible, then contact can be made with the palate, which is adjusted to harmonise with the cuspal guidance in protrusive (after Watt and McGregor 1976).

In low FMA cases, anterior tooth positioning becomes slightly more of a compromise when compared to the original tooth positions, the classic appearance of which is that of the Angle's Class II division 2 case. Clearly if the overbite and minimal overjet of these cases is reproduced in an artificial tooth set-up, the patient could be locked into an impossible situation. So there needs to be some re-positioning of the teeth to reduce the overbite as much as possible without overly compromising aesthetics. If aesthetic demands are such that an overbite must be retained, then it might have to be accepted that there will be little or no protrusive balance, and in fact these patients do cope with this and seem to use lateral excursive movements a lot more. This in turn means that there must be very good lateral balanced articulation, and so the canines in particular should be set a little higher in order to produce canine guidance angles that allow for this lateral balance.

Posterior tooth placement: skeletal Class II cases have, as stated, discrepancies in both the antero-posterior and medio-lateral size and position of the arches. The antero-posterior discrepancy can normally be solved by leaving out either a premolar or the second molar from the lower arch. In addition, an extra premolar can be placed distal to the upper second molar. The medio-lateral discrepancy is more difficult to cope with, and requires a narrowing of the arch form at the premolars. If necessary, in order to keep the artificial teeth within the neutral zone, a cross-bite situation may arise in which the mandibular teeth are placed buccal, not lingual to, the maxillary teeth. If cusped teeth are being used, this requires a slight modification to the anatomy in order to obtain the correct effective cusp angles.

The type of occlusal scheme and articulation needs to be appropriate to the different Class II types of high and low FMA cases. In the high FMA situation, it is important that balance be obtained in the variety of positions used anterior to centric relation. When using cusped teeth, this can be quite difficult if there is a large overjet that is greater than the width of the cusps of the posterior teeth; complicating the situation is the need for fairly steep effective cusp angles, as these cases can tend to have steep occlusal planes and high sagittal condylar guidance angles. If cusped teeth are used in this situation, then emphasis must be placed on providing the best possible contact at all reasonable positions anterior to centric relation. It would also seem sensible to use an articulator that better reproduces the patient's condylar guidance angles, and teeth with steep cusp angles.

In the low FMA situation, where an overbite is retained, then the emphasis is on producing excellent lateral balanced articulation. As stated above, the canine guidance angle is critical in that it needs to be shallow enough to allow for shallower cusped teeth to be used posteriorly, to try to reduce the compensating curves required for balanced lateral articulation.

A further complication arises in those cases where the upper arch is much wider than the lower. In these cases, the lower teeth are first set in their most appropriate positions relative to the lower arch. The uppers are then set in *their* most appropriate positions for aesthetics. If then it is found that the uppers and lowers don't meet, a further line of teeth can be placed palatal to the uppers, or the base can be waxed to the lowers and replaced with tooth-coloured resin (Figure 32).

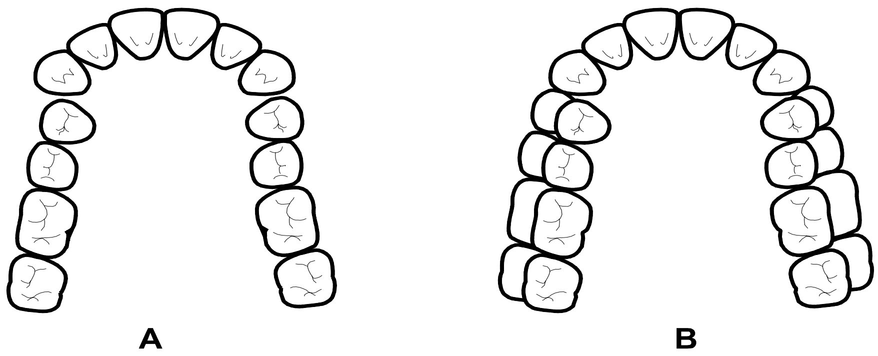


Figure 32: **A**: posterior teeth have been arranged to occlude with the lowers, which are placed in the correct position relative to the lower arch – the result will clearly be a poor appearance. **B**: tooth veneers have been placed buccal to the occluding teeth, purely for aesthetic purposes. This could also have been done the other way round, by placing the teeth in the correct aesthetic positions first, and then adding occluding surfaces (after Curtis et al 1988a).

Thus skeletal Class II cases provide some challenges to the concepts of balanced articulation when using cusped teeth. However, there are alternative schemes which can be used which can produce the same and in some cases better results, such as lingualised articulation. This will be dealt with in a later section.

The prognathic mandible

Introduction

The Angle classification related to this situation is that of the Class III, where the mandible is now in advance of the maxillae. Characteristically the incisor relations in the natural teeth are either in edge-to-edge relationship or display a reverse overjet (where the lower anteriors are in advance of the upper anteriors).

The prosthodontic problem

Once again there are both static and functional problems when constructing complete dentures for these patients, as there is likely to be a discrepancy in arch size and position between the upper and the lower arches. Anteriorly, the requirement, as always, remains to place the artificial teeth in the positions occupied by the natural teeth; but if this means reproducing a reverse overjet, this is often unacceptable to the patient.

Posteriorly, the main problem is the discrepancy in arch size, whereby the lower arch is considerably narrower than the upper. The edentulous lower ridge is in any case wider than that of the upper because of normal bone resorption patterns, but if it had started out wider in the natural dentition, then it can appear excessively exaggerated in the edentulous situation.

Functionally, skeletal Class III cases sometimes display an anterior slide into maximum intercuspation as a result of first contacting the anteriors before the posteriors meet. If this slide persists in the edentulous state, registering the jaw relationship becomes quite difficult, as does determining the most appropriate occlusal vertical dimension.

Possible solutions

Anterior tooth placement: if the patient finds the re-creation of a reverse overjet unacceptable, then the only compromise that could be considered is to place the upper anteriors closer towards the residual ridge into an edge-to-edge relationship with the lowers. At no time should a normal Class I arrangement be considered, even if the teeth *were* originally edge-to-edge: this relationship should be reproduced. In all cases, though, the angle of the incisal edges should be in harmony with the antero-posterior compensating curve.

Posterior tooth placement: if the upper arch is inside the lower arch, then placing the teeth in a normal relationship will mean either extending the upper posteriors far buccally or the lowers far lingually, or both. Clearly this is impractical, and will create more problems than such a solution might cure. So maintaining the artificial teeth within the neutral zone in this case, means that it is necessary to set the teeth in a cross-bite arrangement.

There are several possible alternatives. First, normal cusped teeth can be set with a reverse overjet and the cuspal inclines adjusted to allow for excursive movements. This means that the supporting cusps are now reversed – almost as if the whole case is upside down. This is not as simple as it sounds, because the manufacturers never intended the teeth to work this way around, and so it often requires quite considerable modification to the teeth.

Second, to aid in correct interdigitation the teeth *are* in fact set upside down: the first quadrant teeth are swapped with the third quadrant and the second with the fourth. The only compromise this entails is in the appearance of the premolars – lower premolars do not look as pleasing as their upper counterparts when placed in that position. This can be overcome by using a slightly larger tooth mould for the lowers (which are now the uppers).

A third solution is to use cuspless teeth, and rely only on the compensating curves to achieve bilateral and antero-posterior balance. This is the easiest solution to set up, especially in a static relationship, but the least satisfactory if the patient has, or expects to perform, a range of mandibular movement which would require a fully balanced articulation.

Finally, a modification of the lingualised articulation scheme can be used: this is dealt with in the following section.

Lingualised articulation

Introduction

As is hopefully apparent by now, the use of cusped teeth for fully balanced articulation is the ideal occlusal scheme for complete dentures. However, it may also be apparent that it can often be quite time-consuming to achieve, and that there are adverse consequences for not achieving full balance with cusped teeth.

Fortunately this has prompted the search for alternative schemes, and there has been a revival of interest of late in a scheme first advocated, believe it or not, in the 1920s and again in the 1940s and 1950s. This scheme involves the use of cusped upper teeth with usually 30 or 33 cuspal angles, modified to ensure that the buccal cusps take no part in the articulation. The lower teeth used are either 20 or 0 teeth, modified so that their occlusal surfaces are in harmony with the angles of the upper palatal cusps, as well as the paths traced as the mandible moves in excursive movements.

It is termed *lingualised* articulation because of the semantic phraseology of American English, in which the inner cusps of maxillary *and* mandibular teeth are termed the *lingual* cusps. British English, on the other hand, refers to the inner maxillary cusps as *palatal* cusps, for obvious reasons. But as this occlusal scheme *was* first suggested by Americans, the termed *lingualised* has remained, with a British alternative being suggested, rather clumsily, as *palatal cusp contact* occlusion or, more strictly, articulation. In the interest of compromise and clarity, the term lingualised articulation will be used here to describe the scheme, but the upper palatal cusps will be named as such.

Normal jaw relationships

This section will describe the normal arrangement of the teeth for lingualised articulation, and the following section will discuss the modifications required for different jaw relationships.

There is no difference between the initial placement of the teeth using this scheme, from those already described: anterior teeth are still placed for aesthetic and phonetic considerations, and all teeth are placed within the neutral zone and in the positions occupied by the natural teeth. The only exception is a very slight mesio-distal adjustment of the lower posterior teeth, so that the upper palatal cusps contact the fossae of the lowers, and will not contact any lower marginal ridges.

Similarly, there will be no difference in the determinants of the articulation: the incisal and canine guidance angles, and the condylar guidance angles. Hence the distinguishing characteristic of this articulation will be the manner in which the compensating curves are established, and the cuspal guidance inclines to achieve excursive balance.

Lingualised articulation attempts – and largely succeeds – to have the best of all possible worlds: it is a cusped occlusion in the sense that the upper palatal cusps are used to penetrate the food and the buccal cusps are retained for aesthetics; and it is a balanced cusped articulation, as the same cusps are used for crushing and grinding the food against a lower occlusal surface in much the same manner as a pestle and mortar. Only the upper palatal cusps are used, and that is why the lower teeth are modified into an occlusal table, each of which possesses the appropriate inclines to compensate for the mandibular pathways, so that they collectively generate the appropriate compensating curves. This means that the buccal cusps of the upper teeth and the cusps of the lowers take no part in the articulation (Figures 33 and 34).

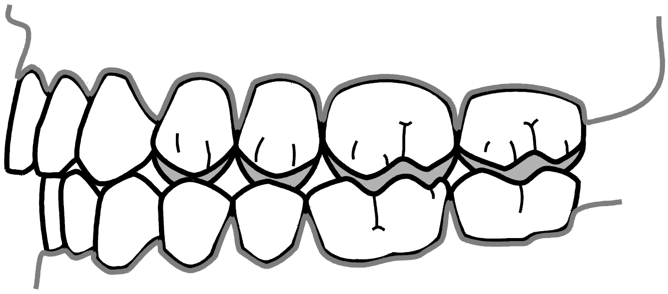


Figure 33: Centric occlusion in a lingualised articulation. The upper palatal cusps contact the central fossae of their opposing mandibular teeth, and the buccal cusps have been adjusted to just raise them sufficiently so that they do not take part in the articulation.

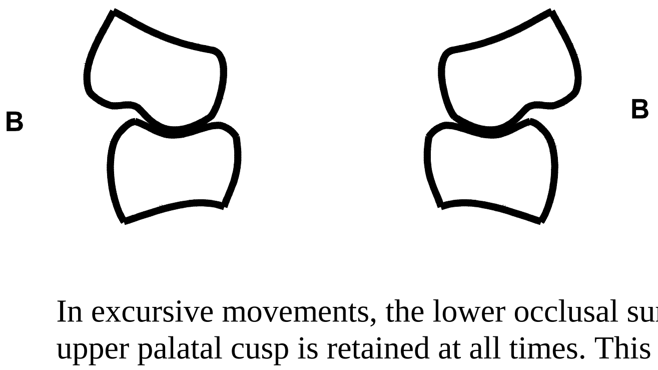


Figure 34: Frontal view of a section through the molars, showing the contact relationship of the upper palatal cusp and the lower occlusal surface and central fossa in centric occlusion. **B**: buccal side.

In excursive movements, the lower occlusal surfaces are adjusted so that contact with the upper palatal cusp is retained at all times. This is done antero-posteriorly to allow for protrusive balance, and for both the inner and outer slopes which effectively become the working and non-working slopes for lateral balance (see Figures 35 to 40).

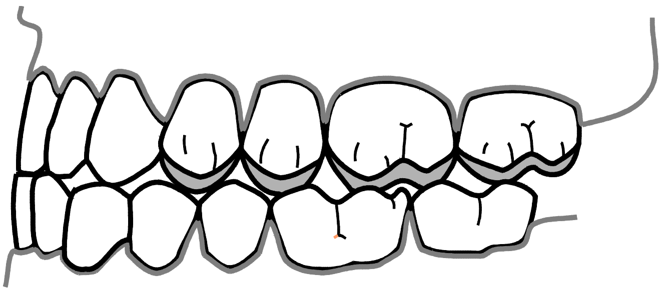


Figure 35: Protrusive position using lingualised occlusion

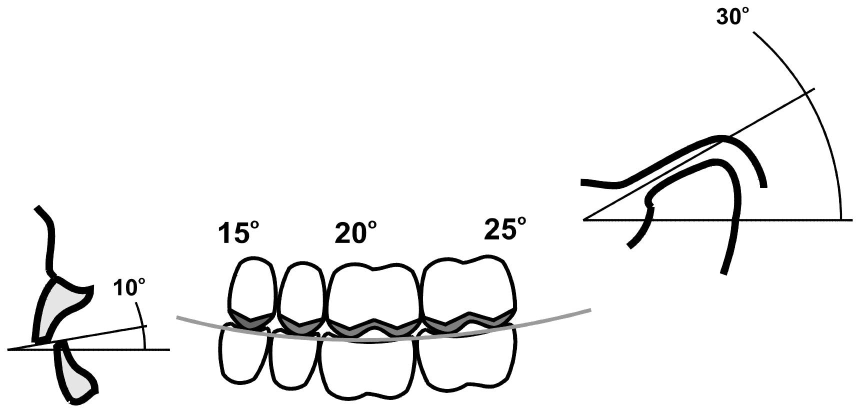


Figure 36: Schematic representation of centric position using lingualised occlusion. Compare with Figure 13. Note that the compensating curve is generated in the same manner, but using only the upper palatal cusps, and the occlusal table of the lowers.

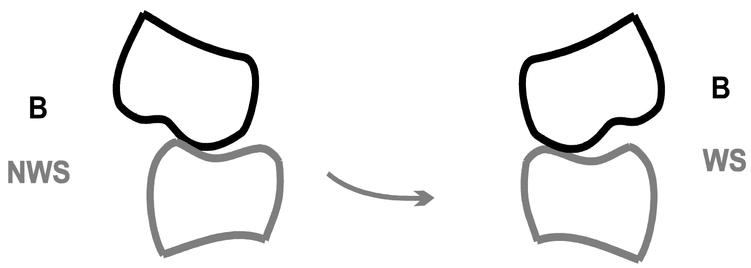


Figure 37: Tooth contacts when mandible moves to the left. Compare with Figures 15 and 19.

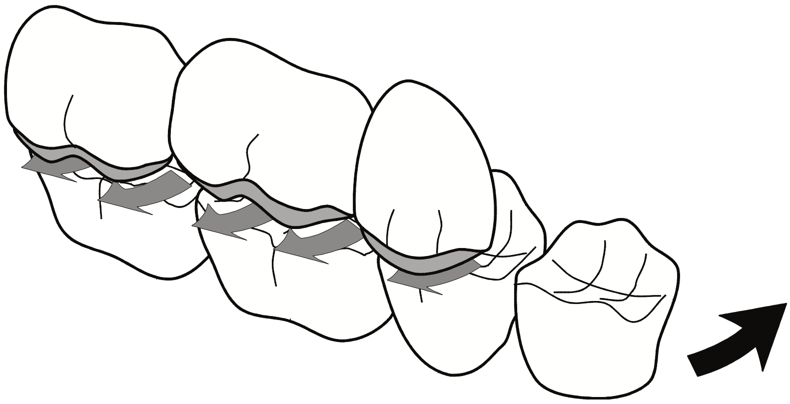


Figure 38: As the mandible moves to the left (solid arrow), the upper palatal cusps slide up the buccal inclines of the lower occlusal surface, in the direction of the shaded arrows. These are therefore the nonworking side contacts.

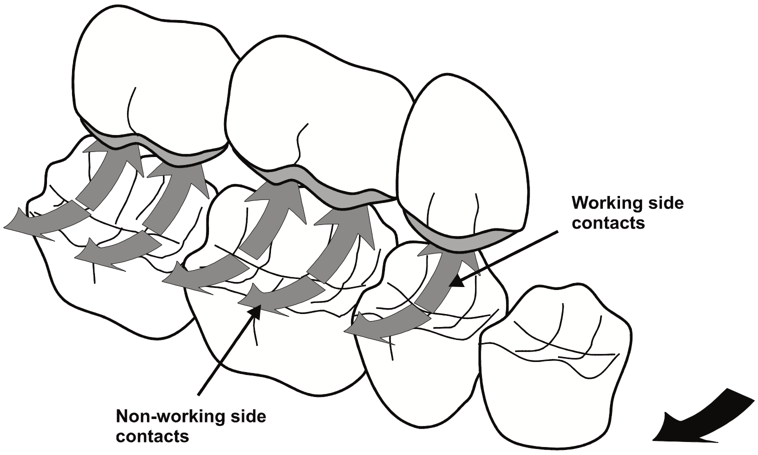


Figure 39: As the mandible moves to the right (solid arrow), the upper palatal cusps slide up the lingual inclines of the lower occlusal surfaces, in the direction of the shaded arrows. These are therefore the working side contacts (the nonworking side contacts are still shown as the arrows from Figure 38).

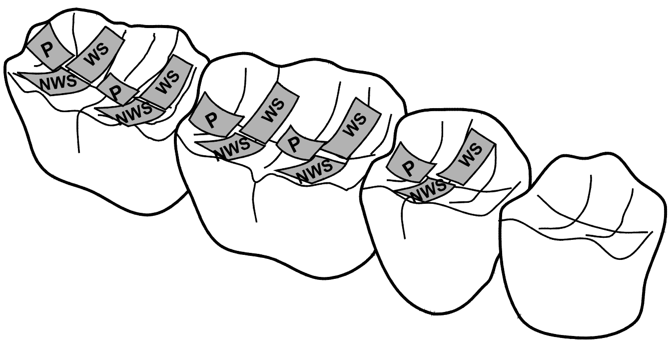


Figure 40: The contact areas are shown for all excursive contacts, including protrusive: each occlusal surface effectively creates the required compensating slopes for the pathways of the upper palatal cusps. **P**: protrusive; **WS**: working side; **NWS**: nonworking side.

Retrognathic jaw relationships

The prosthodontic problems of skeletal Class II individuals have been detailed in the previous section, and the solutions are similar when it comes to tooth placement for coping with both the antero-posterior and medio-lateral arch form discrepancies (Figure 41).

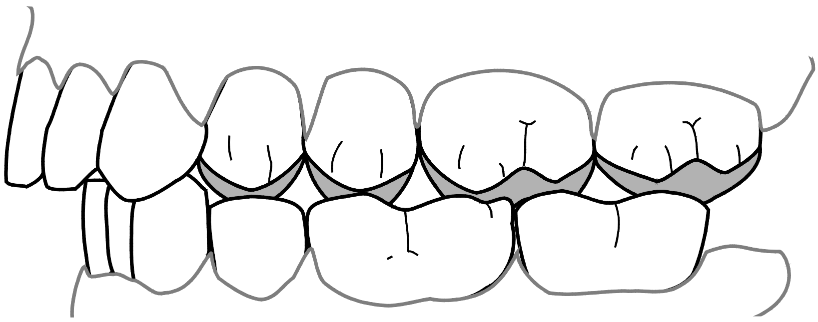


Figure 41: A skeletal Class II centric set-up: a lower premolar has been left out to compensate for the antero-posterior arch discrepancy.

High FMA cases with large overjets and steep sagittal condylar guidance angles will require quite steep compensating curves in the lower occlusal forms to maintain balance with a lingualised articulation. For this reason some clinicians still prefer to use cusped teeth, but in fact in most cases, the lingualised concept provides a more effective solution. As has been stated, the problem is that the patient functions in a variety of positions anterior to centric relation position, and providing for protrusive balance is very difficult with cusped teeth. With a lingualised concept, however, the occlusal tables of each tooth can be successively recruited to maintain contact during protrusion, and a long antero-posterior area of contact can be obtained. This is done by placing the lower teeth on an appropriate compensating curve and then adjusting the occlusal tables for all protrusive movements.

Prognathic jaw relationships

The main problem with posterior tooth placement in these cases, is that of a medio-lateral arch discrepancy and the need for a cross-bite arrangement. In this case, the lingualised concept becomes a “buccalised” one: the upper buccal cusps are now adjusted to contact the lower occlusal surfaces, and the upper palatal cusps are ground so as not to take part in the articulation (Figure 42).

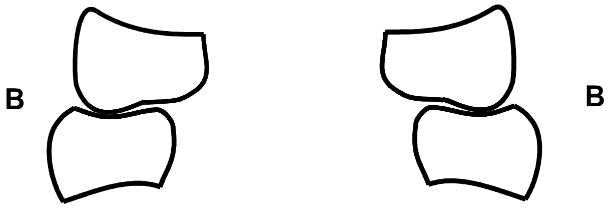


Figure 42: In a cross-bite situation, the adjustments to the lower occlusal surfaces are the same, but it is the upper buccal cusps that now provide the articulation, not the palatal cusps.

Practical considerations

When setting and adjusting the teeth for lingualised articulation, several factors must be taken into account, that make the procedures different from those used for a cusped and balanced articulation.

A study comparing patient responses to a lingualised scheme using 30 upper posteriors to a monoplane scheme, found that a statistically significant number of patients (67%) preferred the lingualised scheme, mostly because they “chewed better”. It would seem that 30 or 33 cusp angle teeth enhanced the effective “pestle” effect of the scheme.

The lower posterior tooth form most often recommended is either a 20 or 0 cusp angle. The choice usually depends on the anatomical form of the occlusal surface, and this varies from manufacturer to manufacturer. Whatever type is chosen, the occlusal surface will need to be re-shaped (Figure 43).

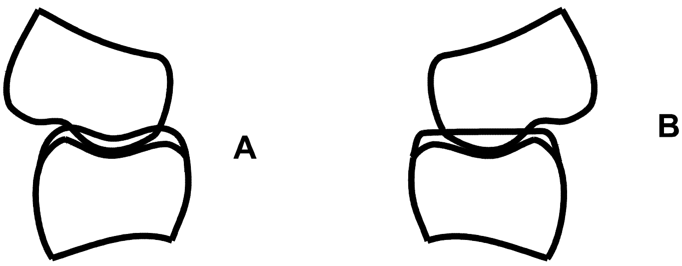


Figure 43: The original occlusal surface of the lower teeth (shown as dotted lines) will need to be re-shaped to conform to the slope of the upper palatal cusp and to the mandibular pathways. **A**: 20° lower tooth; **B**: 0° lower tooth.

This process obviously results in a deepening of the central fossa of the lower teeth, and therefore can affect the vertical dimension of occlusion. This must be taken into account, and the articulator adjusted accordingly: it is sensible to open the articulator 1 or 2 mm and then to re-shape the occlusal surfaces for centric occlusion. Thereafter the centric stops are maintained, and the occlusal surfaces are then adjusted for all excursive movements. It is convenient to use different coloured articulating paper for the centric stops and for excursive movements. All adjustments are made to the lowers, so it is important not to lose the centric contacts when adjusting for lateral excursive inclines and for protrusion.

Clinical considerations

After re-mounting the processed dentures, the occlusion is again refined on the articulator, before being tested in the mouth. Once again the procedures followed are the same as already described for cusped balanced articulation. The only difference is that lingualised articulation is very much easier to adjust for, when correcting any processing errors, or when adjusting for special situations such as steep condylar guidance angles, as only the lower teeth require adjustment.

Clearly, this scheme lends itself to the use of both average-value and semi-adjustable articulators; and again, as for cusped articulation, a semi-adjustable articulator will make the entire process more controlled and very much easier. It is for this reason that this occlusal scheme also lends itself to a variation which is very useful for clinical situations where it is necessary to ensure a reduced rate of wear on the teeth. This is achieved by using porcelain upper teeth and amalgam stops in the lowers (or, if money is no object, gold occlusal surfaces on the lowers). Porcelain teeth can be used because the palatal cusps are never ground and so retain their glaze: when these occlude onto a polished metal surface of the lowers, far less wear will be encountered than acrylic on acrylic, or porcelain (even unglazed) on acrylic. The procedure has been advocated for use in a semi-adjustable articulator, by making individual amalgam stops in each tooth, or by making an amalgam “channel” which extends from first premolar to second molar. The movements of the articulator are used to generate the centric stops and the excursive inclines, which are then refined in the mouth.

An alternative method and, in the author's opinion, a more logical one given the limitations of articulators, is to generate these amalgam stops in the mouth, in the same way in which this is done for single dentures. After the patient has successfully worn the denture for a week or two, with no further adjustments being required, then every alternate lower posterior tooth on one side is prepared to receive an amalgam. This is carved to be more less flat, and the denture returned to the mouth, where the patient makes the required movements to generate the centric stops and the excursive inclines, using the un-prepared teeth to maintain the guidance. Then the other teeth on that side are prepared and filled and the procedure repeated, and then again for the other side of the arch. After each insertion, the excess amalgam is removed and the edges smoothed, but the contact areas are left untouched. One week later the patient returns, the occlusion is checked and the amalgams are then carefully polished.

The same procedure can be carried out using acrylic upper teeth rather than porcelain, which will also reduce the rate of wear but probably not as much: there are no data available as yet to determine the relative rates of wear of unglazed artificial porcelain teeth against amalgam (or gold) versus artificial acrylic teeth against amalgam (or gold).

Advantages and disadvantages of lingualised articulation

This concept has been called “an occlusion for all reasons” and rightly so. There is hardly a clinical situation where it is not applicable and the adjustments, especially at the chairside, are considerably easier to make than with a fully balanced articulation using cusped teeth, for only the lower teeth need to be adjusted. In fact, this occlusal scheme is now frequently used in fixed implant prostheses.

One disadvantage is when there may be an aesthetic imperative to provide well-defined buccal cusps in such a way that they must be involved in the articulation. But even then, they need only be adjusted for working-side contacts with the outer slopes of the lower buccal cusps; alternatively, the lower buccal cusps, not necessary for aesthetic reasons, can be bevelled in such a way that their outer slopes are removed from working-side contact. A further disadvantage might be from an educational point of view: if dental schools *only* teach lingualised articulation, it may detract from a student's full understanding of occlusion and all its implications and varieties, not only in complete dentures. It is, in the author's opinion, far easier to understand, apply and use lingualised articulation once the principles of fully balanced *cusped* articulation have been mastered.

In summary, then, lingualised articulation is recommended for the majority of cases where it can easily solve most difficulties, provided the principles of balanced articulation are strictly adhered to.

Bibliography

Applebaum M. (1984): *Plans of occlusion*. In: Dental Clinics of North America: symposium on removable prosthodontics. Pp 273-285. W.B.Saunders, Philadelphia.

Beck H.O. (1972): Occlusion as related to complete removable prosthodontics. *Journal of Prosthetic Dentistry* 27:246-256.

Becker C.M., Swoope C.C. and Guckes A.d. (1977): Lingualized occlusion for removable prosthodontics. *Journal of Prosthetic Dentistry* 38:601-608.

Berry D.C. and Poole D.F.G. (1974): Masticatory function and oral rehabilitation. *Journal of Oral Rehabilitation* 1:191-205.

Beyron H.L. (1954): Occlusal changes in adult dentition. *Journal of the American Dental Association* 48:674-686

Brown W.A.B., Whittaker J., Fenwick J. and Jones D.S. (1977): Quantitative evidence for the helicoid relationship between the maxillary and mandibular occlusal surfaces. *Journal of Oral Rehabilitation* 4:91-96.

Clough H.E., Knodle J.M., Leeper H.L., Pudwill M.L. and Taylor D.T. (1983): A comparison of lingualized occlusion and monoplane occlusion in complete dentures. *Journal of Prosthetic Dentistry* 50: 176-179.

Curtis T.A., Langer Y., Curtis D.A. and Carpenter R. (1988): Occlusal considerations for partially or completely edentulous skeletal class II patients. Part I: background information. *Journal of Prosthetic Dentistry* 60:202-211.

Curtis T.A., Langer Y., Curtis D.A. and Carpenter R. (1988): Occlusal considerations for partially or completely edentulous skeletal class II patients. Part II: treatment concepts. *Journal of Prosthetic Dentistry* 60:334-342.

DiPietro G.J. and Moergeli J.R. Jr. (1976): Significance of the Frankfort-mandibular plane angle to prosthodontics. *Journal of Prosthetic Dentistry* 36:624-635.

Gibbs C.H., Mahan P.E., Mauderli A., Lundeen H.C. and Walsh E.K. (1986): *Journal of Prosthetic Dentistry* 56:226-229.

Inoue S., Kawano F., Nagao K. and Matsumoto N. (1996): An in vitro study of the influence of occlusal scheme on the pressure distribution of complete denture supporting tissues. *International Journal of Prosthodontics*. 9:179-187.

Johansson A, Fareed K. and Omar R. (1994): Lateral and protrusive contact schemes and occlusal wear: a correlational study in a young adult Saudi population. *Journal of Prosthetic Dentistry* 71: 159-164.

Lang B.R. and Razzoog M.E. (1983): A practical approach to restoring occlusion for edentulous patients. Part I: guiding principles of tooth selection. *Journal of Prosthetic Dentistry* 50:599-606

Lang B.R. and Razzoog M.E. (1983): A practical approach to restoring occlusion for edentulous patients. Part II: arranging the functional and rational mold combination. *Journal of Prosthetic Dentistry* 50:455-458.

Lang B.R. (1996): *Complete denture occlusion*. In: The dental clinics of North America: Complete Dentures, Engelmeier R.L. (Ed). Pp 85-101. W.B.Saunders, Philadelphia.

Lassila V., Holmlund I. and Koivumaa K.K. (1985): Bite force and its correlations in different denture types. *Acta Odontologica Scandinavica* 43:127-132.

Levin B. (1977): A review of artificial posterior tooth forms including a preliminary report on a new posterior tooth. *Journal of Prosthetic Dentistry* 38:3-15.

Lauciello F.r. (1979): Articulator-generated amalgam stops for complete dentures. *Journal of Prosthetic Dentistry* 41:16-20.

Lumsden A.G.S. and Osborn J.W. (1977): The evolution of chewing: a dentist's view of palaeontology. *Journal of Dentistry* 5:269-287.

Mahalick J.A., Knap F.J. and Weiter E.J. (1971): Occlusal wear in prosthodontics. *Journal of the American Dental Association* 82:154-159.

Mehringer E.J. (1973): Function of steep cusps in mastication with complete dentures. *Journal of Prosthetic Dentistry* 30:367-372.

Molnar S., McKee J.K., Molnar I.M. and Przybeck T.T. (1983): Tooth wear rates among contemporary Australian Aborigines. *Journal of Dental Research* 62:562-565.

Nairn R.I. (1973): Lateral and protrusive occlusions. *Journal of Dentistry* 1:181-187.

Nairn R.I. (1974): Maxillomandibular relations and aspects of occlusion. *Journal of Prosthetic Dentistry* 31:361-368.

Ohguri T., Kawano F., Ichikawa T., and Matsumoto N. (1999): Influence of occlusal scheme on the pressure distribution under a complete denture. *International Journal of Prosthodontics*. 12:353-358.

Osborn J.W. (1982): Helicoidal plane of dental occlusion. *American Journal of Physical Anthropology* 57:273-281.

Owen C.P. (1986): The prophylactic reduction of cusps: is it desirable? *Journal of Oral Rehabilitation*, 13:39-48.

Owen,C.P., Wilding,R.J.C., & Osborn,J.W. (1991): Changes in mandibular condyle morphology related to tooth wear in a prehistoric human population. *Archives of Oral Biology*, 36:799-804.

Owen,C.P., Wilding,R.J.C. & Adams,L.P. (1992): Dimensions of the temporal glenoid fossa and tooth wear in prehistoric human skeletons. *Archives of Oral Biology*, 37:63-67.

Parr G.R. and Ivanhoe J.R. (1996): *Lingualised occlusion: an occlusion for all reasons.* In: The dental clinics of North America: Complete Dentures, Engelmeier R.L. (Ed). Pp 103-112. W.B.Saunders, Philadelphia.

Payne S.H. (1952): A comparative study of posterior occlusion. *Journal of Prosthetic Dentistry* 2:661-667.

Reitz J.V. (1994): Lingualized occlusion in implant dentistry. *Quintessence International* 25:177-180.

Shiba A., Hayashi T., Yoshida J. and Tanaka O. (1981): Functionally generated amalgam paths for complete dentures. *Journal of Prosthetic Dentistry* 46:494-497.

Stade E.H., Hanson J.G. and Baker C.L. (1982): Esthetic considerations in the use of face-bows. *Journal of Prosthetic Dentistry* 48: 253-256.

Watt D.M and Macgregor A.R. (1976): *Designing complete dentures.* Pp 370-376. W.B.Saunders, Philadelphia.