THE BIOMECHANICAL BASIS OF RETENTION IN COMPLETE DENTURES

Factors affecting the retention of dentures

Retention is the resistance of the denture to removal along its path of insertion. Strictly speaking, the term *stability* refers to the resistance of the denture to forces tending to displace it by acting in any direction other than along its path of insertion. In complete dentures, the two terms are often interchangeable, but different factors tend to affect retention and stability. The forces that keep the denture in place - mainly retentive, but also stabilising factors, will be the focus of this section.

Adhesion

This is the physical attraction of unlike molecules for each other. In a denture, this implies the interaction between saliva and the mucosa, and between saliva and the material used for the denture base, usually acrylic resin. The closer the adaptation between these substances, the higher the forces of adhesion will be. In other words, the saliva acts as the adhesive between the substrates of mucosa and denture base.

An adhesive is more effective when the contact angle between it and the substrate is low. This is an expression of the wettability of the adhesive relative to the substrate. Saliva wets mucosa very effectively, but is less effective on denture base resins. The viscosity of the saliva will also contribute to this wettability, and also to the thickness of the saliva film beneath the denture base. Ideally, a very thin layer of adhesive acts more effectively than a thick layer, so that while thick ropy saliva may seem to be an advantage, especially in resisting the flow of saliva into the space between base and mucosa, this is negated by its forming a thicker film in the first place.

Cohesion

This is the physical attraction of *like* molecules for each other, and so occurs in the saliva layer. The less the overall amount of saliva, the less will be the cohesive forces, given that a thin layer is required. This merely means that the larger the area of the denture base, the more cohesive forces will act, although it must be realised these forces are not great, and certainly less than the forces of adhesion.

Surface tension

Interfacial surface tension is the resistance to separation possessed by a film of liquid between two well-adapted surfaces. It is the result of the cohesive forces acting at the surface of the liquid. It is similar to the force that causes a liquid to rise in a capillary tube - the capillary attraction, or capillarity. Once again, close adaptation of the denture base to the mucosa will enhance these forces. If two microscope slides have a thin layer of water between them, it is difficult to separate them by pulling them away from each other precisely because of these forces. But they can be more easily separated by sliding one slide over the other, as the forces of adhesion, cohesion, and surface tension and capillarity will be easily overcome. This has implications for the shape of the underlying basal seat area, especially in the upper. If the shape of the palate is high and vaulted, it will be easier to displace a denture base than if the palate is flatter, all other aspects being equal.

Atmospheric pressure

It has been postulated that the film of saliva creates a pressure differential between its peripheral meniscus and the intra-oral air pressure. This negative pressure, though, only acts in response to dislodging forces, and does not exist otherwise, as soft tissues subjected to continuous negative pressure would soon suffer damage.

Peripheral seal

For all of these retentive forces discussed thus far, the requirement has been that the denture base must be closely adapted to the mucosa, and that a thin film of saliva be present in between. Anything, therefore, that tends to disrupt this, will cause a loss of retention. This can happen most easily at the borders of the denture, as here the action of the tissues is influenced by the underlying musculature. Such actions must be recruited to help maintain the layer of saliva between the external surfaces of the denture flanges.

Thus if the denture flange is too thin when the tissues are at rest, and the denture moves, the saliva will rapidly flow between the tissues and the flange and then to the fitting surface, and the denture will be displaced easily. Obviously then, the narrower the channel between tissues and flange, the slower the flow, and the greater the retention (Fig 1).

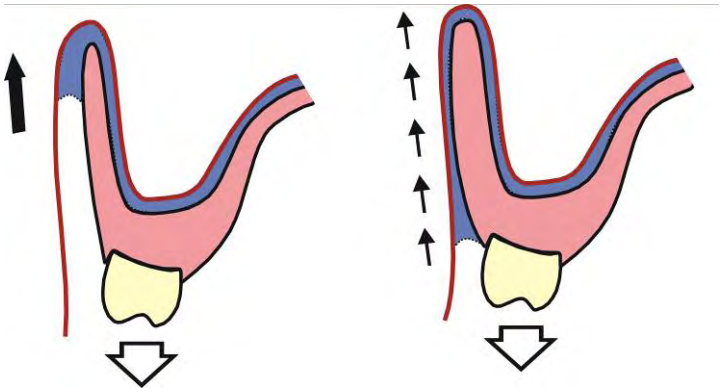

Figure 1: Relationship between the width of the buccal channel and resistance to flow of saliva: left: wide channel, rapid flow, poor retention; right: narrow channel, slow flow, good retention (After Basker,R.M. & Davenport,J.C 1976).

This implies no movement of the tissues themselves, but as they *are* moveable, once again the shape of the flange will either help or hinder retention (Fig 2).

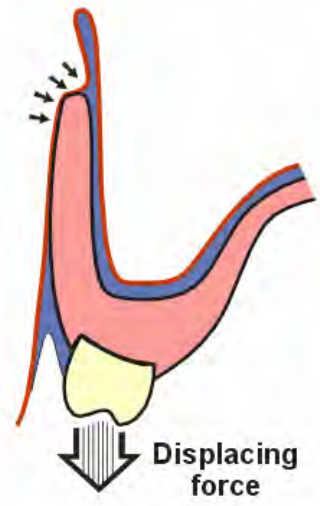

Figure 2: Drop in pressure of the saliva film as a result of a displacing force, causing impaction of the buccal mucosa and greatly increased retention (After Basker,R.M. & Davenport,J.C 1976).

The fact that the tissues do move, constitutes the biggest challenge in the construction of retentive and stable dentures, for the flanges must be of such dimensions as to allow for movement of the muscles and their overlying tissues without causing displacement of the denture base. This is why dentures are comparatively easy to wear, but difficult to use.

An understanding of this is imperative. Observation of the action of the sulcular tissues will show that the sulcus changes shape constantly as the muscles act. At rest, the sulcus is at a different height to that in function. This latter *functional sulcus* determines the extension limit of the denture flanges. If they extend too far into the sulcus, muscular action will cause displacement of the denture, or, equally undesirable, damage to the sulcular tissues in the form of ulceration. If the flange does not extend far enough, there will be insufficient saliva retained, and again, loss of retention. The peripheral seal cannot therefore be retained by the extension of the flange into the sulcus, but rather by the *external* aspects of the flange maintaining close contact with the tissues (Fig 3). This is why it is sometimes referred to as the *facial seal*, a preferable term to that of the often used *border* seal; but this does not take into account the lingual flanges of the lower denture. Hence it is recommended to retain the term *peripheral seal*. It should by now be obvious that this seal is more easily obtained in the upper denture than the lower, because of the greater movements of the lower border tissues, especially lingually.

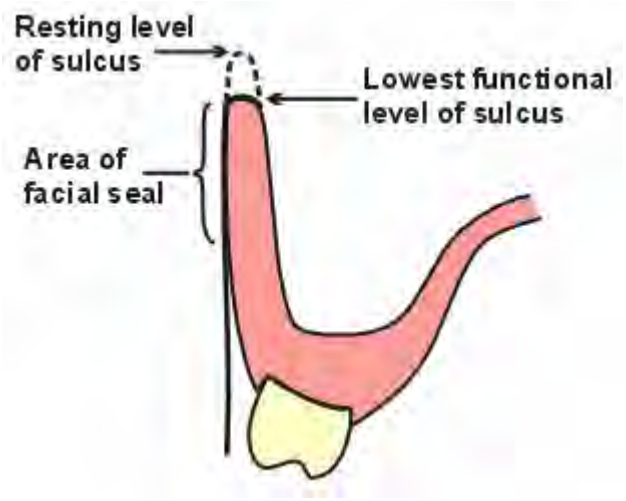

Figure 3: Lateral extension of the buccal flange to produce a facial seal (After Basker,R.M. & Davenport,J.C 1976).

In the upper, the posterior border presents a special situation. The denture must extend as far as possible posteriorly, but is limited by the movement of the soft palate, upon which it cannot encroach. This means that a seal on the external surface of the denture is not possible. The only way that a posterior palatal seal can be produced, is by the denture base displacing the tissues along the posterior border in such a way that when the denture moves during function, the displaced tissue will move with the denture and not break the seal. This is achieved in a variety of ways, but essentially involves creating a raised groove or area along the posterior border, on the fitting surface. This is often referred to as the *post-dam*.

Oral and facial musculature

Additional retentive forces are supplied by the natural action of the oral and facial musculature resting and acting against the polished surfaces of the dentures. This means that these surfaces must be shaped to enable the musculature to fit naturally against the denture in order to reinforce the peripheral seal. It is important to understand that this does not need any conscious effort by the patient: if that is needed, the polished surfaces do not have the correct shape.

In the upper, the buccal flanges slope upwards and outwards from the teeth to allow the action of the buccinators to seat the denture. Posteriorly, the base of the tongue is often recruited to counteract forces exerted anteriorly on the denture, such as during incision, which will tend to tip the denture so that the posterior border rotates downwards. The tongue rises up at the back to press against this border.

In the lower, the buccal flanges slope downwards and outwards from the teeth, again to allow the buccinators to help seat the denture. The lingual flanges have two slopes. Most of the flange slopes towards the floor of the mouth so that the tongue can rest against it. The tongue is guided into this position by the slope of the distal end of the flange. Here, the flange turns towards the ramus, as it extends into the retro-mylohyoid fossa (see later), helping to maintain the peripheral seal, and providing some resistance to lateral forces (Fig 4).

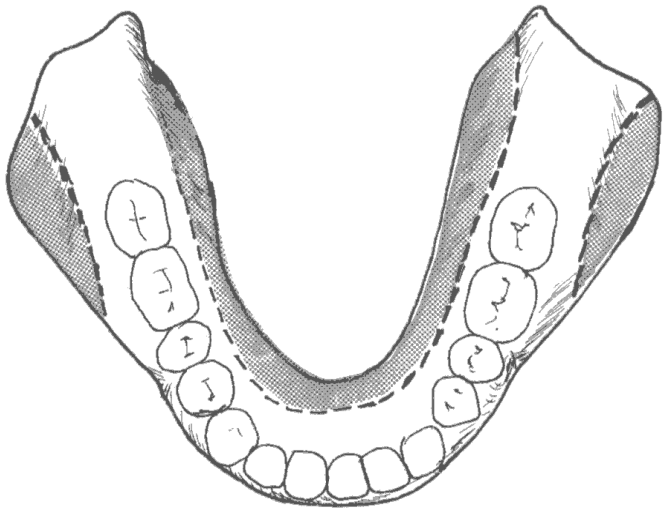

Figure 4: The external form of the denture should allow the cheek and tongue to rest on the buccal and lingual flanges to help hold the denture in place.

Although there should normally be no conscious effort required of the patient, there are many patients for whom the necessary resting position of the tongue against the lingual flange is not a natural one. It is therefore necessary at the first examination of the patient, to observe the position of the tongue when the patient is asked to open. If the tongue naturally maintains a position resting against the ridge or existing denture, then a correctly extended and shaped denture will be easier for that patient to use. If, however, the tongue retreats to the back of the mouth on opening, that action will dislodge a denture. These patients must be made aware of this tendency, and must learn to keep the tongue in a forward resting position, until it does so naturally. This facet is often over-looked, and partially explains why many unsuccessful denture wearers possess dentures that are under-extended, as the operator has erroneously ground away the lingual flange, in the mistaken belief that it is the extension of the flange that has contributed to the unseating of the denture, rather than the position of the tongue.

Occlusion

Two aspects relating to occlusion will be considered here, as they relate to the retention and stability of complete dentures.
The *arch form and position* determine the placement of the teeth, and wherever possible, the aim is to place the artificial teeth in the same positions previously occupied by the natural teeth. This is so that they will occupy a space which will be in harmony between all the muscular forces acting on them, between the lips and cheeks on the one side, and the tongue on the other. Only in this space, will the muscular forces be able to be recruited to advantage, as explained above. This space is termed the *neutral zone* (Fig 5).

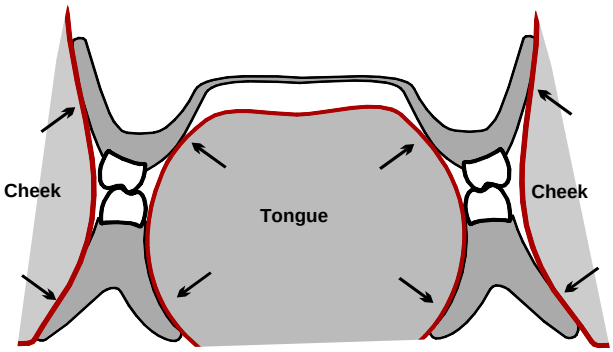

Figure 5: The dentures should occupy a space which will be in harmony between all the muscular forces acting on them, between the lips and cheeks on the one side, and the tongue on the other. This space is termed the neutral zone.

As the dentures occlude, then the manner in which the teeth come together will also have the potential to either help or hinder retention and stability. It is often stated that when chewing, the teeth are separated by the bolus of food, and so the manner in which they occlude is not important. This is wrong, because as the bolus is reduced in size during mastication, the teeth come closer together and as the food particles are ground between the teeth, the tooth contacts increase considerably. Any interference, then, in the ability of the upper and lower teeth to move across each other in this grinding action, will cause the dentures to tip and move more than the patient's ability to control them with muscular action. This means that the way in which denture teeth occlude must be seen dynamically, and not just as a static relationship when in maximum interdigitation. For the forces to be distributed throughout the denture bases, there need to be contacts between as many teeth as possible as they glide over each other, and on both sides of the arch. This is the concept of a *balanced occlusion* and is vital to the successful wearing and use of complete dentures.

Functional anatomical features limiting the extension of denture bases

These features limit the extension of the denture base because of their action in function, or because of the function of muscles influencing their position.

Maxilla

Figure 6 is an intra-oral drawing of the maxillary arch, and indicates the limiting features of an upper denture base.

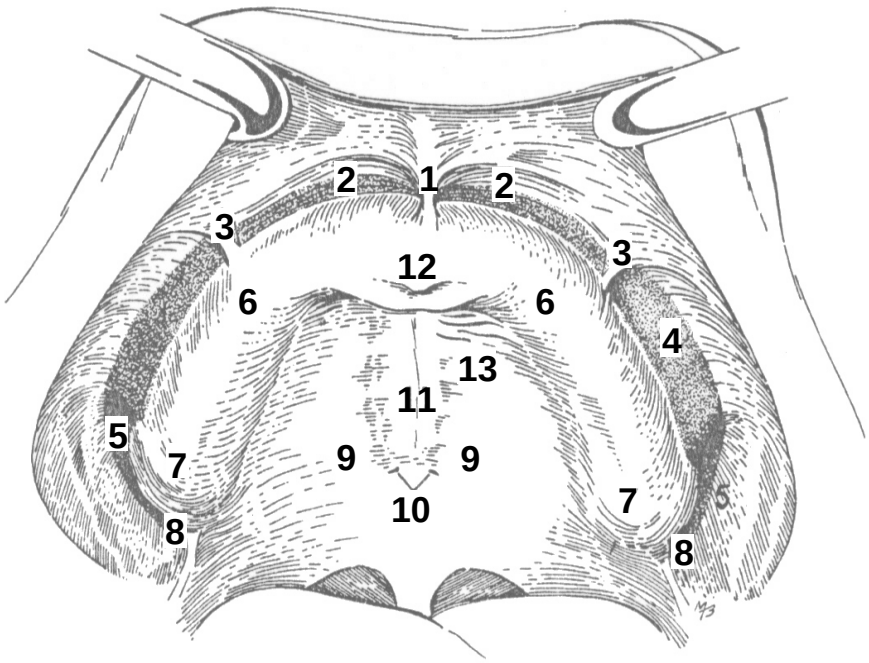

Figure 6: Intra-oral drawing of the maxillary arch. 1, labial frenum; 2, labial sulcus; 3, buccal frenum; 4, buccal sulcus; 5, coronoid contour; 6, crest of alveolar ridge; 7, maxillary tuberosity; 8, hamular notch; 9, posterior palatal seal (post-dam) region; 10, fovea palatinae; 11, median palatine suture; 12, incisive fossa and papilla; 13, palatal rugae (After Martone, A.L. 1963).

The *labial frenum* is a fold of mucous membrane which contains no muscle and has no action of its own. Its attachment on the labial side of the ridge is often low, depending on the degree of resorption of the ridge. The labial flange of the denture must possess a corresponding notch to allow the frenum to pass through. The *buccal frenum* is also a fold of mucous membrane, but varies in shape from a single fold to a broad fan. The levator anguli oris muscle passes beneath it and its action affects its position, as does the orbicularis oris and the buccinator. The former pulls the frenum forwards, the latter backwards. The corresponding buccal notch on the denture must therefore allow for this full range of movement, or the muscle actions will dislodge the denture.

The area between the labial and buccal frena is the *labial sulcus*, into which the labial flange of the denture fits. Distal to the buccal frenum is the *buccal sulcus*, the position of the buccal flange of the denture. The limiting vertical height of the flange is the functional limit of the sulcus. The width of the labial sulcus is determined by the need to replace lost bony tissue to provide for support of the lips, within the limits of the creation of the peripheral seal. The buccal flange also must conform to these criteria, and its height and width are determined by three factors. The height is less of a limiting factor than anteriorly, because of the muscle action in this region, especially in the area of the tuberosity sulcus. The contraction of the *buccinator* limits not so much the height as the width of the buccal flange. The width is also affected by, apart from the need to replace lost bone, the action of the mandible on opening, and the contraction of the *masseter*. As the jaw is clenched, the masseter contracts, and as it is opened and moved to the side, the *coronoid process* also limits the space available.

The buccal sulcus ends posteriorly in the *hamular notch*, situated between the tuberosity of the maxilla and the hamulus of the medial pterygoid plate. It is also the posterior boundary

of the denture base in this region. As there is no muscle or ligament present, the posterior palatal seal (post dam) is placed through the centre of the deepest part of the hamular notch. The posterior border cannot extend further in this region because it will cause pressure on the pterygoid hamulus, and interfere with the action of the pterygomandibular raphe which is pulled forwards as the mouth is opened.

Extending from one hamular notch to the other is the *vibrating line of the palate*. It is not necessarily the junction of the hard and soft palates, but marks the motion of the soft palate. It is easily detected by asking the patient to say "ah", whereupon it can be marked in the mouth, and its position transferred to the base. The posterior border of the denture must extend at least to the vibrating line, which in fact is more of an area than a line, so that it is on soft tissue. This enables the development of the post dam, to create some displacement of the soft tissue. The *fovea palatinae* are not good landmarks for the vibrating line, as they are usually anterior to it.

Mandible

Figure 7 is an intra-oral drawing of the mandibular arch, and indicates the limiting features of a lower denture base. There are more features limiting the extension of a lower base than in the upper, especially because of the movements of the musculature both buccally, and lingually. Lingually the movements have a great range and speed, and this becomes a challenge not only for the operator, but also for the patient. Buccally the movements are slightly easier to control, and maximum coverage, sometimes surprisingly extensive, can be aimed for.

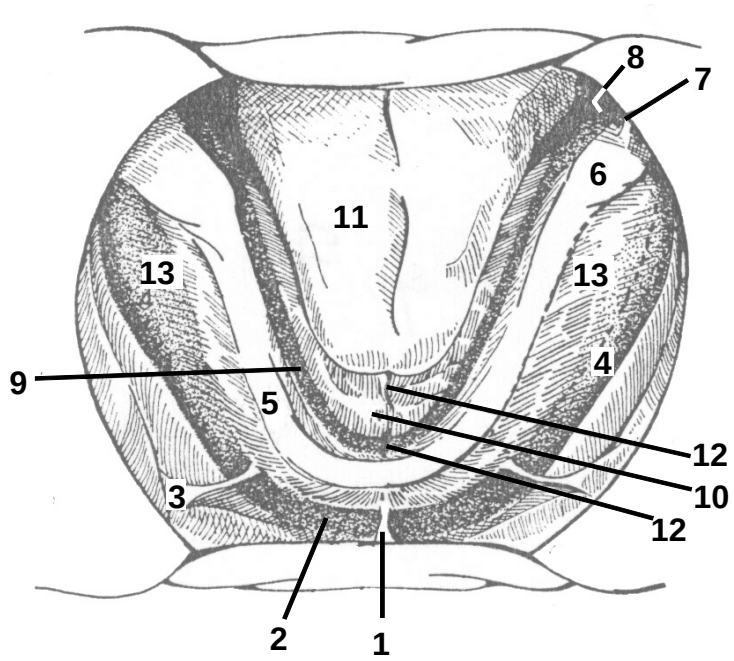

Figure 7: Intra-oral drawing of the mandibular arch. 1, labial frenum; 2, labial sulcus; 3, buccal frenum; 4, buccal sulcus; 5, crest of alveolar ridge; 6, retromolar pad; 7, pterygomandibular raphe; 8, retro-mylohyoid fossa; 9, lingual sulcus; 10, genial shelf; 11, tongue; 12, lingual frenum; 13, buccal shelf (After Zarb et al 1990).

The *labial frenum* is quite active, as it helps attach the orbicularis oris. The *labial sulcus*, or vestibule, is often quite shallow, because the muscle attachments may be close to the crest of the ridge, depending on the degree of resorption of the bone. This makes the shape

and position of the labial flange difficult, as once again it is necessary to replace lost tissues, and ensure that tooth placement is in the neutral zone.

The *buccal frenum* connects as a continuous band of fibrous and muscular tissues through the modiolus to the upper buccal frenum. As in the upper, it is subject to a wide range of movement, which must be allowed for in the denture base. The *buccal sulcus* extends posteriorly from the buccal frenum, and the extension of the buccal flange of the denture in this region is influenced by a variety of factors. The primary area for support for the denture base is the buccal shelf, and the lateral extension of the base will depend on the extent and action of the *mucolabial fold* (where the mucosa passes from the mandible to the cheeks). This often, but not always, coincides with the *external oblique ridge*, which provides a useful landmark, but which in some cases *can* be covered by the denture base. The deciding factor is the position and action of the mucolabial fold. The muscle attachments in the area are less of a factor, as in fact the denture base rests on the lower fibres of the buccinator. This was explained in the section on support, and it is worth repeating that the muscle's fibres and its action are in an antero-posterior direction, so its displacing potential is slight. In practice, it has been observed that there is less resistance to buccal extension of the base after the denture has been worn, relative to that encountered on first insertion. It seems, therefore, that it is possible to displace and possibly stretch the tissues in this area, a goal worthy of achievement, in view of the invaluable nature of the support this region provides.

The distobuccal limit of the buccal flange *is* influenced by the displacing action of a muscle, in this case the *masseter*. As it contracts, it pushes inwards against the buccinator as its anterior fibres pass outside that muscle. This action limits the shape of the flange, and is dependent on the relative size of the muscle, and its shape and direction. These depend on its position of origin and insertion, in turn dependent on the relative shapes and positions of the zygomatic arch and ramus.

The *retromolar pad* defines the posterior limit of the superior surface of the denture. This triangular, pear-shaped soft pad of tissue is valuable in creating a peripheral seal, and should be covered by the denture base. It does, though, contain fibres whose activities may limit complete coverage. Buccinator fibres enter from the buccal, and superior constrictor fibres enter from the lingual. Some fibres of the temporalis tendon often enter the pad, as does the pterygomandibular raphe.

The *lingual sulcus* extends from the *lingual frenum* to the *retromylohyoid fossa*. The tissues forming this sulcus are unlike other border tissues limiting flange extension, because of the mobility of the floor of the mouth along its extent. The denture flange rests entirely on soft tissue, and not on mucosa in contact with bone as in other areas. The lingual sulcular tissues are easily distorted, and so a sensitive impression technique must be used to record the correct functional sulcus - the position and shape of the functioning mucolingual fold. The sulcus and corresponding denture flange can be considered as having three regions: anteriorly from the lingual frenum to the anterior part of the *mylohyoid ridge*; the mylohyoid ridge region itself; and the retromylohyoid ridge area.

The anterior part of the lingual denture flange must first allow for the full function of the lingual frenum, which, being very active, means that the lingual notch of the denture is quite shallow. The extension from here posteriorly must allow for the function of the mylohyoid muscle when the tongue is protruded. Although the attachment of this muscle is close to the lower border of the mandible, the sublingual salivary gland lies over it, so that the flange becomes quite shallow. Just before the mylohyoid ridge, a *premylohyoid fossa* is

created where the convex curvature of the mylohyoid ridge meets the concave curvature of the mandible. This creates a corresponding eminence in the denture, and causes the characteristic S-curve of the lingual flange, from the premylohyoid area to the retromylohyoid area, which forms another eminence on the flange (Fig 8).

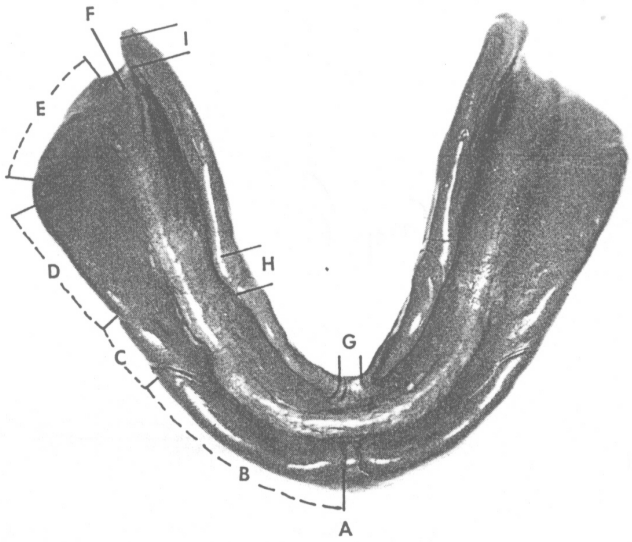

Figure 8: Final impression for a mandibular denture. A, labial notch for labial frenum; B, labial flange; C, buccal notch for buccal frenum; D, buccal flange; E, area influenced by the action of masseter; F, retromolar pad area; G, lingual notch for lingual frenum; H, premylohyoid eminence in premylohyoid fossa; I retro-mylohyoid eminence in retro-mylohyoid fossa. The S-curve of the lingual flange is created by the slope of the lingual flange: posteriorly towards the mandible into the retro-mylohyoid fossa, anteriorly towards the mandible again into the premylohyoid fossa, and in between, the flange slopes towards the tongue just beyond the attachment of the mylohyoid muscles on the mylohyoid ridge (After Zarb et al 1990).

The mylohyoid region of the flange is an area that causes a great deal of confusion and misunderstanding concerning the correct extension of the base. The problem stems from the fact that the attachment of the muscle to the mylohyoid ridge is often quite high, especially in resorbed ridges. Further, the ridge itself is often sharp, and there is an undercut below it, inferiorly. This means that the denture flange can neither rest *on* the ridge, nor extend *below* it. However, neither can it stop *short* of the ridge, as vertical forces acting on the base in this region will cause soreness, and peripheral seal will not be maintained because the flange will not maintain contact with the *mucolingual fold*. The answer to this dilemma lies in an understanding of this mucolingual fold (Fig 9).

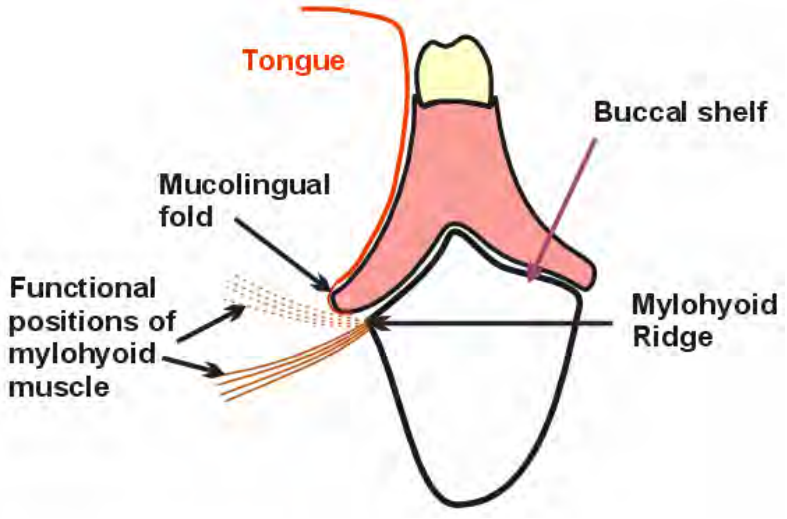

Figure 9

During actions of the floor of the mouth that are functional, (by which is meant not excessive), the fold in this area is just *lingual* to the mylohyoid ridge. This means that the lingual flange can slope towards the tongue, allowing the tongue to rest on top of it (Fig. 9). It will also provide space for the floor of the mouth to be raised during function without displacing the denture. The peripheral seal will be maintained, as contact with the mucolingual fold will be maintained. This shape of the flange in this region coincides with the need for the polished surface to be of the correct shape, as discussed above (see Fig 4).

Beyond the mylohyoid ridge posteriorly, the distal end of the lingual flange curves back towards the mandible as it extends into the retro-mylohyoid fossa. This extends from the distal end of the mylohyoid ridge to the *retro-mylohyoid* curtain, which is the most posterior limit of the lingual flange, governed by the action of the medial pterygoid (Fig 10). The extension of the denture base into the retro-mylohyoid fossa improves stability of the base, and allows the tongue to be guided on top of the lingual flange.

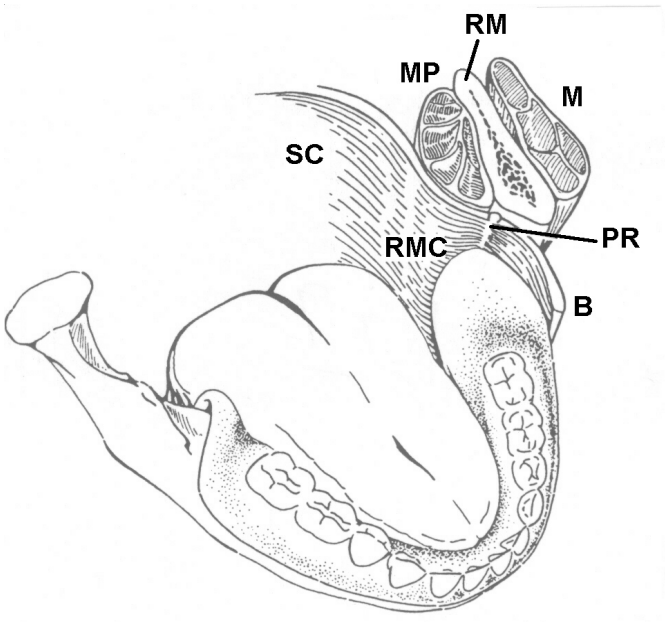

Figure 10: The disto-lingual limits to the denture flange. RMC, retro-mylohyoid curtain, the mucosal covering of the superior constrictor (SC); B, buccinator; PR, pterygomandibular raphe; RM, ramus of mandible; M, masseter; MP, medial pterygoid, the contraction of which causes RMC to move anteriorly, limiting the posterior extension of the lingual flange in the retro-mylohyoid fossa (After Zarb et al 1990).

Clinical implications

Clearly, all the factors that contribute to the retention and stability of denture bases must be enhanced during the clinical techniques involved in the construction of complete dentures. Perhaps the most important aspect is that the impression techniques used must ensure the correct extension of the denture bases: their length, width and overall shape.