

THIS CRITICAL REVIEW OF LITERATURE
CONCERNING MAXILLO-MANDIBULAR RELATIONSHIP IS
SUBMITTED IN SUPPORT OF CANDIDATURE
FOR THE DEGREE OF MASTER OF DENTAL SURGERY.

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VERTICAL DIMENSION AND CENTRIC RELATION
OF THE ADULT EDENTULOUS PATIENT.

A CRITICAL REVIEW.



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FOREWARD

It is felt that the problems of centric relation and vertical dimension are so closely inter-related that it would be impossible to adequately discuss one topic without considering the other. The contents of this thesis are artificially divided into two sections purely from the point of efficiency of presentation rather than to infer that these are two distinct subjects. An attempt has been made to effect a rhetorical union of the two sections by discussing the muscle physiology, which controls both positions, in an intermediate position.

I feel that the two topics may be collectively referred to as "Maxillo-Mandibular Relationship".

A brief section on relevant anatomy has been included not as part of the thesis but as a starting point upon which one's logic must be based.

ANATOMY OF PARTS RELEVANT TO MANDIBULAR PLACEMENT.

Governing the positioning of the mandible we have the forces acting upon it and applied by the muscles of mastication, elevation and depression, together with the hard and soft structure of the temporo-mandibular joint. In both the dentulous and edentulous patient the inclines and positions whether normal or otherwise of the cusps of the teeth and their articulation with their antagonists, is of prime importance in the positioning of the mandible in the later stages of the closing movement. This will not be dealt with here as it is felt that the topic is related to the problems of articulation and occlusion which are not under consideration at the moment. The first factor, therefore, to be discussed here is the muscles of mastication.

The muscles of mastication are four in number, the masseter, temporal, Internal Pterygoid and External Pterygoid. Three of these muscles exert a powerful vertical force upon the mandible whilst the latter acts at right angles to this plane and protracts the mandible. These muscles, in conjunction with the suprahyoid muscles, work in groups and not as individual units in the effecting of mandibular excursions.

The Masseter:

This is the most superficial of the masticatory muscles. It is quadrilateral in outline and extends from the zygoma and zygomatic arch to the lateral surface of the mandible. It can be divided by means of its origin into a superficial and a deep part. The superficial portion arises from the lower border of the zygomatic bone with strong tendinous fibres. If it is particularly well developed the origin may extend as far as the outer corner of the zygomatic process of the maxilla. Cunningham states that the origin of the superficial part extends posteriorly along the anterior two thirds of the zygomatic arch, while Sicher points out that the origin never extends posteriorly beyond the zygomatico-temporal structure. The fibres run in a downward and backward direction and are attached along the lower one third or one fourth of the posterior border of the ramus and

along the lower border externally to the level of the second molar. The bulk of the muscle is attached, according to Sicher, to the outer surface of the ramus in its lower half, while Cunningham depicts the attachment as covering almost all the outer surface of the ramus as far superiorly as the coronoid process. The masseter is constructed as a muscle of great power, having its fibres shortened but increased in number and arranged at an angle to the long axis of the muscle. The deep fibres take origin from the inner surface of the zygomatic arch and at its most posterior part also from its lower border. These fibres run exactly downwards and are thus at an angle to the fibres of the superficial muscle plate. The deep part of the masseter is most inseparately fused with the most superficial fibres of the temporal muscle.

The action of the muscle is that of a powerful elevator of the lower jaw closing the jaws and exerting pressure upon the teeth, especially in the molar region. The superficial portion exerts pressure at right angles to the posteriorly ascending occlusal plane of the molars. The deep portion, because of the angulation of its fibres, is able to exert a retracting component which is important during the closing movement.

Temporal Muscle:

This is characteristically described as being fan shaped and has its origin in a wide field in the lateral surface of the skull bounded by the inferior temporal line. The field of origin covers a narrow strip of parietal bone, temporal squama and parts of the frontal bone, temporal surface of the greater wing of the sphenoid bone, the sphenoid bone as far inferiorly and including the infra temporal crest. The muscle also arises from the temporal fascia, especially in its upper part where the tissue assumes an aponeurotic character. The fibres of the muscle converge from this large origin, to the opening between the zygomatic arch and the lateral surface of the skull. The bulkiest part of the muscle is anteriorly where the fibres are almost vertical. As the muscle extends posteriorly the fibres become increasingly oblique until those which arise from the most posterior part of the temporal fossa run in an almost

horizontal direction and these bend downwards and forwards in front of the articular eminence to reach the mandible. Thompson (1941) indicates the temporal muscle has been shown to be composed of at least 5 heads.

The muscle is inserted into both lateral and medial surfaces of the coronoid process and there is an extension of the insertion down the anterior edge of the ramus. The insertion is by means of a tendon, which is in part an extension of the point of the coronoid process into the muscle. It is attached to the coronoid process at its apex and posterior slope to the deepest point of the condylar notch. Other fibres of the muscle insert on the outer surface of the coronoid process, and two groups of fibres send their tendons far down towards the posterior end of the alveolar process. The most lateral of these tendons is attached to the temporal crest of the mandible. The most anterior fibres of the former group may become continuous with the fibres of the buccinator muscle. The deep tendon is, as a rule, stronger and longer than the more superficial one.

The fibres of the temporal muscle are longer than those of the masseter, but not as long as they are usually illustrated. The muscle is built for movement rather than for power and is an elevator of the mandible basically; however, its posterior fibres do have a retracting element which is related to the angle of the fibres after they have passed to be inserted beyond the root of the zygomatic process.

The plane of the temporalis muscle approximately bisects the angle formed by the masseter muscle and internal pterygoid muscle.

Internal or Medial Pterygoid Muscles

This muscle is situated medially to the ramus of the mandible. It is a rectangular powerful muscle and its main origin is in the pterygoid fossa. Inferiorly fibres arise from the INNER surface of the lateral pterygoid plate near its inferior end and extend their origin anteriorly to the inferior surface of the pyramidal process of the palatine bone. The fibres from this origin constitute the "greater head" of the muscle while the fibres of the lesser head arise by strong tendons from the maxillary

tuberosity. The greater and the lesser head merge together as the muscle progresses posteriorly. The fibres of the muscle run downwards and backwards and outwards and are inserted into the angle of the mandible on its medial surface. The insertion occupies a triangular area which is bounded by the lower half of the posterior border of the mandible and by two lines which start at the mandibular foramen. The area of insertion is marked by irregular transverse ridges of bone. At the posterior and inferior borders of the insertion, the fibres of the medial pterygoid may meet those of the masseter in a tendinous structure. This muscle is anatomically and functionally a counter part of the masseter, although not as strong. The internal structure of this pterygoid muscle consists of an alternation of fleshy and tendinous parts so that the muscle fibres arise from one tendon and end on another and are, therefore, arranged at an angle to the general direction of the muscle. This arrangement increases the power of the muscle. The muscle acts in a synergistic manner with the masseter muscle and is thus a mandibular elevator. It is doubtful if it can act together with the external pterygoid muscle to shift the mandible to one side although it must be considered as a possibility. Gray in his book of anatomy (Ed. 22) states that "If the pterygoid internus and externus of one side act the corresponding side of the mandible is drawn forward whilst the opposite condyle remains comparatively fixed, and side to side movements such as occur during tituration of food takes place."

External or Lateral Pterygoid Muscles

This muscle is deeply placed in the infra-temporal fossa. It arises by means of two heads, the larger of which is more inferiorly placed and originated from the outer surface of the lateral pterygoid plate, while the smaller takes its origin from the infra-temporal surface of the greater wing of the sphenoid bone, medial to the infra-temporal crest. The fibres of the upper head are directed laterally and backwards in a horizontal direction, whilst those of the lower head run in a more ascending direction from their origin. Posteriorly the fibres of the two heads fuse into one muscle and there is, therefore, a common insertion. The upper fibres of this united group of fibres are attached to the anterior surface of the articular capsule and thus indirectly to the anterior.

Intra-Mandibular Muscles:

These may be divided into two groups, the suprahyoid and the infrahyoid. Only the former need to be considered here as only these are attached to the mandible. The infrahyoids act as far as this discussion is concerned to stabilize the hyoid bone so that contraction of the suprahyoids may produce some effect on the mandible. Also in this section the platysma muscle will be briefly considered as its presence has bearing on the postural position of the mandible.

The Suprahyoid Muscles:

Digastric Muscle:

This muscle consists of two fleshy parts, a posterior and an anterior belly which are connected by a strong round tendon. The posterior belly arises from the mastoid notch, medially to the mastoid process; the intermediate tendon is fixed to the hyoid bone and the anterior belly finds its attachment in the digastric fossa of the mandible at its lower border close to the midline. The two bellies of the muscle form an obtuse angle. The posterior belly is much longer than the anterior belly, almost circular in cross section and only slightly flattened in inter-medial direction. Gradually tapering anteriorly, the posterior belly continues into the round intermediate tendon. The anterior belly, arising from the intermediate tendon, is much shorter than the posterior. It consists in most individuals of a thicker lateral and a thinner medial part. Its insertion into the mandible is partly fleshy and partly tendinous. The intermediate tendon is not directly attached to the hyoid bone, but is fastened to it by strengthened fibres of the cervical fascia, which form a loop around the tendon sometimes separated from it by a synovial bursa. Variations of the digastric muscle are frequent and usually affect the anterior belly.

Lyo-hyoid Muscles:

This muscle forms anatomically and functionally the floor of the oral cavity. The muscle arises from the mylohyoid line on the inner surface of the mandible. Its most posterior fibres take origin from the region of the alveolus of the lower third molar. The origin of the anterior

fibres deviates more to the lower border of the mandible. The posterior fibres of the coarsely bundled muscle run steeply downwards medially and slightly forwards and are attached to the body of the hyoid bone; the majority of the fibres, however, join those of the contra-lateral muscle in the mylohyoid raphe. The muscle plate is considerably thicker in its posterior part.

Geniohyoid Muscles:

This arises from the anterior end of the mylohyoid line from the inner surface of the mandible close to the midline and lateral to the mental spines, by a short and strong tendon. The muscle, in contact with that of the other side, proceeds straight posteriorly and slightly downwards and is attached to the upper half of the hyoid body. Posteriorly the muscle gradually widens and assumes in cross section a triangular shape.

Infrahyoid Muscles:

These muscles extend between the hyoid bone above and the sternum, clavicle and scapula below. The two superficial muscles, sternohyoid and omohyoid directly connect the shoulder girdle and the sternum with the hyoid bone; the deep layer is divided into two muscles - sterno-thyroid and thyro-hyoid.

The function of these muscles is two fold: they may either depress the hyoid bone and with it the larynx, or they may fix the hyoid bone in its position anchoring it, as it were, to the trunk.

Platysma Muscles

This is a flat and wide muscle plate which covers most of the lateral and anterior region of the neck. Its posterior border reaches from the acromion to the angle of the jaw, its anterior border from the region of the sterno-clavicular joint to the chin. At its upper border many of the platysma fibres find attachment on the lower border of the mandible, the rest continue into the face. At the lower end the bundles of the muscle cross the clavicle and cover a variably wide part of the infra-clavicular region where they end with their tendons in the skin.

Anatomy of the Temporo-mandibular Joint:

This is a highly specialised joint and is distinguished from most other articulations by the fact that the articulating surfaces of the bones are not covered by hyaline cartilage, but by an avascular fibrous tissue. It is further characterised by the fact that the two articulating complexes of bone carry teeth whose shape and position, exert a decided influence on the movements of the joint. The coupling effect of the two joints by way of the body of the mandible also affects a further restriction on movement.

The articular space is divided into two compartments by means of the articular disc which is interposed between the mandible and the articulating surface of the temporal bone. The inferior synovial cavity is the smaller of the two joint cavities and it is here that the ginglymoid or hinge action takes place. In the larger upper synovial cavity, the arthrodioid or gliding action occurs. There are no true spaces or cavities only a potential cavity existing. All surfaces are in contact. These are lubricated by a small amount of synovial fluid. The head of the mandible articulates through its upper and anterior surface. According to Sicher the condyle measures 15 - 20 m.m. long and is 8 - 10 m.m. thick. The axes of the two condyles form an obtuse angle varying from 145° - 160° and if extended backwards the axes of the two condyles would cross approximately at the anterior circumference of the foramen magnum. The condyle is strongly convex in an anterior posterior direction and slightly convex medio laterally. This latter convexity may be marked by a variably prominent sagittal crest. The lateral pole of the condyle is only slightly prominent beyond the outer surface of the ramus and is rough for the attachment of the temporo-mandibular ligament. The inner pole juts considerably medially from the inner surface of the ramus.

The articulating surface of the temporal bone is situated anteriorly to the tympanic bone on the squamous temporal and comprises the articular fossa and the convex articular tubercle. The posterior part of the articular fossa is elevated to a ridge which increases in height laterally - this is the posterior articular lip. Laterally it is thickened to a cone-

like prominence which lies immediately anterior to the external auditory meatus this is termed the post glenoid process. Medially the articular fossa narrows and is bounded by a bony lip which leans against the angular spine of the sphenoid. This is sometimes elevated to a triangular process - the temporal spine. Anteriorly, is the articular eminence, a transverse bony ridge which is structurally the root of the zygomatic arch. It is strongly convex in an antero posterior direction and somewhat concave in a transverse direction. Above the condyle the bone is very thin and devoid of medullary structure. In no instance Sicker found was there a perforation between the glenoid fossa and the middle fossa, but in many cases the separating bone was paper thin. The entire articulating surface of the temporal bone is covered by a layer of fibrous tissue which is thickest at the posterior slope of the articular eminence.

The articular disc is an oval fibrous plate of great firmness, it is thinner centrally than peripherally and posteriorly it is especially thickened. The variations in thickness of the disc seem to be correlated to the prominence of the articular eminence. The condyle is separated from the temporal bone by the thickest part of the disc. Here the disc is firm, white and translucent. The distance is approximately four times that of the bone separation at the anterior surface of the condyle. Posteriorly the disc continues into a thick layer of loose and vascularized connective tissue which meshes to and fuses with the posterior wall of the articular capsule.

The disc of the joint is described as having four clearly defined transverse ellipsoidal zones which may be termed:

1. Anterior band which is moderately thick but relatively narrow from before backwards (pars nanisca).
2. The intermediate band which is thinner than the others and narrow. (pars gracilis).
3. The posterior band which is the thickest of the three and widest antero-posteriorly. (pars posterior nanisca).
4. The bilaminar zone which consists of an upper stratum which is attached to the posterior wall of the glenoid fossa and symplectic suture and a lower stratum which is attached to the back of the mandibular condyle.

The synovial capsule of the joint is attached to the rim of the temporal articular surface. It fuses with the disc around its entire circumference and continues below the disc to the mandibular head. There it inserts at some distance from the articulating surface itself and reflects upon and covers the bone to the border line of the articulating facet. A part of the mandibular neck is, therefore, covered by the synovial capsule.

The fibrous capsule of the mandibular joint follows closely the synovial capsule and is rather thin. The lateral surface is strengthened to a fairly distinct ligament, the temporo-mandibular ligament. In centric relation the capsule is partially folded loosely between the temporal bone and the disc to allow sliding movement in the upper compartment of the articulation. It is much tighter between the disc and the mandibular head and is especially tense between the disc and the two poles of the condyle.

Histologic Findings

Only the areolar type of synovial layer is distinguished microscopically in the articular disc. The areolar type is a closely packed cell rich layer averaging 3 cells deep and is seen as a distinct membrane. In the mid-sagittal plane the areolar type of synovial layer is found covering the posterior third and anterior one sixth of the disc. There is a small transition area between the synovial layer and the central portion of the disc where no definite synovial layer exists. The central portion of the disc has an incomplete cell layer. Collagenous fibres form most of the surface with only an occasional fibre-blast. These surface fibre-blasts have unusually long processes running parallel with the surface.

Typical fibre-cartilage was not found on any of the discs examined and there were no homogeneous capsules. A transition type between fibre-cartilage and fibrous connective tissue is increasingly evident in discs of persons over twenty years of age. The cells are generally oval, but many variations occur. Near the surface parallel rows are evident, but otherwise there is a random distribution. The interstitial substance contains many compact collagenous bundles. This type of tissue found in the discs of older subjects is in the middle one third and posterior half of the

anterior third.

Very thick closely packed parallel collagenous bundles are the main constituent of the fibrous connective tissue. The fibre-blasts are arranged in the spaces between and parallel to the collagenous bundles. The tissue constitutes the main bulk of the disc. In the children under 16 years of age it forms nearly the entire disc. In the older groups this type is found in the areas covered by the areolar type of synovial layer. Only in the central area is there a tendency to a transitional fibre-cartilage type. Blood vessels are found only in those areas covered by the areolar type of synovial layer. The vascular plexus is particularly rich, especially near the surface where many capillaries are found in the synovial layer.

Basically two movements of the mandible can be distinguished:

1. Rotary or hinge.
2. Translatory or sliding of the mandibular head - this may be symmetrical or asymmetrical.

The insertion of part of the external pterygoid muscle to the particular disc is the single fact which is always quoted to explain the combined forward or sliding of the disc condyle. However, it has to be remembered that the disc has a protractor, but no retractor muscle, also cadaver experiments show that translatory movements of the mandible occur in the upper articular compartment. The discs simply follow the sliding movements of the mandible because it is tightly attached to the poles of the condyle. Therefore, it seems that the capsular attachment of the external pterygoid serves more as balancing fixation of the disc than as a protractor.

The functional movements of the mandible are combinations of the basic movements:

1. Opening and closing movements.
2. Symmetrical protrusion and retrusion.
3. Asymmetrical lateral shift or rotation.

The first of these is a combination of rotatory and translatory movements, i.e. the lower jaw rotates around a frontal axis (i.e. hinge axis) which passes through the centres of the two condyles. The translatory movements may cause the condyle head to reach the height or even the anterior slope of the articular eminence. The rotatory movements may be extensive enough that the opening between the upper and lower teeth will accommodate 3 fingers. During ~~capitulum~~ the opening, the soft tissues behind the capitulum sink in and a shallow groove becomes visible. During opening and closing, the rotatory and translatory movements are not evenly combined. The opening movement starts with an almost pure rotatory or hinge movement which depresses the mandible to or slightly beyond its rest position. From then on the two components combine to a smooth movement. After maximal opening the closing movement commences with a phase in which the translatory movement, that is, the backward movement preponderates in this way mouth is closed to about $2/3$ of its maximal opening and at the same time the head of the mandible is brought from the anterior slope to the high or posterior slope of the articular eminence. The last two thirds of the closing movement occurs again in smooth combination of translatory and rotatory movements. The combination of rotatory and translatory movements was, therefore, acquired and fixed as a neuro-muscular phenomenon. The intricate movement is not necessitated by the shape of the articulating bodies or by the course of the ligaments and two basic movements can be enacted independently.

The forward and backward movements of the mandible are simple translatory movements of the mandible if the teeth are not in occlusion.

A lateral shift of the mandible results only if the condyle and the corresponding disc are pulled forward to the articular tubercle. During the shift or lateral rotation of the jaw the mandible moves around an almost vertical axis only slightly inclined forward and backwards which passes a few millimetres behind the condyle of the side toward which the chin deviates. The condyle to which side the mandible is moving does not rotate in situ but moves also slightly forwards and outwards. This movement is known as Bennett's movement. Due to the great freedom of the

temporo-mandibular joint the mandible can be moved from one extreme position into the other without returning to the rest position. This is of importance for it proves that one point of the mandible of an edentulous jaw can be made to glide along paths of widely varied inclinations to the horizontal, if the plane only falls within the limit of the movements of the jaw.

Temporo-mandibular Articulation:

Shore (1959) in his book gives the following information on movements in the joints:

1. Movements between the condyle and meniscus.

In the retrusive position the posterior thick band of the meniscus lies just in front of the transverse condylar ridge. As the condyle is moved forward its ridge passes 5-6 mm across the posterior thick band onto the intermediate thin zone of the meniscus. When the jaw is forced as far forward as it will go, the ridge crosses the anterior band and comes to rest just in front of it. From the extreme retrusive to the extreme protrusive one, the excursion of the condylar ridge, relative to the meniscus, is not more than 8 mm.

2. Movements between the Meniscus and the Temporal bone.

Since the total forward excursion of the condylar ridge relative to the temporal bone is at least 15 mm, and since it has been found that the maximum movement of the ridge relative to the meniscus is 8 mm, we should expect that the meniscus should move forward on the temporal bone at least 7 mm. It is evident that the movement of the condyle and meniscus forwards out of the glenoid fossa necessitates something else moving in to take their place. In dissected joints the back of the meniscus curls downwards away from the temporal bone leaving an air space when the condyle is moved forward. In unopened joints and in the living subject, of course, the meniscus must remain in contact with the temporal bone as no air can enter the joint. The appearance of a depression on the surface of the face of the condyle when the jaw is opened in the living subject supports

the view that soft tissues at the back of the joint move into the vacated glenoid cavity and this is confirmed in specimens frozen in the protrusive position before sectioning when the glenoid fossa is occupied by the bilaminar zone of the disc. This relatively thick but loose structure has evidently been wedged forward into the space vacated by the condyle.

3. Bolander (1956) - Innervation and blood supply of the joint cavity.

The temporo-mandibular articulation is supplied by the auriculo-temporal and masseteric branches of the mandibular nerve. Terminal fibres of sensory and vaso-motor nerves are found in the connective tissue of the synovial membrane. The cartilage of the joint of course has no nerve supply.

The vascular supply of this articulation comes from superficial branches of the external carotid artery. Tiny branches pass into the ends of the bones to the margins of the articular cartilages and to the articular capsule. The surfaces of the cartilage have no blood supply as would naturally be expected. The synovial membranes located above and below the articular disc are supplied with a rich network of minute vessels at the synovial fringes.

ANATOMY OF LIGAMENTS:Temporo-mandibular Ligaments:

The fibrous capsule of the mandibular joint is rather thin. Only the lateral surface of the fibrous capsule is strengthened to a fairly distinct ligament, the temporo-mandibular ligament. It may be called the external lateral ligament and is described by Shore⁽¹⁹⁵⁴⁾ as running from the outer temporal part of the zygomatic arch and the articular tubercle to insert on the lateral and posterior margins of the neck of the condyle. This is the main suspensory ligament of the mandible during moderate opening movement and it strengthens the lateral aspect of the capsule.

Sphenic-mandibular Ligament:

This is a remnant of Meckel's cartilage. It arises from the angular spine of the sphenoid and is directed downward and outward. It spreads fan like toward the mandible to which it is inserted at the mandibular lingula, the lower border of the mandibular foramen and the lower border of the groove of the mandibular neck. It is in most individuals, a thin layer of dense connective tissue with indistinct anterior and posterior borders.

Stylo-mandibular Ligament:

This is a re-inforced part of a fascial lamella which extends from the styloid process and stylohyoid ligament to the region of the mandibular angle. Part of its fibres are attached to the mandible itself, but the majority continue into the fascia on the medial surface of the internal pterygoid muscle. The upper border of the stylo-mandibular ligament is often sharp and thickened.

Ligaments, like connective tissue, cannot withstand a permanent stretch. The ligaments only limit the extent of various movements; they do not guide them. They may, however, guide them in their most peripheral movement. They are but checkers and restrainers of the joint, the permanent stability is ultimately obtained and maintained by the musculature.

VERTICAL DIMENSIONIntroduction

There seems amongst the authors of today's literature no doubt as to the importance in the establishment of the correct vertical dimension during the process of constructing full dentures.

Boyle (1947) considered the establishment of vertical dimension is a factor of very greatest importance in the construction of complete dentures. He states that whether the alveola ridges remain practically unabsorbed or whether they have completely disappeared is immaterial. The problem in all cases is to restore the vertical height of the lower third of the head and face to the proportions of yesterday, in order to provide the highest attainable efficiency and at the same time to meet all aesthetic requirements. The provision of complete dentures having 100% aesthetic qualities cannot be achieved unless the vertical dimension has been correctly judged.

Different authors consider the establishment of vertical dimension to be important for various reasons. One consideration as above mentioned is that of aesthetics. Burtenshaw in 1948 indicates that there are sixteen muscles of expression, ten of which are in the oral and dental section, and control the expressions of contempt, sneering, determination, laughing, sobbing, sadness, disgust and kissing. Thus the dental section of the face controls most of the expressions. Block in 1953 agrees "successful dentures must look good, feel good, function well and do a minimum of damage to the foundation tissues under them - when we restore proper vertical dimension we fulfil these requirements".

Boos in his writing is noted for his approach to the problem. He stresses its importance in his articles and remarks that in basic

diagnosis of a full denture patient there is required a location of vertical dimension, centric relation and the horizontal rotation centre of the mandible in order to establish a jaw position for occlusion.

Most who write on the subject are acutely aware of the physiological importance in the establishment of vertical dimension. Amongst these include Block (1953) and Pound (1947) who say that the factors of centric relation and vertical dimension are extremely important to the equal distribution of stresses and to ridge preservation and Boos (1940) who indicates "the proper relationship between mandible and maxillae would include function of the muscles, balanced occlusion and the provision of ideal conditions for each patient". Kazis in 1948 points out that it is obvious that the physiologic and anatomic relations between the skull, the teeth, the mandible, the temporo-mandibular articulation and the muscles of the head and neck are characterised by interdependence. Should any one of these component factors fail or become defective in the functioning the resultant effects will be destructive to the proper synchronization of the parts involved in the complex system.

Harris (1938) considers the establishment of vertical dimension in the edentulous case as the establishment of a norm. He says that restoring vertical dimension of the face is one of the fundamental principles of the spherical theory of occlusion. To appreciate fully the effects of lost vertical dimension of the face we must have in mind three fundamental important factors. First, that there is a difference between the norm and the normal, second that there is a distinct relationship between the structure and the form of living bone and the forces exerted by muscle action, and third that the basic sciences of anatomy and physiology linked together with clinical practice and experience are a basis for a clear understanding of the importance of restoring lost vertical dimension.

Patient comfort is yet another facet of the problem which is illustrated in the writing of Bennett as early as 1928 when he related vertical dimension to comfort. He says "there is yet one factor which is of vital importance in the construction of artificial dentures and that is height of the bite - but I believe that the exactly correct height of bite for a particular person is very important and that incorrect height is a frequent cause of discomfort and failure - I think most practitioners will agree with me that if we can determine with precision the correct height of the bite and the position of the central incisors most of the real difficulties in making full dentures, or dentures for patients without a fixed bite, vanish, especially when one remembers also that the taking of the correct anteroposterior^{er} bite is facilitated". There seems to be unlimited and universal agreement on the importance of obtaining correct vertical dimension but perhaps the problem is most forcibly illustrated by our errors. Willie⁽¹⁹⁵⁸⁾ writes that in a survey which he conducted he found that the majority of dentists felt that an error in intermaxillary relationship was a major factor in full denture failure. Again Morrison in 1959 quoting a personal communication from A.W. Schultz reports that the grievance committee of the Los Angeles County Dental Society finds that 50% of their problems involve prosthetics and that of the prosthetic problems approximately one-third involve incorrect vertical dimension.

The universal acceptance of the importance of the correct establishment of vertical dimension is sufficient encouragement in itself to study the problem further. I would like to now consider the definition for vertical dimension.

Definition

The need for an accurate definition of a given subject is obvious and does not warrant discussion; however it is interesting and necessary to study the impressions of different workers on the subject so that a working definition for the purpose of this thesis may be developed.

In 1947 Boyle produced two definitions:

- (a) The vertical height of complete dentures is the vertical distance from the point corresponding to the crest of the alveolar process of the maxillae in the midline of the incisor region to the crest of the alveola ridge of the mandible.
- (b) The correct vertical height (presumably this refers to vertical dimension) of complete dentures is that vertical measurement which when the dentures are in the mouth and fully occluded restores to the lower third of the face those proportions which appertained before the loss of the natural teeth.

He discerns a difference between the height of the dentures and the aesthetic value of the dentures but does not seem specific enough for the purpose of discussion, although as Swenson⁽¹⁹⁵³⁾ in his textbook has said regarding vertical dimension "The only definite statement that should be made is that it is an indefinite procedure -- there is no measure that tells us the exact point of closure".

Graham in 1950 enlightens us further when he says vertical dimension is the distance between the alveolar ridges for any given position of the mandible. However the correct vertical dimension exists in an edentulous patient only when the mandible is in a position analagous to that formerly assumed with the natural bite held lightly in centric contact assuming that a normal free way space had existed.

In 1938 Harris emphasised the fact that vertical dimension is that which is taken at centric relation. He takes his measurements from the base of the chin rather than intraorally, stating that this is the portion of the face which changes most in life owing entirely to detrimental changes which alter the occlusion. Harris' explanation lends distinction to the vertical dimension of the face at rest position which is sometimes confused with occlusal or centric vertical dimension.

In 1956 there was compiled a glossary of Prothodontic Terms which provides the following definition: "Vertical dimension is the measurement between the two jaws which exists when the mandible is in the physiological rest position".

For the purpose of this thesis, however, this definition will not be accepted as the True Vertical Dimension and the following definitions are given and such will be the reference throughout this discussion.

True Vertical Dimension is that distance which exists between the jaws, regardless of the points of measurement, when the mandible is in such a position that should the natural teeth be present in perfect occlusion or in the norm of occlusion for that patient the teeth would be held lightly in centric relation. This distance will be referred to simply as "Vertical Dimension".

Resting Vertical Dimension is a distinct measurement taken when the mandible is in its physiological rest position. It will be referred to as such throughout this thesis.

The division of vertical dimension measurement into two separate entities was pointed out by Thompson in 1954 and has been mentioned by others such as Niswonger (1934/38), Tench (1938) Gillis (1941) Holic (1948), Pleasure (1951), Boos (1952) and Schlosser (1955).

Case Analysis

In presenting an analysis of the problem of vertical dimension an attempt is made to produce and discuss in a logical sequence the philosophies of the writers and the underlying ideas on which they base their clinical techniques. There does not seem to be one idea presented which is not subject to some criticism. The many writers of articles have highlighted and wrangled amongst themselves the many facets of the problem and yet after some 30 years of intense discussion the net result seems to be considerable scientific confusion.

We may perhaps commence with a statement by Ralph Boos (1952) who presents the problem broadly saying that vertical dimension involves aesthetics, space area for the placement of teeth and leverages and the amount of force that may be placed upon the occlusion and oral structures. Hight in 1934 presents his idea on the problem by stating that the first relation to be considered in all full denture cases is the vertical separation of the jaws which may be referred to as the denture space. An acceptable vertical dimension should meet the aesthetic requirements in establishing the contour of the lower third of the face. It should also permit a ridge relation which allows for a satisfactory arrangement of the teeth. To present this multitude of writing in any form it appears necessary to divide the problem into sections.

Facial measurements. Into the first category falls the writing of Bennett who, as early as 1928, was experimenting with a facial measuring device, one of his own design, called a Dakometer, in an attempt to find a norm for vertical dimension. The original article does not appear to be followed up with the results of his experiments and he makes no attempt to describe the clinical technique based on his findings. In 1947 Boyle presented his interpretation of the

problem. He used a technique of division of the adult head into three equal thirds in the horizontal plane as the means of analysis. The upper third consists of that dimension between the vertex and a horizontal plane drawn at the level of the crests of the supraorbital ridges. The middle third extends from this line to the level of the alae of the nose. The lower third of the face extends from the level of the alae of the nose to the base of the chin and it is held to be the most important third in relation to vertical dimension.

It contains:

1. All the upper and lower teeth including the roots and supporting structures.
2. The palate, soft palate and oropharynx.
3. The floor of the maxillary antrum on either side.
4. The whole of the mandible except the necks of the condyles, the tips of the coronoid processes and the sigmoid notches.
5. The whole of the tongue including some attachment to the hyoid bone.
6. The genial, digastric and mylohyoid muscles on the floor of the mouth.
7. The pharyngeal and palatal muscles at the back of the mouth.
8. The orbicularis oris and the buccinator muscles in the lateral and buccal regions.
9. The mandibular insertion of the great elevator muscles of the mandible.
10. The mandibular attachments of the depressor muscles of the mandible.
11. The oral cavity, lips, and at the back the pharyngeal orifices of the Eustachian Tubes.

Boyle then goes on to further subdivide this lower facial third into upper and lower sections divided by the upper and lower incisocclusal plane whose normal height is such that it theoretically divides the lower third of the face into an upper third and lower two-thirds.

Willis in 1935 recommended a technique involving facial measurement claiming that the length of the face from the nose downward bears a definite proportion to the upper part of the face. He claims that for thousands of years it has been accepted, that the distance from the bony shelf under the nose to the bottom of the mandible should be equal to the distance from the pupil of the eye, to the rima oris, or the parting line of the lips.

Schweitzer (1942) acknowledges the existence of such claims to proportions, and points out that these distances do approximately equal each other in many individuals but if used indiscriminately many mistakes will result. This relationship is particularly misleading in the case of deep bites when the lower third of the face is smaller than with other types of bites.

Logan in 1935 refers to the system of measurements as being idealistic and unpractical in contrast to the realistic approach using physiological reference points and he is joined by Terrell in 1951 who points out that in some cases proportions would work but in many patients these ratios would not be correct from an aesthetic point of view. We cannot make our patients all fit a rule. McKevitt (1952) also feels that no average vertical dimension can be struck as measurements from incisive papilla to the mid-line of the mandibular ridge have been found to vary between 8 and 32 millimetres.

Stansbury in 1951 reports he still uses a facial measuring device - the Dento-profile scale - in conjunction with the system of facial measurements based on individual types. He does, however, consider the following factors: - facial appearance, functional position, mechanical factors and phonetic factors.

Although faces are not sufficiently stereotyped to allow the use of facial measurements as an accurate guide to establishing vertical dimension, it is necessary to have an appreciation of facial form, outline and contour. The region with which we are most interested is the lower third of the face, as this is the area which we are able to control with denture design. However it is necessary in an aesthetic analysis to consider the overall size and shape of the face for the purpose of contouring and obtaining an harmonious result. (See fig 13)

Swenson in 1953 states that the lip line or rima oris should have the corners as high as the centre portion without necessarily being straight all the way across. Earlier in 1948 Burtenshaw has advocated a line of closure to straight or only slightly curved. The upper lip should be rounded at the lower edge in its centre portion, the lower lip usually rests on the insisal edge of the maxillary teeth and for that reason the edge of the lip should bend out from the mental sulcus. The vertical dimension should be sufficient to prevent undue creases or wrinkles in the region of the mouth. However this dimension should not be so great as to result in a stretched, expressionless appearance around the mouth. The fullness of the dentures, especially the mandibular denture, should be restricted to prevent an overfull flat appearance around the corners of the mouth.

Picard in 1958 considered that all facial factors are significant in producing a pleasing harmonious facial expression.

Such factors include:

1. The relative overall size of the face.
2. The proportions of the face and the ratio of the facial dimensions.
3. The profile of the face.
4. The outline form of the face.
5. The mouth size, commissure length and form.
6. The thickness, form, curvature, prominences and tenseness of the lips.

7. The creases and folds in the facial tissue.
8. The squinting of the eyes.
9. The breadth of the nostrils.
10. The spacial position of component elements of the face, nose, eyes, mouth and chin.

Burtenshaw in 1948 pointed out that age, beauty, strength of character are mainly exhibited in the dental section and are governed by the vertical distance between the nose and chin. The nearer the chin approaches the nose the wider the mouth appears, the thinner the lips become, the broader and shorter is the face.

According to the laws of physiognomy the face is divided into three equal parts, namely the forehead, nose and the lips and chin. The favourable or unfavourable impression we receive depends upon the correct balancing of each portion one with the other. The most important is the dental section. It is important as it contains the mouth, which the meeting place of the physical and mental forces. It has been called the "key to the vigour of the mind". Balkian in his character analysis says "the mouth is one of the most accurate and positive indices of character study. Unconsciously the student of human nature judges character by the mouth more than any other feature of the face".

Burtenshaw feels that in the normal mouth there is a straight line of closure, or one that is only slightly curved. Lips that are of medium fullness, the masculine being thinner than the female. Lips, upper and lower, which are equal in size, with the upper lips slightly more forward than the lower.

This normal arrangement, accordingly to Burtenshaw, indicates a balanced mind and character. Thin lips are supposed to convey the traits of meanness, cruelty, resentfulness, vanity, greed and selfishness, whereas medium lips indicate love of pleasure, affection, wit and generosity. The degree of compression indicates the control that

the will and animal forces have over animal nature. Firm compressed lips indicate determination, mental activity, control, decision and concentration. Thin compressed lips indicate bitterness, secretiveness and weakness. A short upper lip shows a lack of independence and dignity - a poor finisher of tasks begun. Loose open lips indicate uncontrolled passion, temper, weak will and character with a lack of mental energy. Forward projection of the lower lips always shows objectionable traits. The upper lip should always be in advance of the lower even if the upper projects beyond normal. It is never as objectionable as the projection of the lower lip. In the male it indicates original power of mind and is ideal from the point of view of beauty and character. The normal female chin naturally recedes slightly from this, the line being less aggressive. The projecting position indicates lack of sound judgement or mental power and shows avarice and dishonesty.

S. Silverman in 1956 stated that when the arch form, vertical dimension and free-way space are under consideration they must be established in consequence of the patient's biological, psychological and social history. One cannot routinely idealise a patient's face height by employing an anatomic norm or established socially desirable face height which is not in harmony with the patient's history.

Physiologic Approach

The physiologic approach to the case involves a consideration of the musculature and muscle action.

Section A:

Boos attempts to approach the problem from the angle of the ability of the musculature to produce maximum force on contraction. His theory is that greater power can be exerted by the masticatory muscles at the correct vertical dimension, claiming that the greatest pressure by the natural dentition is exerted when the teeth are at

the level of rest position.

Dr. Gysi* found that the average force of the temporal muscle was 60 pounds, the masseter had an average of 52 pounds and the internal pterygoid an average of 32 pounds. Thus when co-ordinated considerable power can be generated. The important part of muscle function is that there is a critical point in the distance from the origin at which the muscle can exert the greatest force in contraction. When the distance from origin to insertion is shortened the muscle has less efficiency. When the muscle is stretched beyond the critical point the efficiency is also reduced.

Upon this theory Boos constructed his Bimeter which is a gnathodynamometer adapted to a central bearing point for the purpose of measuring the force which the musculature can exert at various vertical levels.

On the instrument the vertical dimension can be altered. The instrument is accurately calibrated in pounds. Boos feels that the measurement is a relative registration of resistance to determine the position of maximum registration for the individual patient. The registration might be considered as based on an examination of all the factors in denture construction, including muscle strength, tissue tolerance, tissue bearing areas and the condition of the patient.

In various cases it was found that the maximum power varied from 13 - 100 pounds. Men average from 60-65 pounds and women from 25 - 30 pounds. The variance of biting force depended directly on the vertical dimension. In some cases there was as much as 16 pounds pressure^{difference} in two millimetres of change in the vertical dimension.

* Quoted by Boos. R.H. 1940

The greatest variance was found in those patients who had the greatest biting power. A typical example is as follows:

Vertical Dimension	117	121	122	125	128
Biting Force in Pounds	30	31	40	46	38
Vertical Dimension	114	116	118		
Biting Force in Pounds	20	28	20		

Recognition of the possibility of fatigue was evidenced by proceeding slowly and observing the condition of the patient. Several patients were examined with a relapse of six or ten months between registrations. In these cases the point of maximum power remained the same in the intermaxillary relation, although the numerical value of the actual biting force may have varied from day to day. Furthering his studies, Boos found that patients wearing extremely closed dentures had weaker biting power than those whose dentures were nearer the dimension of maximum power.

Boos states that the rest position and maximum biting force are the same position in vertical level. This provides a position of reference for establishing efficiency in mastication. In ideal cases the bolus of food is placed on the posterior teeth and the maximum force may be applied when the occlusal surfaces are absent two millimetres apart. This condition is present when there is a normal minimum free way space of three millimetres measured extraorally nose to chin. If a greater free way space is provided by closing 4 - 6 millimetres from rest position the bolus is compressed at a reduced muscle length and the force is less. The reduced force may be desired for patients with tender ridges. The free way space may be varied according to the desired conditions of force and aesthetics but it must never be reduced to less than two millimetres. The patient will have a space between his teeth when he rests or there will be tension of the muscles.

Boos in his technique using his gnathonometer^{dy} noted that biting force registration made by the patient would be effected by two important factors, First, psychological and second general health. Fear of pain was removed. The factor of general health was directly related to the force effort for the registration and recovery of the muscles. A conditioning treatment which included muscle therapy by the stretch reflex exercises was indicated for some patients.

In 1948 Burtenshaw commented on this work of Boos and stated that after opening the vertical dimension his failures appeared to be due to too much pressure on tissue not capable of withstanding the biting force. His failures amounted to 2% of women and about 8% of men. This coincides with Boos' findings that women on the average have a far lesser biting force than men. Burtenshaw also feels that women also tolerate more inconveniences to keep the vertical dimension for appearances, but Black offers some criticism of this system of Boos when he says the force of the bite of the individual is altered very materially:

1. By the use habitually made of the teeth.
2. By injury or infection to the periapical tissues.
3. By diseases of the peridental membranes.

These latter two factors of course are relevant only to the dentulous case.

Black feels that limitation of the power of occlusion as shown by a gnathodynamometer is a register of the power of resistance of the peridental membrane or supporting tissues and not a register of muscle exertion.

Burtenshaw modifies the statement to say that limitation of power of occlusion is a register of the power of resistance of the underlying tissues and not a register of muscle exertion.

In 1949 O'Rourke indicated that most frequently interpretation of the results of tests for biting strength have been based on the assumption that they measure muscle power alone. Yet it is clear that where muscle power is applied there must also be resistance to that power. There must be concern for the capacity of the supporting tissues to tolerate a force sufficient for mastication of a satisfactory diet with freedom of anxiety of physical comfort. The tolerance of the supporting tissues may vary widely in health and in oral or systemic disease.

The sensory or psychic control of applications of muscle power in the normal activities of man are both selective and protective, for example Schroeder reported an increase of 70% biting strength after block anaesthesia.

In edentulous patients the factor of greatest influence of a sensory point of view is the tolerance of the tissues supporting the dentures. This in turn is influenced by the surface characteristics of the base material in contact with the tissues and by the extent to which the forces of mastication are distributed throughout the supporting tissues.

The denture patient is likely to experience pain at comparatively low levels of biting force and in addition to fear of pain, he has the fear that the denture may be displaced if the force is increased.

Section B:

Yet another approach to the case based on normal physiologic procedures uses the often repeated action of swallowing as an aid. This system is mainly used by Shanahan (1956) who in his several articles discusses his concepts. He feels that the constant function of swallowing saliva is the basis for establishing the mandibular position and occlusion. In swallowing saliva the mandible rises to its habitual closing terminal, and then, as the saliva is forced backward into the pharynx by the tongue, the mandible is retruded to its physiologic centric relation. These are the mandibular movements used in determining vertical dimension and the centric relation in complete dentures. He feels that the mandibular positions under consideration are determined by functional movements. The principal physiologic movements are those engaged in mastication and swallowing and Kurth in 1942 has shown that the former are in general in a vertical direction; they are cyclic in nature as shown by Boswell⁽¹⁹⁵¹⁾ and Jankelson (1953) has pointed out there is little or no occlusal contact when food is interposed between the teeth. It can readily be deduced that the true functional movements of the mastication are not factors in determining the position of centric relation or vertical dimension. Shanahan⁽¹⁹⁵⁶⁾ contends that in swallowing saliva the mandible leaves its rest position and rises to the natural vertical dimension of occlusion then as the saliva is forced back into the pharynx by the tongue the mandible is retruded along with its tongue to its natural centric relation. This pattern is performed from 1500 to 2400 times a day, it is the same for the edentulous infant as for the edentulous adult. A similar pattern prevails for natural and artificial teeth. It is deductible that the constant intermittent occlusal pressure that occurs during the swallowing of saliva prevents further eruption of the first and second dentitions and that normal occlusion takes place at the physiological vertical dimension.

Complete dentures should also occlude at the natural vertical dimension during the physiologic function of swallowing saliva.

With the loss of natural teeth there are degenerative changes of the musculature. Although the pattern of swallowing remains the same the reflexes lack the sharpness of earlier days. Therefore in determining the vertical dimension and centric relation for middle-aged and elderly patients with uncertain muscular reflexes considerable care must be exercised to select the appropriate swallowing level and to be certain that it has an accompanying interocclusal distance.

Section C:

This technique involves the physiologic use of the mandible in the pronunciation of words, that is the science of phonetics. Many writers have based their techniques on an application of mandibular position during the production of various sounds. For this reason it is important to have some understanding of the mechanism of speech and the limitation of its application to dentistry. Webster's Collegiate Dictionary (Edition V, Springfield) defines phonetics as "the science of speech sounds considered as elements of language". It is the study of their formation by the speech organs and it is the science that must receive consideration by us in this as in other phases of prosthetics.

Fletcher in 1946 points out that although there are many different languages spoken in different parts of the earth, and each language has a system of speech sounds of its own, there is a great similarity amongst these fundamental speech sounds. This is necessarily true since there is only a limited range of distinct sounds that can be made by the organs of speech, although the mechanism of producing particular speech sounds in the various languages is somewhat different, the general mechanism of producing speech is similar for all people.

Potter, Kopp and Green⁽¹⁹⁴⁷⁾ in their textbook give a picture of the speech mechanism. This they feel may be regarded as five parts or processes. Any one part of the mechanism may be described only as static and non-functioning, since in speech all of the parts interact as a highly co-ordinated unit. The five parts are:

- (a) Brain - used to control the speech processes
- (b) The vocal cavities.
 - i) nasal
 - ii) oral
 - iii) pharyngeal

These are used to suppress and select overtones.
- (c) The lower respiratory tract.
 - i) trachea
 - ii) lungs
 - iii) diaphragm
- (d) Vocal chords used to modulate the breath stream.
- (e) Articulators used to vary the vocal cavities.

McDonald (1951) points out that the actual production of the sound takes place in the pharynx, nose and oral cavities. Resonation occurs in the oropharynx, oral and nasal cavities. Articulation is produced in the oral cavity; tongue and teeth, as well as the vault of the hard palate have an important function in speech production. The tongue by constant change in position against the teeth and the palate modifies the direction and volume of the air stream.

Allen (1958) indicates that sound is produced by vibration. The overtones produce the quality of the human voice. Sounds of speech are complex being composed of many simple sounds, each of which has a fundamental frequency, pitch amplitude (loudness) and tone quality (timbre).

The three basic fundamentals of normal speech are:

1. Correct breathing and proper utilization of breath.
2. Correct kinesthetic or muscular imagery, which is designated as the oral position or oratous.
3. A combination of 1 and 2 to effect normal output of speech.

Roth (1940) presents a division of sounds of speech.

1. Stops or consonants. These may be oral, nasal, vibrated (voiced), breathed or voiceless. These are produced by vibrated or unvibrated breath passing through the larynx, obstructed, interrupted and modified by the tongue, lips, teeth and palate. (Fig 3)
2. Continuants or vowels. These are sounds which are produced by vibrated breath passing through the larynx uninterrupted by lips, tongue or teeth. In the production of these sounds the tip of the tongue plays no part, and the soft palate by contracting and sealing the pharynx with the aid of the pharyngeal musculature allows more of the vibrated air to pass into the nasal cavities. (Fig 4)
3. Diphthongs. This is a combination in the same syllable of two vowel sounds which are so blended in pronunciation that they seem like one sound.

Consonantal Groups. (see Figure)

1. Linguo dentals - the tip of the tongue is placed against the maxillary gingiva of the incisors and the premaxillary section of the palate.
2. Bilabials - these are lip sounds produced by lip movements.
3. Labio-dentals. These are produced by placing the lower lip against the insisal edges of the maxillary anteriors.
4. Post-dentals - the "Z" and "S" sounds or fricatives. These are made by occluding the maxillary and mandibular teeth and exhaling through them. The front of the tongue almost touches

- the incisal edges of the maxillo-mandibular incisors which are nearly closed, the tip being placed a little higher and the stream of breath is sent in a thin straight line along the groove in the tongue. 'TH' sounds are made by placing the tip of the tongue lightly against the incisal edges of the maxillary incisors and forcing the air out between the tip of the tongue and the maxillo-mandibular incisors.
5. Front palatals. The 'SH' sounds. These are produced by nearly closing the jaws, the front of the tongue is widened and exhaling through the maxillo-mandibular incisors.
 6. Back Palatals. The 'K' sounds (plosives), 'G' (plosive-voiced) 'N' 'S' (nasal voiced). 'K' and 'G' are made by pressing the back part of the tongue against the soft palate, quickly lowering at the end with the sudden release of air slight explosive sounds are made.
 7. The Linguals. 'L' and 'R' (fricative). 'L' is produced by placing the tip of the tongue either against the maxillary incisors, gingivae or pre-maxillary area and the breath is expelled over the sides of the tongue.
 8. Aspirate. 'H'. The breath passes through the glottis unvoiced and unmodified by the peripheral organs of speech. The tongue takes the position of the vowel that follows it.

The Continuants or Vowels. There are fifteen vowel sounds. For the production of the vowel sound of 'U' the lips assume a rounded position and the back of the tongue is lowered from a high to a half low position respectively. In the production of the other vowel sounds the lips are unrounded.

Diphthongs. There are nine diphthongs in the English language. They are divided into two groups - the rising and the falling. The second vowel sound in a rising diphthong is made higher in the mouth than the first while in the falling diphthong it is made lower. There is always an 'R' in the word containing a falling diphthong.

Allen in 1958 says that as breath issues from the larynx it is broken up into two streams of air. This is accomplished by the uvula and soft palate. The upper air stream is used in speech only for the sounds 'n' 'm' and 'ng'. All other sounds are produced in the lower breath stream as it strikes the palate.

Potter, Kopp and Green indicate that these sounds 'n', 'm' and 'ng' have been classified as part of the larger unit of vowel and vowel-like sounds.

Action of the Oral Organs

Illustrating the prothetic significance of the application of phonetics, Silverman (1956) points out that it is the function of the articulatory mechanism to break up and to modify the laryngeal tones and to create new sounds itself, within the oral cavity. The new sounds are essentially consonants which are defined as sounds accompanied by frictional noises. The consonants are formed as the air stream passes by opposing structures which are in contact, that is the lips, teeth and the tongue, and the palate. The final action of the articulatory apparatus is to articulate, that is to join in a fluent sequence all the sounds which have been synchronised into symbols. Without the articulatory capacity the sounds produced would be only of variable pitch, volume and quality like a vowel sound. It is obvious that a language built upon this basis would be a series of vowel tones like the wail of a dog and would be inadequate.

In 1927 Tench indicated that with the action of the articulators, the mandible may only ascend and descend to allow the tongue to act against the teeth in forming syllables. In other instances it also advances to permit the cutting edges of the mandibular incisors to assume a position directly below the cutting edges of the maxillary incisors. J Thompson pointed out in 1954 that in performing the

functions of speech the mandible moves through the various positions combined with oblique lateral protrusive and retrusive movements, without tooth contact. These require co-ordinated action of the upper and lower sections of the right and left joints.

Silverman in 1951 pointed out that the production of various phonetic sounds will cause the mandible to assume certain positions in relation to the maxilla. It will be found that the levels of the mandible will be in different positions for different patients for the same sounds. Some sounds will bring the mandible to the closest level, others to wider levels of varying degrees. It must be remembered that no organ of speech has an absolute position. All positions are relative. Becoming more precise on this subject, Silverman classifies the vertical relationship of the jaws according to phonetics as:

1. Centric occlusion
2. Centric relation
3. Speaking range which is (a) speaking centric level and
(b) wider speaking levels.

The speaking range is divided into two levels for classification:

1. Wider speaking levels are usually numerous in each patient and should not be considered in the measuring of vertical dimension because the determination of the distance between mandible and maxilla is difficult.
2. The speaking centric level is the most accurate, due to the fact that the mandible is usually at a constant level when the phonetic sounds are enunciated. It is therefore advisable to use the measurements of the speaking centric level in order to determine the vertical relationship of all patients.

One or more of the six sibilants generally cause the mandible to be on the closest level to the maxilla during speech. It may be simpler to use only the sibilant 'S' of 'yes' in the measure of vertical dimension

as this sound is the most frequently used of the sibilants in speaking and reading and it gives an accurate measurement for all patients. He emphasises in another article in 1952 that his technique is a physiologic one. He feels that his system of recording vertical dimension is based on physiologic function of the muscles while used in speaking. The sibilants 's', 'z', 'sh', 'zh', 'ch' and 'j' in such words as "yes", "buss", "first", "measure", "church" and "judge" produce the closest speaking level of the mandible in relation to the maxilla in 90% of a series of patients examined. The desirability of using the group requiring the small orifice, that is the 's' group, becomes apparent as the patient must have incisal clearance to master this group of sounds if he is to speak satisfactorily. The mandible is closest to the maxilla when these sounds are produced than at any other time in speaking. In some patients the teeth may even contact slightly. Silverman refers to this position as the closest speaking level.

Potter, Kopp and Green in 1947 indicated that these sounds are classified as fricatives. In this classification there are two types, the voiceless fricatives which are produced primarily by frictional modulation, and the voiced fricatives which are produced by combined frictional vocal cord and cavity modulation. The fricatives may be discussed in pairs because the two consonants in each pair are made from similar articulatory positions. The voiceless sound in each pair $h - f - \theta - s - \int$ is produced primarily with frictional modulation which is sometimes supplemented with cavity modulation. The voiced sound of each pair $h - v - \delta - z - \text{ʒ}$ is made with frictional modulation plus vocal cord and partially closed cavity modulation.

The most important to our field of study are the 's z' sounds and the \int and ʒ sounds.

The 's' and 'z' sounds are made by most speakers from one or both of two positions which are usually described as the tongue point-alveolar ridge and the tongue-blade alveolar ridge position. The important considerations for making these sounds are:

1. Forming a narrow groove along the midline of the tongue, tip or blade as it is held against the alveolar ridge.
2. Placing the sides of the tongue against the teeth and teeth ridge to direct the breath stream through the narrow groove.
3. Having a narrow opening between the upper and lower front teeth.
4. Opening the lips and spreading them a little.
5. Closing the opening between the throat (pharyngeal) and nasal cavities.
6. Emitting a continuous voiceless or voiced breath stream through the narrow groove and against the cutting edge of the teeth.

Examples of such sounds are found in the words: Sew, Scene, Answer, Psalm, Buzz, Discern, Force and Xylophone.

The \int and z sounds are produced generally with the tip of the tongue raised and beneath the anterior portion of the palate, but in some cases the blade of the tongue instead of the tip may be raised. The more important factors in making these sounds include:

1. Forming a wide shallow opening between the flattened tongue tip and the anterior palate.
2. Placing the sides of the tongue against the teeth and teeth ridge to direct the breath stream through the wide shallow opening.
3. Having a narrow opening between the upper and lower front teeth.
4. Opening the lips and rounding them a little.
5. Closing the opening between the throat (pharyngeal) and nasal cavities.

6. Emitting a continuous voiceless fricative or voiced breath stream through the wide shallow groove against the cutting edge of the teeth and through the cavity formed by the lips. The "f" is described as a voiceless fricative continuant and the "v" as a voiced fricative continuant because in the latter there is the presence of the vocal chord partially closed, cavity modulation which is absent in the former. Examples of such sounds are: She, Nauseous, Pension, Ocean, Glazer and Rouge.

Other sounds in which we are interested include the "f" sounds.

The "f" sounds are fricatives and are produced by:

1. Forming a small or restricted opening between the lower lip and the upper teeth.
2. Closing the opening between the throat and nasal cavities.
3. Emitting a continuous stream of voiceless or voiced breath through the restricted opening.

For both the "f" and "v" sounds the articulators are in similar positions but the sounds are modulated differently. Both sounds are produced with frictional modulation but the "v" combines frictional with vocal chord and cavity modulation. The "f" is referred to as the voiceless fricative continuant and the "v" as its voiced equivalent. In physiologic phonetics the "f" is described as a voiceless labio-dental fricative and the "v" as the voiced labio-dental fricative.

Examples of such sounds are: Feel, Half, Laugh, Van and Halves.

Application of Phonetics to Prosthetic Dentistry:

As indicated by Willie in his survey of 1958 many operators use phonetic tests as a guide or prime indicator of the vertical position of the mandible in an attempt to determine the correct vertical dimension.

Many tests have been advocated. In 1956^MSilverman pointed out the function of speech has been traditionally regarded in our tests essentially as a phenomenon in prosthetics. Such an approach is essentially a mechanical one and does not represent a full picture of how a denture performs in co-ordination with the speech process. For example, when we ask a patient to say a speech sound such as 'f' and 'v' or even the sibilant 's' we are establishing an artificial relationship. Such a view of speech does not imply the symbolic communicative and psychological aspects of speech in which phonetics is only an automatic contributory phenomenon rather than the focal point of a speech situation. Thus a patient may subordinate the swallowing the respiratory function in order to pass the phonetic test of the prosodontistth.

A better speech test for a denture is to engage the patient in meaningful conversation where:

- (a) he expresses himself emotionally and employs his facial muscles in the expression of thought.
- (b) he modifies and adjusts his respiratory rate and vigour in response to the emotional moods and
- (c) swallows repeatedly his accumulated saliva.

Earlier, in 1940, Roth applied his phonetic groups of the oral curve, his vowel and diphthong charts for the determination of normal and defective speech in the practice of dentistry. (See fig 5)

He felt that in the making of speech tests before and after dental and oral restoration, whether they be in the sphere of prosodontics^{ch}, oral surgery or orthodontics, one should employ for this purpose simple words, phrases or sentences. He feels they should meet the following requirements:

- (a) be suitable for application in the second groups of the oral phonetic curve, vowel and diphthong chart. (See Figure 5)
- (b) be simple of construction

- (c) be suitable and applicable for detection of variations in the individual normal faculty of speech production.
- (d) be of such selection and nature as to invite an intelligent response and reply, the test, if possible, to pertain to the cultural and vocational life of the patient.

After the bite blocks are made and inserted, certain tests, observations and records are made and recorded for the determination of the proper length for the restoration and the correct vertical height for the lower half of the face, for proper contours, for inter-maxillary clearance and for the determination of the posterior boundary of the maxillary denture. For some of these we may utilize the functioning speech apparatus.

After the upper bite plate has been made so that its incisal segment is on a horizontal plane extending slightly below the lower border of the lip at rest and parallel with a line drawn through the pupils of the eyes and the occlusal plane is parallel to a line connecting the external auditory meatus and the alae of the nose, the lower bite block is built to meet it, following which we are to determine if the correct vertical height in relation to the upper and total face height has been made. The intermaxillary bite opening must meet and be in harmony with all the physiologic requirements of mastication and phonation. For the determination of the proper intermaxillary clearance the test generally used has consisted of the pronunciation of the word "Mississippi", spelt phonetically *mí-sí-sípí* and with Webster's diacritical markings *mí^u/sí^u síp^u/í^u*. The consonants 'm' and 'p' are sounds in the same phonetical bilabial group produced by lip movements and if difficult of pronunciation may indicate an over extension of the plate outline, too much fullness in the bite plates or trial setup or too great an intermaxillary separation, ^{which} varies approximately from 1/20 of an inch to 1/12 of an inch, with the pronunciation of the syllables in "Mississippi".

The four vowel sounds of 'i' and 'I' are produced approximately alike in the front high position of the mouth with the blade of the tongue situated high in the premaxillary vault area and pronounced as the 'i' in "city" and "six". One may determine with the use of this word the clarity and quality of the sibilant 's' or the presence of any mutation of sound which assumes the characteristics of lisping or whistling.

Weir in 1932 pointed out that bilabials such as 'p' or 'b' are particularly important to the proodontists as the tension of the orbicularis oris depends on the maxillo-mandibular relation. A. Ylppo in 1955 uses this phenomena to determine if the bite height is too high. He feels in such a case these bilabials are difficult to pronounce because it is hard to bring the lips together. This same author also uses in the manner indicated by^M Silverman the sibilants to indicate an over-closure of the vertical dimension, for when the vertical dimension is below the normal, articulating of the sibilants will cause premature contact and clicking of the teeth.

As recently as 1957 Kaires has pointed out that sole reliance on the phonetic system of obtaining vertical dimension may lead to errors. The patient in his test was capable of adapting himself to the predetermined vertical dimension and thus it was difficult to discern the effect of altering the vertical dimension of occlusion on the various speech sounds by listening to the tape recording. However he did indicate that the greatest difficulty experienced by the patient was in the pronunciation of those words containing sibilants. This would seem to indicate that such words are likely to give a more accurate result than other phonetic means.

Effect of Palatal Contour:

An important problem facing the dental profession is the determination of the effect upon the quality, pitch and amplitude of the voice when appliances made of diverse materials are inserted

into the mouth in varying shapes and sizes. The problem may be quite complicated in certain cases as, for example, where all teeth have been removed, for in spite of our re-establishment of centric occlusion we must still cope with the physiologic and psychologic variables which have a direct bearing on the re-establishment of the functions of mastication and phonation.

In an experiment by Boghosian and Spangenberg it was found that the insertion of the prosthetic appliance - palatal coverage only - :

1. did not cause the amplitude or the frequency of the first major reinforcement to change markedly
2. caused a decrease in the amplitudes of other reinforcements
3. caused an increase in the number of frequency components in every vowel studied, except that of 'a' as pronounced in the word "tape".

It was further concluded that there was a more noticeable change caused by the prosthetic appliance in the frequency spectra of the two vowels 'a' and 'e' (as in "team"), than in the other four vowels which seems to verify the physiologic observation that in the production of the vowels 'a' and 'e' the mouth is divided into two effective resonance chambers by the tongue; that the volume of the anterior chamber was greatly reduced by the prosthetic appliance thus causing a diminution of the frequencies resonating in this chamber; that the production of the vowels 'u', 'o' and 'a' the mouth acts as a single resonating chamber and that the insertion of the prosthetic appliance caused a dissimilar percentage of decrease in this resonating chamber than in the case of 'a' and 'e'.

(1952)

Allen prepared palatograms for the sound and found that amongst the vowels the 'o' sound could be made without the tongue touching the palate.

The addition of one millimetre wax thickness in the anterior region from cuspid to cuspid made speech awkward, difficult and indistinct. The entire vault area could be filled with wax to the outline of tongue contact. Allen concentrated contouring in the area immediately around the palatal aspect of the teeth. He found that if this area was thickened together with the incisive papilla a normal 's' and 'sh' sound could be produced.

It would seem to me that this is probably due to the obtaining of an effective seal so that the breath stream may be directed against the incisal edges of the maxillary teeth.

The concept of Rest Position and its relation to Vertical Dimension

Of the positions of the jaw there are several which can be defined. Among these are centric relation, occlusal position and rest position. The latter is of great importance in the study of vertical dimension of the edentulous patient as it may present a position from which measurements can be taken; that is a point of reference.

Jarabak in 1957 refers to the writing of the Hunter Brothers who, as early as 1771, recorded "in the lower jaw as in all joints of the body, when the motion is carried to its greatest extent, in any direction, the muscles and ligaments are strained and the person is made uneasy. The state therefore into which every joint naturally falls, especially when asleep, is nearly the middle between the extremes of motions by which means all muscles and ligaments are equally relaxed. Thence it is that commonly and naturally the teeth of the two jaws are not in contact nor are the condyles of the lower jaw as far back in the cavities as they can go".

Since the time of these writers we have arrived at somewhat more specific conclusions and a more precise definition. Much of the work has been done by Niswonger who, in 1934, described rest position as that position of the mandible in which it is involuntarily suspended

by the reciprocal co-ordination of the muscles of mastication and the depressor muscles with the upper and lower teeth separated. It is a neutral position of the mandible since the flexor and extensor or opening and closing muscles are in a state of equilibrium. The rest position may be assumed voluntarily and is constantly assumed subconsciously.

More recently still, Boos in 1959, adds that physiological rest position is assumed when the head is in the normal upright position and the elevator and depressor groups of muscles are in a state of equilibrium and tonic contraction. To assume this position the muscles are at normal length, actually the same length as for maximum efficiency.

Definitions sometimes are theoretical and impractical. This is especially true when a clinical term is defined in non-clinical language. The rest position is a clinical position usually defined in terms which are not easily determined clinically e.g. "the mandibular position assumed when the head is in an upright position and the involved muscles, particularly the elevator and depressor groups, are in equilibrium and tonic contraction and the condyles are in a neutral, unstrained position". This is the definition supplied by the Glossary of Prosthodontic Terms in 1956. Clinically, the dentist cannot predetermine the muscle equilibrium or the condyle position. Consequently, such definitions may mean little to the practising dentist. Perhaps a simpler, more clinical definition would be: - "The habitual postural position of the mandible when the patient is at ease is an upright position".

Robinson, 1946, points out that rest position is not passive but must be thought of as an active process. A constant shower of impulses comes to the brain from the tension in the muscles largely from overcoming the force of gravity. These apparent impulses reflexly control the motor fifth nucleus to maintain the jaw in the

rest position. By this method we keep the mandible in position against gravity in the same way that we control other anti-gravity muscles.

Edwards in 1955 also states that the term "rest" is a misnomer, since not all of the muscle fibres are at rest, but some of them are in tonic contraction. Landa, 1954, emphasises that rest is relative, not absolute, and that it implies relative emotional and psychic tranquillity.

Boos in 1952 has also stated that the muscles are in a tonus of rest and that there is a slight function of some of the fibres but no contraction or extension of the muscle as a whole. When neither elevator nor the depressor muscles nor the external pterygoid muscles are in function, a neutral central rest position of the mandible is assumed.

Thompson and Brodie (1942) quote Sherrington's electro-myographic work and agree that the position of rest is maintained actively, for the same motor impulses that caused one set of muscles to contract caused an inhibition of tonus in their antagonists. Thus the rest position of any movable part may be taken as an equilibrium between all of the forces operating upon it. If these forces happen to be entirely muscular there is an equal pull on both sides of the part through a state of tonus. Thus even a rest position must be viewed as a dynamic condition.

Although rest position is not a passive one McLean in 1944 points out that researches in the field of electro-myography demonstrate that a minimum action potential in a muscle is recorded during the rest position.

The physiologic importance of the rest position as indicated by Shore in 1959, lies in the fact that it permits the tissues of the stomatognathic system to rest and thus repair themselves. It has

been shown that even slight pressure, if it is constant, will cause pathological tissue changes.

Intermittant pressure, on the other hand, provides a period of rest during which self repair can take place.

Origin of Rest Position:

J Thompson, 1954, has pointed out that as the position of the mandible is dependant entirely on neuromuscular physiology, all functional movements of the mandible begin from, and end in, the rest position, because only at that position is the mandibular musculature in tonic equilibrium.

Brodie and Thompson in 1942 showed that the position of the mandible with regard to the head is established as early as the third month of life. Their investigations were carried out using roentgenographic cephalometric method to study the head, as previously outlined by Broadbent in 1931.

Earlier, in 1934, Niswonger has stated that one can clearly observe rest position in the new-born infant. Again in 1938 he claimed that the position prevails from the time man is born until the time that he dies - it is on an anatomic and physiologic arrangement. Rest position is one designed by nature which involves the minimum amount of muscular contraction to give time and opportunity to restore muscle energy. It may be assumed voluntarily and is constantly assumed subconsciously.

In 1956 Moyers agreed with the concept of Niswonger, stating that neonates already have a postural reflex. This is not surprising since a starting point is needed for some of the reflex movements of the mandible during sucking, swallowing and coughing. Perhaps this is the only postural reflex developed so early. Only the postural position is consistently observed prior to the eruption of teeth.