The Significance of Root Form as Determined by Occlusal Stress*

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The dental profession is becoming more conscious of the importance of the functioning dentition to the supporting tissue of the tooth. It is very disturbing and discouraging to see the bone and periodontal membrane become diseased and destroyed, with a resulting loss of an efficient masticating mechanism. Our inability to correctly determine the causes of the changes so frequently found in these tissues has made their treatment and results uncertain. We, in orthodontia, are ascribing such conditions to malocclusion. But upon what biological or clinical information can we do this? A reading of the dental literature reveals a lack of fundamental information as to the normal relationship between the forces produced during function and the manner in which these are resisted. After all, the tooth is a tool and the root is the handle by which it is held and through which it receives its support. The handle of any tool has that form and size which permits most efficient handling and the best resistance to forces produced by the working of the tool. In the case of the tooth our problem would seem to be a determination of the amount and direction of normal stresses, and then an analysis of the sources of the anchorage or support available to withstand these stresses. Does not the root form, like the handle of any other tool, reflect the amount of stress and its direction? If so, one would expect to find dissimilarities in the roots of teeth of dissimilar function. The most logical place to start such an analysis would be in the earliest and most simple root form.

In studying the evolution of teeth we find that the first form of tooth was the dermoid scale of the shark, which was attached to a cartilaginous rim by fibrous tissue. These teeth are simple cones, extremely sharp and used only for grasping.

As time went on, we find increased power in the jaws with bone replacing cartilage as a medium of support for the teeth. This change was accompanied by a change of tooth attachments, which increased efficiency. Here we find the first indication of root development. In most cases, at this period of evolution the teeth were ankylosed to the bone.

The next evolutionary changes were probably variations in the digestive tract, and alterations in the defense mechanism. Both of these were re-

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flected in changes in tooth function and there was a change in crown form, root form, and in tooth support. The roots were larger and were placed in alveolar sockets in the bone. They were now attached by fibrous tissue.

Let us first study the general principles governing the support of tooth stress. The stress placed upon the crown is transmitted through the roots and thence to the bone around them where it is resisted. An examination and study of the simple function and the resistance to the stresses, as seen in various animal dentures, will permit a better analysis of these principles.

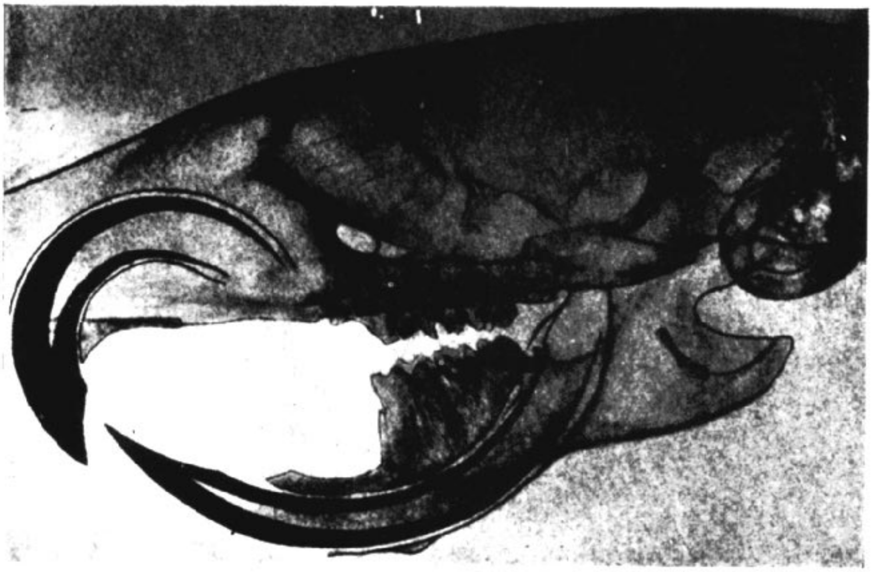

Fig. 1
Tracing of x-ray of rat head, showing the form and relationship of the upper and lower incisors.

The incisor of the rodent is without doubt the most efficiently functioning tooth in the animal kingdom. It is highly specialized, serving as a tool, a weapon and for prehension. The mandibular incisor of the rat arises posterior to the last molar, runs in an even arc under the molars, and emerges in the anterior portion of the jaw. The maxillary incisor arises anterior to the molar series and forms an arc of a smaller circle as it travels through the jaw to emerge in front. (Fig. 1.)

These teeth are covered with enamel only on the labial side, which is the outer surface of the arc. The mesial, lingual, and part of the distal surfaces are covered with cementum, to which periodontal membrane is attached. A cross-section measurement of this tooth gives a ratio of enamel surface area to cementum surface area of approximately three to five. (Fig. 2.) The incisor of the rodent is a tooth of continuous growth and eruption —an adjustment for the rapid wear of its functioning surface. These teeth are shaped in an arc form to protect the continuously functioning ameloblasts and odontoblasts. This tooth form permits a distribution of stress throughout the tooth which is supported by a suspensory tissue, the periodontal membrane, on the lingual and inner portion. The periodontal membrane is

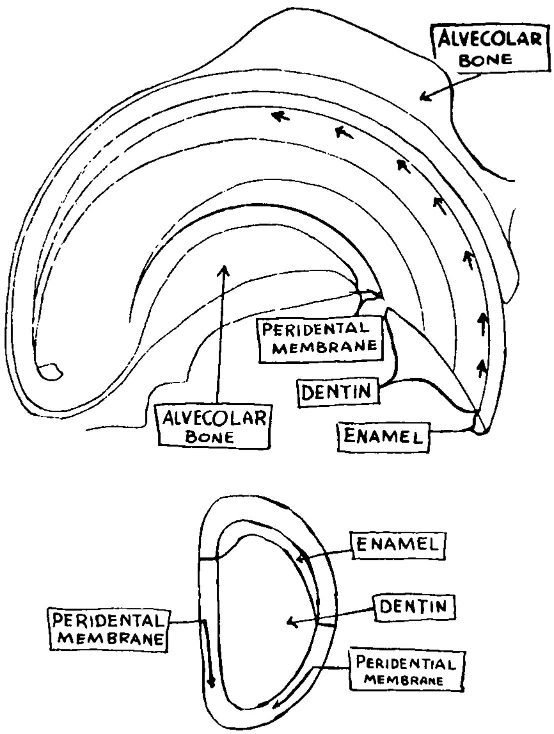

Fig. 2
Tracing of sagittal and cross-section of rat incisor.

attached to the alveolar bone and here the stress is finally resisted. The outer portion of the tooth is covered with enamel and the apical one-half with functioning ameloblasts. There is no protective tissue between the enamel and the bone or between the ameloblasts and the bone, which could serve as a buffer against any stress directed through this area. This, I think, is conclusive evidence that the periodontal membrane functions as a suspensory tissue; rather than as a cushion. The tooth is hung, literally speaking, in this network of suspensory strands. These serve as a group of guy wires, which are tensed by the function.

Let us now direct our study of principles to a tooth which has an entirely different form and function—the carnassial of the carnivore. It has only one function, that of cutting food, which in the case of these animals is flesh. I used the domestic cat because it is quite typical and easily obtained. The crowns of these teeth are flat buccolingually with two sharp high cusps set anteroposteriorly. They have an average buccolingual thickness at the gingival line of two millimeters. This tapers occlusally to a knife edge. (Fig. 3.) When the maxillary and mandibular teeth are brought

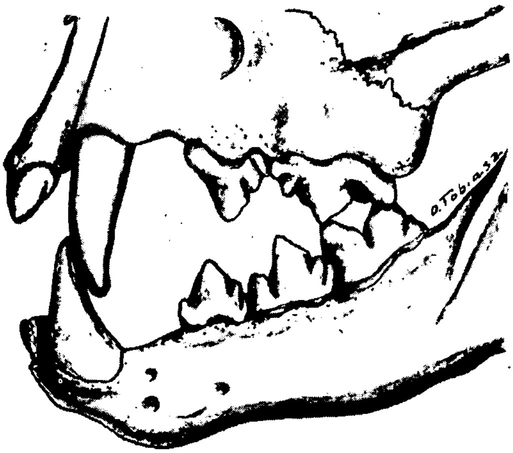

Fig. 3
View showing beginning of stroke, with diamond-shaped opening.

together, the cusps of each form contact first, leaving a diamond shaped opening, bounded by four cutting blades. In this opening the food is trapped and cannot escape. It might be compared to two pairs of shears operating simultaneously and thus feeding each other.

It is interesting to note that there is only one pair of teeth functioning at one time. The heights of the cutting blades of the maxillary and mandibular teeth are so arranged that when the posterior teeth of the buccal segments are in function, those mesial to them are not in contact. Only after the cutting edges of the most posterior have passed each other is it possible for the pair just mesial to them to have intermaxillary contact. We can readily see the efficiency of this method of occlusion. To place all of the buccal teeth in function at one instant would demand a great increase of power in the masticating musculature. When power is increased, resistance must be increased. This would necessitate an increase in the medium through which the power is transmitted. An increase of both power and bulk would decrease speed and efficiency in such a cutting and shearing machine.

In a pair of shears we find a traveling point of contact, the efficiency of which depends upon the maintenance of a tight contact throughout the stroke. This same principle is necessary in the functioning stroke of the carnassial teeth. The mandibular tooth passes the maxillary tooth on the lingual surface as it completes the stroke. The stress in the maxillary tooth is towards the buccal and in the mandibular it is toward the lingual.

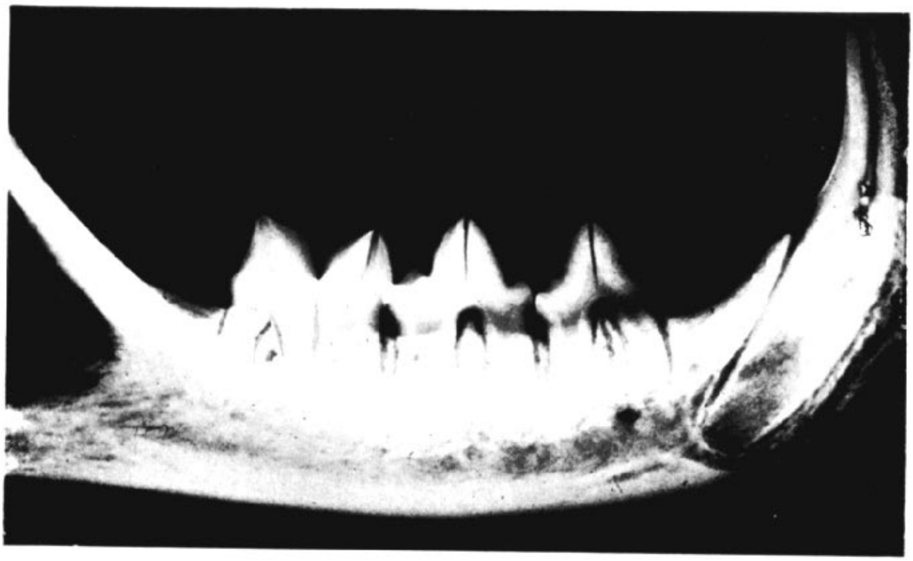

Fig. 4
X-ray of mandible of the carnivore, showing the root form and its relationship to the crown.

To support these stresses, we find a mesial and a distal root, both of which are flattened buccolingually. They therefore have approximately four times as much surface area on the buccal and lingual surfaces as there is on the mesial and distal surfaces. (Fig. 4.) The stress, being lateral, is expended through the buccal and lingual surfaces of the root. We can readily recognize the significance of the flat roots in increasing the efficiency of this suspensory tissue. This is further emphasized by the fact that we have the greatest bone development on the lingual side of the upper and buccal side of the lower.

The upper carnassial, which is the third premolar, shows a variation in crown form having an occlusal functioning surface in the mesiolingual area.

This is called a talon, and in most jaws is only a resting place for the lower molar. The stress on this area is towards the apex of the root. Here we find a cone-shaped root placed at approximately right angles to the occlusal surface and this is the best form and position for resistance to the stress placed upon it.

Fig. 5
Occlusal view of upper second and third molars of horse. Notice the ridges and fossas formed by the enamel, dentin, and cementum. Also notice nature of contact.

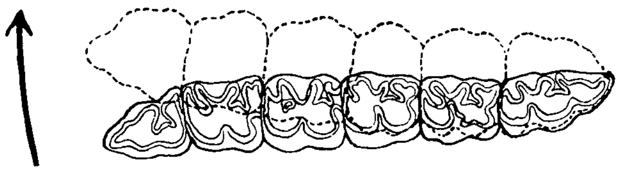

Fig. 6
Diagram representing the occlusal relations of the left buccal teeth at the beginning of the stroke, showing the wave of occlusion. (Solid lines represent the mandibular teeth, broken lines the maxillary.)

The herbivorous animals, living on roots, grains and grass, present a characteristic crown and root form which are as different from the group just described as is the diet. For the purpose of this study I have selected the horse from this group. Attention will be confined to the buccal teeth which include the premolars and molars. The functioning area or occlusal surface is composed of enamel, dentin, and cementum. (Fig. 5.) The cementum and dentin, having less density, wear down at a faster rate, developing grooves and depressions between the harder enamel ridges.

The mandibular stroke is in a horizontal direction, traveling across the maxillary teeth from buccal to lingual. Upon superficial examination, the stroke appears to be in a direct buccolingual direction, but this is not so. (Fig. 6.) The mandible travels in an arc from buccal to lingual with the condyle of the functioning side serving as the center of the arc. This might be termed the horizontal arc. We also find an anteroposterior arc formed by the occlusal surfaces of both jaws. This is due to the variation in height of the teeth, and it might be termed a vertical arc. We also find a horizontal curvature in the buccal segments from mesial to distal which supplements the arc of the stroke. The arcs of the stroke cause the mandibular teeth to travel from distal to mesial approximately twenty degrees during the stroke.

The maxillary teeth have an inclination to the buccal, but the occlusal surface has an inclination toward the lingual. Thus the buccolingual angle is acute. The mandibular teeth have a more perpendicular axial position but the occlusal surface is lower on the buccal edge and thus forms an obtuse

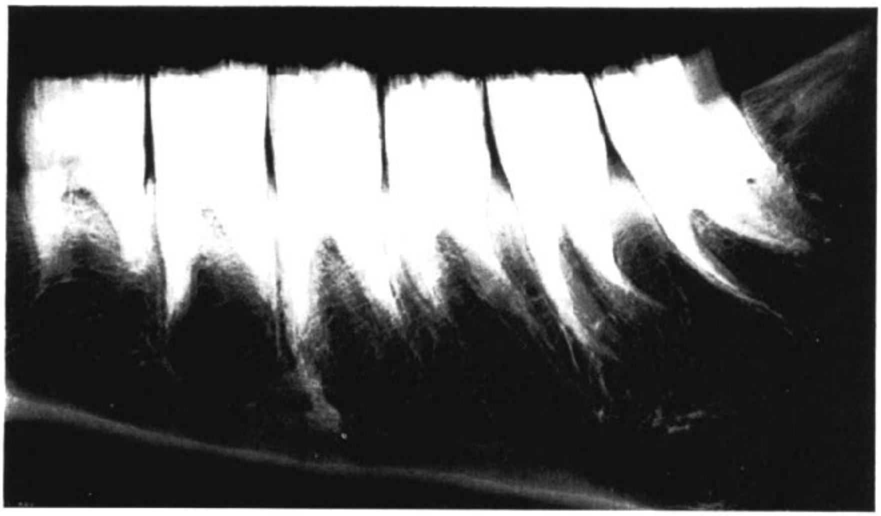

Fig. 7
X-ray of the mandibular teeth of a herbivore, showing the axial inclinations.

angle. Thus we find the resultant of the occlusal stress in a buccal direction in the maxilla, and in a lingual direction in the mandible.

The teeth of the maxillary and mandibular buccal segments have very wide, tight contact surfaces. (Fig. 7.) These contacts are maintained by the mesioaxial inclination of the third molar, the last tooth of the segment, and by the distoaxial inclination of the second premolar, the first functioning tooth. (Fig. 8.) In the segments I examined, I found it impossible to remove any of the teeth in the middle portion of the segment without first removing those anterior or posterior to it. They are mechanically interlocked, and appear to function as a unit. In examination of the stroke, however, we find they function individually, but lend support to each other as a unit.

The maxillary molar presents three roots, a mesial, a lingual, and a distal. The lingual root is flattened on the lingual and buccal surfaces, and the mesial and distal roots are flattened on the mesial and distal surfaces. In some cases, the mesial and lingual roots are fused, while in the others all three are fused, leaving only the buccal area open. The roots are flattened, and present many grooves. This gives them the appearance of a corrugated plate, and these corrugations increase the surface area of the roots.

There are two exceptions to this general root pattern, namely, the mesial root of the second premolar, and the distal root of the third molar. These

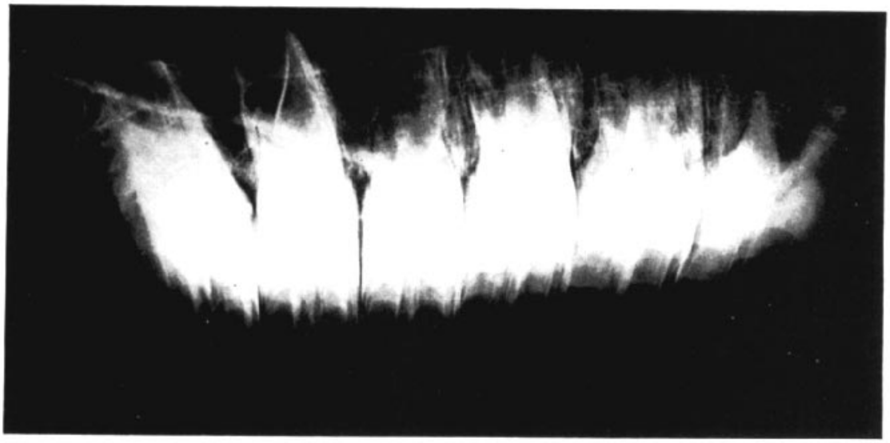

Fig. 8
X-ray of the maxillary teeth, showing the axial inclination.

are pyramidal shaped, and provide a distal surface, a mesiolingual surface, and a mesiobuccal surface in the second molar, and a mesial surface, a distolingual surface and a distobuccal surface in the third molar. The second premolar has a distal inclination and the third molar a mesial inclination. This root form provides a greater surface area for these two end teeth, which are the only ones that do not enjoy the support of two neighbors.

The mandibular molars have only two roots, a mesial and a distal. The form is similar to those of the maxillae, being flattened mesiodistally and presenting many grooves. We find here the lingual and buccal edges of the root plates either curling in upon themselves, or presenting enlargements at these areas. Either of these modifications increase the area for the periodontal membrane attachment from the buccal and lingual. The mesial root of the second premolar and the distal of the third molar present pyramidal shaped roots almost identical to those of their antagonists in the maxilla. All of these striking modifications in the herbivorous molars seem to reflect an adaptation of form to the resistance of the functional stresses of these teeth. The many grooves increase the surface area for periodontal membrane attachments, and we find the greatest area provided on the side of pull or opposite to the direction of pressure. In the maxillary molars where the direction of the greatest amount of stress is toward the buccal, we find a large lingual root with the greatest surface area on the lingual side of the root, and a well developed mesial and distal root to help support the mesial stress.

There is considerable difference between the root form and surface area of the mandibular molars and that of the maxillary molars. This is readily understood if we examine the functions of these two parts. As Brodie has pointed out, the main function of the mandible is mastication, and the dense structure of the bone reflects this condition. The maxilla has the added function of housing the upper end of the respiratory system and the organs

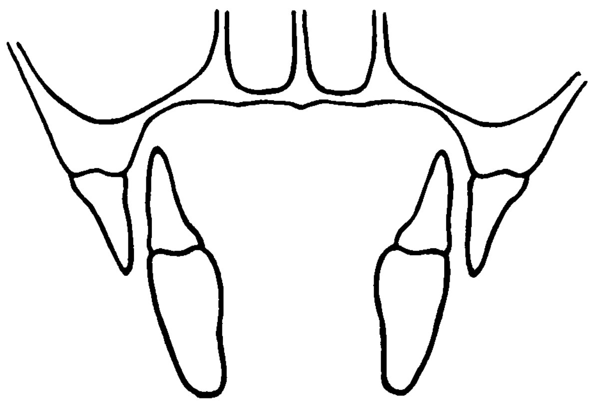

Fig. 9
Diagram representing a frontal section through the carnassials in a rest position.

of sight. These demand greater surface area but still must maintain the same strength for mastication. Thus we find modifications in the design of the supporting bone to meet these different demands. In masticating function, the maxilla is stationary, while the mandible is the moving portion of the machine and strikes the blow. The maxilla can be compared to the anvil and the mandible to the hammer. The occlusal surface area reflects a difference in function, which I will discuss later. From the evidence presented, we can conclude that the periodontal membrane and bone reflects the arrangement best suited to lend a maximum of support for the suspension of the tooth, with a minimum expenditure of material.

To better understand the relation of the functioning area to the supporting area let us first make comparative gross examinations of the entire dentures. The denture of the rodent is so arranged that it is impossible for all of the teeth to function at one time. When the anterior teeth are in function, the mandible is in a protrusive position, taking the buccal segments out of their intermaxillary contact. (Fig. 9.) To place the molar segments in function, the mandible must be returned to its retrusive position. The difference in the distance between the buccal segments in the maxilla and the mandible and the stroke used makes bilateral function an impossibility. Therefore, we can safely say that the rodent can function only in the right or left segment at any one time, but not both.

In the carnivore, the width of the mandibular arch is less than that of the maxillary arch. (Fig. 10.) The carnivorous molars, as stated before,

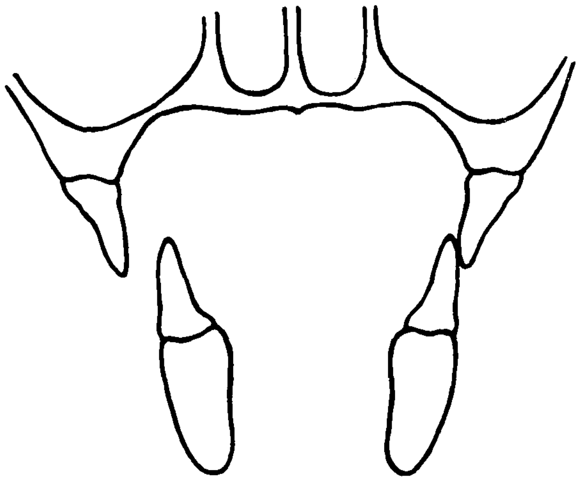

Fig. 10
Diagram representing a frontal section through the carnassials as one pair goes into function. Note that the opposite teeth are well out of function.

depend upon a tight contact between the upper and the lower teeth for function and to attain this contact the entire mandible shifts slightly to the functioning side. This leaves the opposite side out of contact with its opposing segment. The stroke is preponderantly vertical and the teeth arranged so that only one tooth in the mandibular and one tooth in the maxillary segment are in function at one time.

In the herbivorous animal the width of the buccal segment and the distance between the two buccal segments in the maxilla are greater than in the mandible. (Fig. 11.) In placing the right molar segment in function, the mandible swings to the right, moving the left condyle forward in its fossa, while the right condyle stays in its fossa, but rotates. It is only when the mandible starts to return to centric position that function begins. At this time we find the left side has no intermaxillary contact until the mandible returns to centric position. (Fig. 12.)

With these observations behind us our next effort was directed toward the establishment of the ratio between the functioning surface area and the root surface area of the teeth. In all cases, area covered with cementum, to which the periodontal membrane is attached, was taken to represent the root surface. The incisal or occlusal surfaces were measured in order to arrive at an approximate ratio between the two.

In the maxilary incisor of the rodent, the ratio of the incisal functioning surface to the root surface area was found to be 1 to 11. The mandibular incisor shows a decrease of root surface area and yields a ratio of 1 to 9.

The buccal segment of the domestic cat shows a variation between the teeth of the upper and lower. The first premolar and the molar of the maxilla are vestigial, leaving the second and third premolars the only functioning teeth in the segment. The functioning surface area of these two teeth have

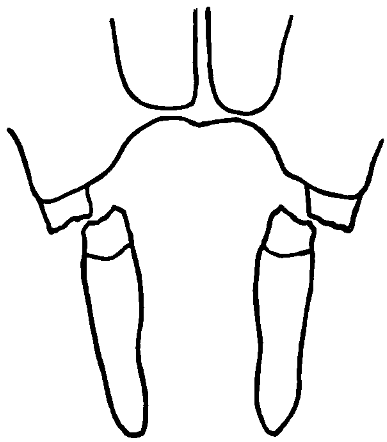

Fig. 11
Diagram representing a frontal section through the molar area of a herbivore, with the teeth in rest position. Notice that they do not meet occlusally, the incisors carrying the load, and that the mandibular teeth are almost completely lingual to the maxillary.

an approximate ratio of one-to-nine of root surface area. The mandible has two premolars and one molar, all of which function, and the ratio of the functioning surface area is one-to-seven of root surface area.

The dental formula of the maxillary and mandibular buccal segments of the horse is four premolars and three molars. The first premolar of both segments is vestigial and lost early. The occlusal functioning surface area of the maxillary segment has a ratio of one-to-four of root surface area. The mandibular segment has a ratio of one-to-seven. This seemed to be a contradiction of our premise that the maxillary ratio runs higher than the mandibular. An attempt to explain this apparent contradiction in the horse led us into a more detailed examination of tooth function in general and opened the way for the next phase of our study.

Actual measurements had revealed that while there was more root surface in the maxilla of the horse than in its mandible, the ratio was reversed by virtue of the fact that there was almost twice as much occlusal surface area in the maxillary teeth; the upper yielding 4485 sq. mm. to 2529 for the mandible. It then occurred to us that the smaller of these two figures would have to be taken as representing both upper and lower, since no more than this amount could be functioning at one time. When this ratio was

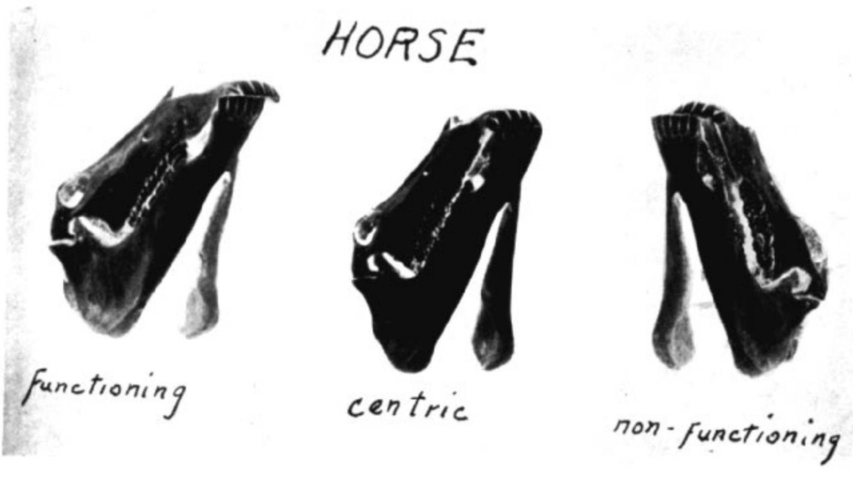

Fig. 12
Photograph of horse's skull showing relationship of functioning and of non-functioning sides.

taken, it yielded a maxillary value that was higher than that of the mandible. This raised the question of whether or not we were justified in taking all of the occlusal surface into account in establishing our ratios.

In observing the stroke of the rodent we find only the enamel edge in contact at any time during the stroke. Measuring the functioning enamel we established an area of 2 sq. mm. for the maxilla and 2½ sq. mm. for the mandible. The mandibular incisor is the moving portion of this unit, and it alternates its stroke. In one stroke, the incisal edge of the mandibular incisor travels over the maxillary surface and in the next stroke the mandibular incisor surface travels over the maxillary incisal edge. Having made this correction we find that the ratio of functioning edge and root surface for anchorage is markedly altered. The approximate ratio between incisal edge and root surface area or anchorage becomes as one-to-fifty.

The carnivorous stroke functions through traveling points of contact, as has been explained. If we take the length of the functioning edge of the carnassial teeth and multiply this by its width, which is less than 1 mm., we obtain a ratio of approximately one-to-fifty or more with the root surface.

In the horse the mandible is the moving portion of the denture, and at no instant is it possible to have more area of contact in the maxilla than in the mandible. But by increasing the buccolingual width of the maxillary occlusal surface area, the functional efficiency of this machine is increased. The mandibular segment has a greater area over which to work in each

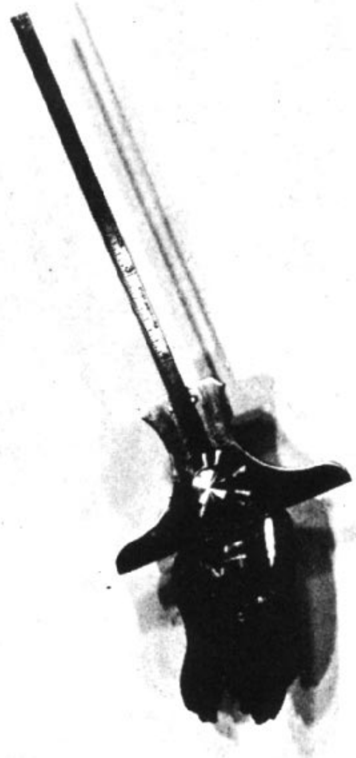

Fig. 13
Depth gauge in position on occlusal surface of herbivorous molar, showing the difference in height of enamel ridges of buccal third, and lingual third of enamel ridges.

individual stroke. This increases the work per unit of time, but decreases speed which, in the case of this particular animal, is not essential.

In examining the occlusal surface of the molars of the horse, we found large grooves and depressions separated by enamel ridges of approximately one to two millimeters in width. These enamel ridges are the only places where intermaxillary contact is possible. Thus it was equally improper to take the entire surface as a basis for the establishment of our ratio.

In analyzing the stroke of the horse, it was found to be mainly in a horizontal arc and at no time during the stroke was there complete contact of all of the enamel ridges of the mandibualr teeth. (Fig. 12.) With the use of the depth gauge, we measured the height of relationship of the enamel ridges from buccal to lingual. (Fig. 13.) The enamel ridges in the middle one-third portion of the occlusal surface were found to be lower than those of the buccal, and the lingual thirds. This was true in both mandible and maxilla. Thus we have two concave surfaces functioning against each other, an arrangement which never permits more than one-half of the enamel ridges of any tooth to be in contact at any instant. When we measured the surface area of such functioning enamel ridges it changed our ratio to approximately one-to-forty. It should be pointed out that in the case of these teeth we measured the roots as though they were smooth surfaces. It is readily seen that many corrugations would still further increase our ratio.

The purpose of this examination of animal dentures was to seek the principles, if any, of the relationship between occlusal stress and supporting areas. This very superficial examination of the problem would seem to indicate that some such relation does exist.

Conclusions

In summing up the principles revealed in the animal dentures, we would list the following:

First: The periodontal membrane acts as a suspensory tissue. The alveolar bone is the recipient of the occlusal stress through the tensing of the periodontal membrane. The incisor of the rodent is the finest example of this principle.

Second: In animal dentures at least, each tooth seems to function individually.

Third: In no case is the entire occlusal surface of even the individual tooth in function at any single instant.

Fourth: The root form of any tooth reflects its occlusal stress.

Fifth: There is evidence that a uniform ratio between functioning surface and root surface area may exist and it appears that this ratio is similar, regardless of the function and stroke whether in rodent, carnivore or herbivore.

When we turn our attention to the omnivora, such as man, our problem becomes ve"v much complicated. Thus far I have found it impossible to even determine, much less measure, the functioning areas that may be in contact at any particular instant. I have therefore had to content myself with an analysis of the general forms of the different classes of the teeth, the manner in which they are set in the arches and the vectors and resultants of the forces that are known to play upon them.

In function and support the omnivorous teeth present characteristics of each of the other groups discussed. Human teeth can be divided into three groups according to their function as well as their position in the dental arch—the anterior segment, and the right and left buccal segments. The anterior segment is used for shearing. In function the mandible is moved forward until the mandibular incisors meet the maxillary incisors end-to-end, and then the mandibular teeth move up the lingual incline planes of the maxillary incisors in completing the stroke. They do not function as true shears because their incisal edges remain parallel. Rather do they resemble the action of the chisel. The form of their crowns and the pattern of wear reflect this fact.

The buccal segments somewhat resemble the herbivorous in function. The marginal ridges have shearing properties and the grooves and various cusps are capable of crushing.

The premolars and molars have larger occlusal surfaces and constitute the true masticating groups. In normal function, the human mandible has considerable lateral excursion. In mastication on the right side the mandible is caused to swing in this direction by a forward movement of the condyle on the left side, and a rotation of the right condyle. The right buccal segment functions as the mandible swings back to centric. As the ridges of the mandibular teeth pass those of the maxillary, a shearing action is produced. When the stroke is reaching completion, the cusps settle into the pits and grooves of their antagonists and produce a crushing effect. The buccal segment on the opposite side does not have intermaxillary contact until the stroke is almost completed and the mandible has returned to centric position.

Knowing the direction of the stroke of the mandible the direction of the forces acting upon any tooth can be readily appreciated. Thus the fact that the lower incisor functions against the lingual surface of the upper, makes it apparent there is a labial force on the upper and an equal and opposite on the lower. In a like manner, the pressure of the mandibular buccal teeth against the inclined ridges of the maxilla results in a buccal force above and a lingual force below.

There are certain accessory factors which antagonize these forces and thus contribute to the support and anchorage of these teeth. The first and most important is the continuous arch form. Man is the only animal that has continuous tooth contact throughout the dental arch; all others have two or more diastemas. Such a continuous contact lends to each tooth in function the support of all the teeth in that arch. Strict analysis does not tend to support the accepted theory of three point contact and simultaneous functioning of a number of teeth in any animal denture. In man it may occasionally happen during a lateral and protrusive movement, but only when there is nothing interposed between the teeth. In studying the arc that the mandible travels during the stroke, and the arch form with its curve of Spee, it would seem that man also has unilateral function. There seems to be a wave of occlusion in the buccal segments similar to that in the herbivorous animals. This would mean that each tooth functions individually for an instant as the wave of occlusion passes through the contact points. The best evidence that such functional forces are resisted at the contacts is seen in those cases where teeth are lost.

We have all seen the effects of the loss of one or more contact points. For example, if the right central incisor is removed, the left central will move mesially and the canine will do likewise. When a contact point is lost in the buccal segment, it is usually followed by a mesial movement of the teeth posterior to it. We can not have loss of contact points without loss of normal arch form. Furthermore, the loss of contact relationships in one jaw is usually followed by a disturbance of those in the opposing jaw.

The facial musculature also plays an important part in maintaining arch form and tooth contact, and therefore must be mentioned as an accessory to the support of the teeth. Its major contribution is a squeezing action which tends to keep the upper teeth from spreading.

Another force which tends to maintain continuous contact is that which operates through the arch from the second molars forward. This force is termed the anterior component and is the resultant of the mesial inclination of the molars plus the muscular forces.

Let us now turn our attention to the design of the teeth themselves and see if this factor contributes to maintenance of their positions. The upper central incisors have a mesial and labial axial inclination. Furthermore, the stress of function upon these teeth is in a mesial and labial direction. We are not surprised, therefore, to find that the root is pyramidal in shape, having its greatest surface area for periodontal membrane attachment on its mesial, distal and lingual surfaces.

The crowns of the upper lateral incisors are normally about two-thirds as large as those of the centrals. The axial inclinations are very similar. The stress is again in a labial and mesial direction, but there is a lessening of the labial vector due to the position of these teeth and to a decrease in their size. The mandibular canines occlude on the distolingual surfaces of these teeth, thereby increasing the mesial force. The root form reflects this added mesial vector, presenting a greater surface area for anchorage on the mesial and distal as compared to the buccal and lingual.

The mandibular incisors have a labial axial inclination but stand almost upright mesiodistally. The stress is in a lingual and distal direction. The lingual stress is largely resisted by the arch form and contact points. The roots are markedly flattened mesiodistally, having about double the surface area for periodontal membrane attachment here as compared to the buccal and lingual surfaces.

The canine may be considered as a connecting link between the anterior and buccal segments. The axial inclination of the maxillary canine is to the mesial and labial. That of the mandibular is more perpendicular with a very slight lingual and mesial inclination. The greatest stress on the maxillary canine is in a mesial direction and on the mandibular it is likewise. In examining their functioning surface we always find the greatest wear on the distal half. The roots have their largest surface area on the mesial and distal to supply anchorage against these stresses.

The maxillary buccal teeth have a mesial and buccal axial inclination. This axial inclination together with the curve of Spee and the direction of the stroke produces stresses in a buccal and mesial direction. The bicuspids are unstable and very often congenitally absent. Their crown form is variable in cusp formation and there is considerable variation in their intermaxillary relationships. Root form of these teeth is correspondingly unstable.

The mesial and buccal inclination of the maxillary molars produces stresses in a buccal and mesial direction. The first molar has three roots—mesial, lingual and distal. The mesial root is flattened mesiodistally and presents about twice the root surface for anchorage here as on the buccal and lingual. The distal root is very similar in form to the mesial, but smaller. The lingual root is the largest and is flattened buccolingually. It has about double the surface area for periodontal membrane attachment on these surfaces as on the mesial and distal.

The stresses on the second molar operate in the same direction as on the first molar. The crown is smaller, with a smaller functioning area. The root form is similar, but also smaller. We find a greater variability in the crown form and likewise more modification of root form. The roots are closer together and very often fused.

The mandibular buccal segment is the moving portion of this crushing and shearing unit. The bicuspids play a small part in function as compared to the molars. Because of their variability and instability we will omit their analysis.

The first molar has a lingual and mesial inclination which results in stresses in a mesial and lingual direction. It has two roots, a mesial and a distal. Both are markedly flattened mesiodistally, and present more than twice the surface area for support in this direction.

The second molar is similar to the first in function, crown form and root form. It has less occlusal surface area and also less root surface area. The roots are closer and show more variability in form.

Summary

This completes our analysis of the root form of the human teeth. I should like to summarize the findings:

First: Evidence seems to point to the fact that the human denture, like those of the lower animals, has a unilateral function, which resembles that found in the herbivorous dentition.

Second: The anterior teeth of the human function as chisels.

Third: The human denture has some accessory elements of support not possessed by lower forms. These are the continuous arch form with full mutual contact and the facial musculature. Both lend considerable support against the stresses of occlusion.

Fourth: Some of the general relationships of root surface to functional stress as found in the animal dentures seem to be present in the human dentition. Almost universally the greatest surface is presented on the side where tension is known to occur.

I do not wish to be understood as considering this presentation more than a preliminary and very superficial survey. The methods I employed, and particularly those for the measuring of surface areas, were very crude. The fact that even such a cursory examination should have revealed any correlation would seem to indicate that this line of investigation would be worth following with more exact methods.

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