The Hidden Force

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FOREWORD

Through the reappraisal and correlation of information, much of which is generally accepted by our profession, the explanation is hereby presented which makes understandable the various clinical phenomena observed in anchorage and orthodontic tooth movement.

INTRODUCTION

For years we have known that tooth movement is accomplished by orthodontically induced pressures and tensions within the periodontal membrane, which in turn effects changes in the bony media surrounding the tooth.

Aisenberg[1] is one who early said we should become familiar with this structure, and Thompson[29] pointed out long ago that the periodontal membrane was the most important single structure to the orthodontist.

The following orthodontic phenomena can be explained in the light of knowledge of the principal alveolar fibers of the periodontal membrane combined with a formerly unsuspected hidden force:

(1) The various phenomena observed in the Begg method, including the biomechanical mechanism by which clinically obvious anchorage is often maintained with this technique, plus the other formerly inexplicable phenomena involved in the technique.

(2) The understanding of the anchorage principles utilized in the Tweed technique, aside from that derived from headgear and the mechanical resistance embodied in twelve to fourteen tightly ligated lower teeth.

(3) The reactions of teeth to various orthodontic forces, including intrusive forces.

(4) The reason that the mandibular plane angle of the mouthbreather opens severely during treatment.

(5) Numerous other phenomena which lack of space precludes our mentioning in this paper.

Orban[19] describes the principal fibers of the periodontal membrane as being gingival, transseptal and alveolar. The alveolar group is divided into alveolar crest, horizontal, oblique and apical. We are concerned chiefly with those principal fibers which frustrate the orthodontist in some of his endeavors and yet which aid him so greatly in others, the oblique group. This is the group which is decidedly the most abundant of the fibers supporting the tooth.[5,14,19,27]

Figure 1 is a schematic diagram showing the principal group of alveolar fibers in their relaxed state in which they exhibit an "S" shaped curvature, and an enlarged schematic view of the important area of the intermediate plexus where the fibers are able to become disengaged under certain circumstances.

It is fairly well agreed that the oblique fibers cover most of the lower two-thirds of the roots of the teeth

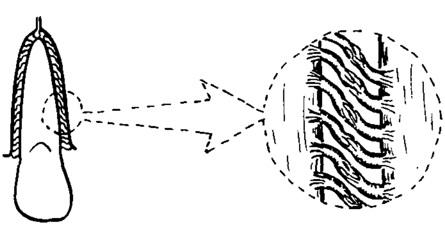

Fig. 1

and that they suspend the tooth in the alveolus. They run from the alveolar bone apically at a 45° angle to insert in the cementum and their function is to counteract vertical stress placed upon the teeth.[8,14,19,23]

Intrusion of the Teeth

The subject of intrusion of teeth is one about which little has been written, considering that many cases end as complete failures because the necessary intrusion was not attainable. Some write as if it is merely a matter of placing an intrusive bend in the archwire, while many others are of the opinion that intrusion simply cannot occur. The clinical orthodontist feels that it can occur when employing certain techniques, but he does not understand how and why these achieve intrusion. He is even more confused when noting that a simple bend in the archwire apparently produces intrusion in one instance but not in another, seemingly identical instance.

Aisenberg[2] and Graber[9] feel that intrusion cannot be accomplished without the use of pathological forces. Thurow[30] is less definite concerning the possibility of intruding teeth but mentions that its attainment is at best difficult. Graber states his case a little more strongly when he says:

> A depressing force against a tooth probably meets with less success in terms of absolute tooth movement than any other force applied. The oblique fibers of the periodontal membrane are so attached to the root surface and to the alveolar bone that a blow or pressure along the long axis of a tooth is strongly resisted by those fibers, as they cushion the fundus of the alveolus against damage. A depressing force in the long axis is transmitted as tension to both the tooth root and the alveolar bone . . . To actually depress a tooth, extremely strong force is required—a force sufficient to tear the fibers loose from their attachments, unsplice the intermediate plexus, rupture the delicate blood vessels of the periodontal membrane and *then* exert pressure on the alveolar walls and apex.

Yet Modlin[18] has consistently achieved depression of cuspids of up to four millimeters distance, as measured cephalometrically. In his investigation of intrusion in dogs, Bunch[6] feels that it was achieved in each of the teeth in which he attempted it.

Many[7,13,22,26,28] have achieved depression with the Begg technique, as evidenced by cephalograms.

What are the reasons for the discrepancies among some of the preceding statements? Let us review the manner in which a tooth is moved orthodontically in order that we may answer this.

In the classical orthodontic movement, a force acting laterally* on a tooth causes pressure in the periodontal membrane on the side toward which the force is acting and tension is created in the periodontal membrane on the side from which the force is acting. On the pressure side this force eventually causes a resorption of the cortical plate, consequently detaching the ends of the fibers which were formerly embedded in the alveolar bone. These fibers are again embedded when pressure and movement cease.

On the side of tension** during the classical lateral tooth movement while the tooth was receiving no pressure, the fibers were relaxed and "S" shaped. However, when the tooth receives lateral pressure, the fibers on the tension

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*In this paper, "lateral" forces and movements are defined as those forces and movements which appreciably widen or narrow the periodontal membrane.

**Tension in the long axis of the principal fibers is not the mechanism which causes apposition to occur. The tension which causes apposition of bone is that tension which is present when the periodontal membrane is widened.

side are straightened somewhat as the tooth moves away from the alveolar wall. The bony wall on this side is not resorbed, however, and the fibers remain attached to it and the cementum. Therefore, if the tooth is allowed to move appreciably, it is necessary for lengthening to occur within the fibers. Modern investigators[5,9,17,20,25] apparently agree that this elongation on the tension side occurs in the area of the intermediate plexus, possibly through an unraveling of the previous connections by some action of the fibroblasts. This unraveling causes a temporary disconnection of these unstretchable fibers from their alveolar half. We have already seen that the fibers on the pressure side are disconnected in a different manner, i.e., through the resorption of the bone in which they were anchored. However, both these reactions will be referred to simply as "detachment". We can then say that the principal alveolar fibers on the sides of both tension and pressure have undergone detachment and have thus temporarily lost their ability to resist forces placed on the tooth. Reattachment occurs when movement ceases.

There are various types of depressive forces and each type must be appraised individually, for the environment of the tooth reacts quite differently to each. Let us first consider the instance of the classical nontipping direct depressive force by comparing it with the classical nontipping lateral force. Figure 2 illustrates what would happen if a force were to move a tooth mesially .2 mm (the average width of the periodontal membrane in patients of treatment age).[19] The tooth would be in contact with the alveolus along its entire mesial surface and resorption would occur on the mesial wall due to pressure. Apposition, due to tension, would begin on the distal wall.

However, if a force were to move

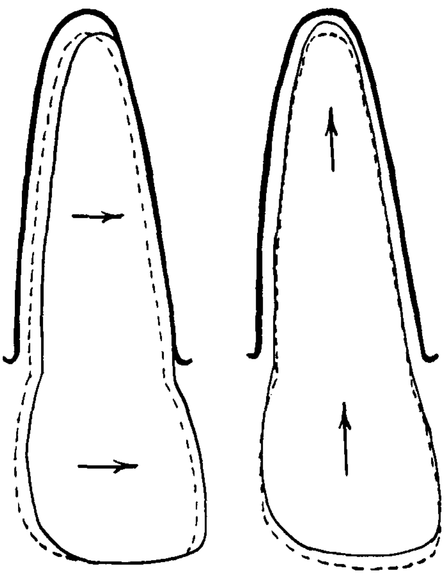

Fig. 2 The hatched lines represent the initial positions of the tooth. The solid lines represent its position after it is moved mesially .2 mm or apically .2 mm from its initial position.

a tooth apically .2 mm, the only area which would be reduced in thickness the full .2 mm would be the area of the fundus. The other areas of the periodontal membrane would be reduced in thickness imperceptibly, as the movement would be almost parallel to the axial walls of the alveolus. Therefore the oblique fibers would remain taut but intact, and further apical movement could not occur.

As the principal alveolar fibers are not capable of being stretched, the microscopic intrusion which results from such a direct intrusive force occurs only to the extent that the oblique fibers are straightened from their usual "S" shaped curvature. In such a movement the tooth is, for practical purposes, no nearer the alveolar wall than before in any areas except at the apex. Therefore the area around the apex is resorbed and reorganized. The fibers in other areas remain intact because there is no lateral pressure or tension in the

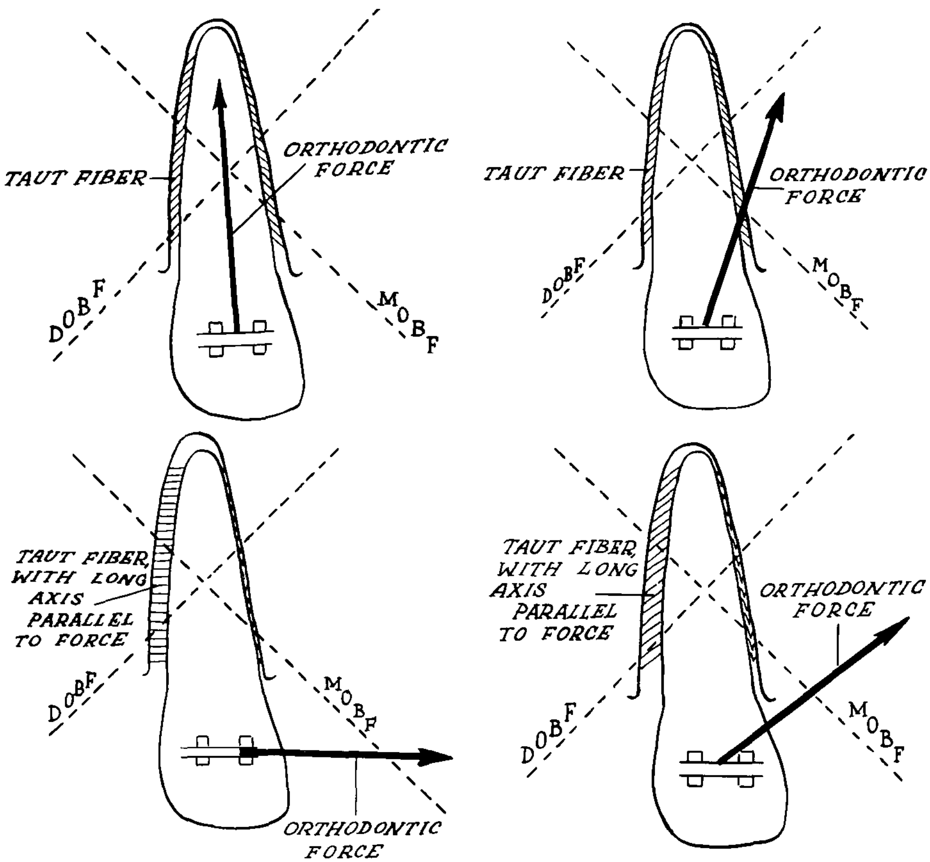

Fig. 3 A and B above, C and D below.

periodontal membrane in other areas. There is merely tension through the long axes of the oblique fibers. Therefore resorption or apposition do not occur from a direct nontipping intrusive force except at the area of the apex and thus significant intrusion does not occur.

We must note that there is only one force which can be placed on a tooth which causes a straightening of the "S" shaped fibers designed to resist that force, and yet which does not appreciably widen or narrow the periodontal membrane around those fibers. It is the direct or almost direct intrusive force. This is why direct intrusion of the teeth is unattainable with physiologically compatible forces. When intrusion is achieved, it must occur in a different manner, one which will be described later.

Nontipping Intrusive Forces

Figure 3 shows what happens to the oblique fibers (and consequently the tooth) when various *nontipping* forces are placed on an anterior tooth. The lines "MOBF" and "DOBF" represent the angulation (45°) of the mesial and distal oblique fibers in their usual orientation. Any nontipping orthodontic force, extended from the bracket site, which passes through both these lines will place the oblique fibers on both mesial and distal under tension and will allow no lateral movement. For the tooth to be moved at all laterally, the force traced from the bracket site must pass through only *one* of the lines.

If traced from the bracket site, a nontipping direct intrusive force (Fig. 3A) goes directly through the apex intersecting both lines (MOBF and DOBF). This places all the oblique fibers under tension along their long axes resulting in an attempt at movement along the direction of force in Figure 2, in which no significant movement can take place. Only that slight movement occurs which is allowed by the straightening of the oblique fibers.

A nontipping, almost direct intrusive force (Fig. 3B) is one which has an intrusive and a lateral component with the intrusive being stronger than the lateral. If traced from the bracket site, such a force intersects both line MOBF and line DOBF placing both mesial and distal fibers under tension. The tooth is again suspended in a hammock of taut oblique fibers (as in Fig. 3A). This means that the slight movement yielded by the straightening of the fibers allows the tooth to move only directly apically to a minute degree and not at all laterally. As we saw in Figure 3A, a direct apical movement cannot occur to any significant extent.

Figure 3C demonstrates the classical nontipping lateral force. It has no intrusive vector and is demonstrated in order that we can better understand the nontipping intrusive forces. Traced from the bracket site, its vector passes through only line MOBF consequently causing lateral movement. The distal fibers become oriented in the direction of the force while the fibers on the mesial are under pressure, resulting in tooth movement. Such a force causes no intrusion, of course, as it is perpendicular to the long axis of the tooth. Bone is resorbed on the side of pressure and later is deposited on the side of tension. This continues until the force is dissipated.

A lateral-intrusive force (Fig. 3D) is a nontipping force which, like that of Figure 3B, has both a lateral and an intrusive component. However, in this case the lateral is the stronger of the two force components, i.e., when traced from the bracket site, the force passes through only one of the two lines MOBF and DOBF. Consequently, lateral movement occurs. The fibers on the distal are oriented along the direction of force, while pressure occurs on the mesial wall. Therefore all the principal alveolar fibers are detached and intrusion begins. Bone is deposited on the tension side and is resorbed on the pressure side. Of the forces shown in Figure 3, this is the only one which yields intrusion, even though it is indirect. When viewing any of the forces shown, it should be remembered that we are looking at only the mesiodistal planes of these teeth. The same basic principle applies also to any labial or lingual nontipping forces.

It has been pointed out that tension in the oblique fibers results in a reorganization of the trabecular bone which indirectly supports these fibers.[1,14,19,27,30] This change, plus resorption at the fundus, is the only structural change which occurs as a reaction to an orthodontic force of a direct or almost direct nontipping intrusive nature. Graber and Aisenberg are undoubtedly correct if they are speaking of this type of depressive force when they say that such a force cannot produce intrusion unless it is strong enough to be pathological.

Bunch possibly achieved intrusion in his experiment on dogs. Although he lamented that tipping also occurred, this very tipping was necessary for him to achieve intrusion. He was using a force which was eventually causing lateral pressure or tension in all the

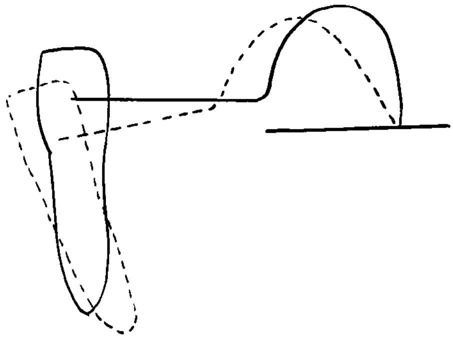

Fig. 4 Light tipping intrusive force of Bunch.

areas of the periodontal membrane combined with an intrusive vector. The force which he employed was divided into light tipping and light intrusive components (Fig. 4).

Huettner and Whitman[10] felt they obtained direct intrusion of teeth in the monkey. However, there was no cephalometric evidence to substantiate this nor was there an adequate description of their control situation. Lefkowitz and Waugh[15] felt that they too had achieved direct depression, but bite changes occurred and again, no cephalometric evidence was presented. Much histologic data were shown in which reorganization was in evidence at the fundus. However, it appears that they incorrectly interpreted, as evidence of depression, these changes at the fundus plus other isolated areas of reorganization. All of these areas of reorganization are easily explained. Those at the apex have already been explained, and the changes at the crest of the ridge are simply the result of inadvertent initial tipping. Other (small) areas are merely examples of a phenomenon which occurs perpetually on all teeth, that of the reorganizing of small areas of principal fibers.[19] However, it is obvious that, regardless of the number of oblique fibers that are detached, significant intrusion cannot occur as long as *any* intact oblique fibers are present. Their photomicrographs showed that the vast majority of these were intact in a taut state. This latter point alone is sufficient to show that orthodontic intrusion did not occur. What did happen was a temporary, reversible, microscopic intrusion which would be lost within hours after the forces were removed. The resumption of their "S" shape by the straightened, tense oblique fibers would result in the minute, extrusive movement required to place the tooth at its initial level followed by apposition at the fundus.

The intrusion which occurs with any tooth is a result of forces which act with lateral pressure and tension throughout the entire periodontal membrane and thereby cause the detachment of the principal alveolar fibers while simultaneously containing an intrusive vector. In other words, an intrusive force may be successful when acting at a time when the oblique fibers have become detached sufficiently for (1) pressure resorption to occur around the apex and for (2) the tooth to be free to move into this area of resorption. In no instance has intrusion conclusively been shown to have occurred unless movement of other than an intrusive nature was occurring simultaneously. In certain unusual circumstances teeth undergoing a relatively short period of rapid extrusion can be intruded into their former nonreorganized socket. This does not result in a net intrusion, however.

Let us now review the forces involved in those methods which were successful in achieving what we will call "indirect" intrusion.

Modlin has shown cephalometrically how cuspids may be routinely intruded a distance of approximately four millimeters with a sectional edgewise archwire by incorporating a gingival deflection mesial to the first molar combined with a closing loop. This intrusive movement is routinely accomplished

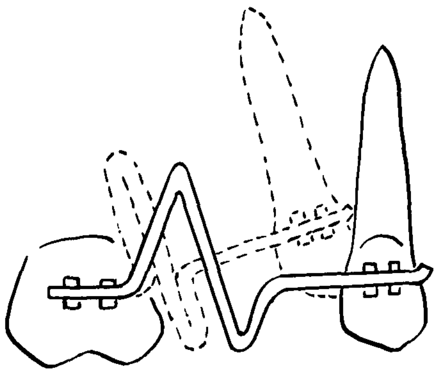

Fig. 5 Lateral intrusive force of Modlin.

through the detachment of the oblique fibers by the action of a lateral force which simultaneously contains an intrusive vector (Fig. 5). The lateral force is supplied by the activated closing loop, and the lighter intrusive vector by the gingival deflection placed in the archwire just mesial to the molar. The resultant force is similar to that in Figure 3D.

The Begg technique of incisor and cuspid intrusion, when successful, is similar to the previously mentioned methods where intrusion was gained in that it is achieved through the detachment of the oblique fibers by lateral forces combined later with the then effective intrusive vector. In this technique the lateral force is a lingual or distal tipping one and is supplied primarily by Class II and intramaxillary elastics. The intrusive vector is supplied by the tipback (anchorage) bend in the molar region. It is effective only after tipping has caused a detachment of the principal alveolar fibers on all areas of the anterior teeth.

Tipping-Intrusive Forces

Light noncontinuous

Any light tipping force (one ounce or less) has a fulcrum point, meaning that in such an area the tooth is neither nearer nor farther away from the alveolar wall than it was initially (Figs. 6A and 6B). Around this fulcrum, therefore, no lateral pressures or tensions exist, and the oblique fibers in this area remain integral and intact. If the movement ceases at this point, the other areas of the periodontal membrane undergo the cycle of lateral tension or pressure, then apposition or resorption, and finally, complete reorganization with new principal alveolar fiber connections. During this cycle the intact oblique fibers around the fulcrum successfully resist the light intrusive force. Therefore tipping occurs but intrusion does not.

Light continuous

In a light continuous tipping force the fulcrum changes[30] (Figs. 6A, 6B and 6C). When the fulcrum shifts, all areas of the periodontal membrane, including the former fulcrum area, will be receiving lateral pressures and tensions sufficient to detach the oblique fibers. As it is a continuous movement, none of the areas of the periodontal membrane will be able to continue the cycle past the resorption and apposition stage (and thus to principal fiber reattachment) until the tipping movement ceases (Fig. 6D). This means, therefore, that from then until the tipping force is dissipated, all the principal alveolar fibers are detached. The tooth is clinically mobile, supported only by the intact transseptal fibers and the cushioning of the detached periodontal membrane. The tooth is then susceptible to a light continuous intrusive component, and will continue to tip and intrude until a change in force components occurs. Such a force is classically exemplified by Beggs' light continuous tipping-intrusive force on the anterior teeth.

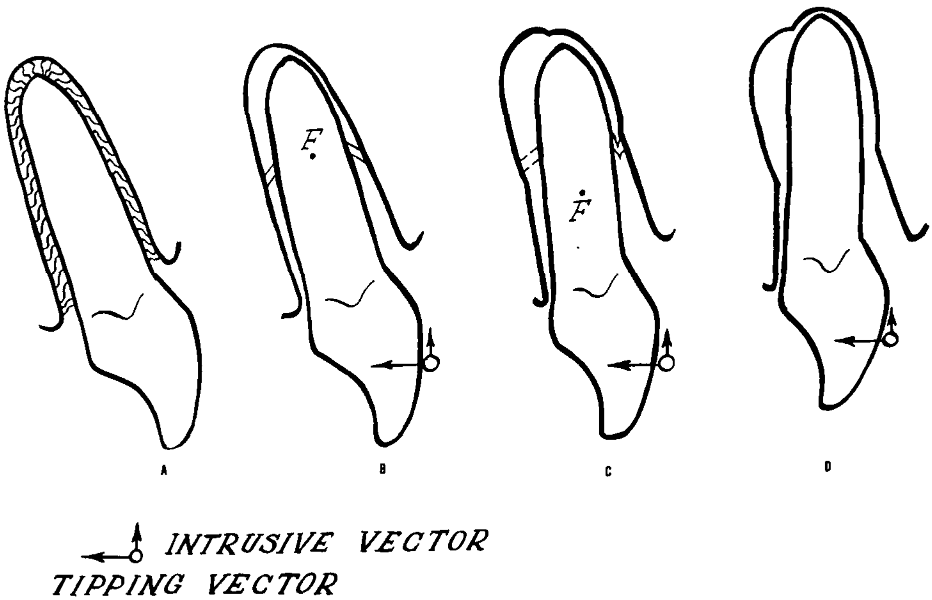

Fig. 6 (A) The undisturbed tooth. (B) the initial reaction to a light tipping-intrusive force.
(C) The reaction following (B) if the light tipping-intrusive force is continuous.
(D) The reaction following (C) if the light tipping-intrusive force is continuous.

Moderate to Heavy Tipping-intrusive Forces

This is the type of force which results on a tooth whose bracket is located more incisally or occlusally than its neighbors when a round wire is used in initial leveling procedures. It also often results when either round or edgewise wire is used toward the end of treatment in attempting to reduce a remaining deep overbite. Though one attempts only to achieve intrusion of certain teeth, tipping is the only movement which occurs. However, extrusion of near or distant teeth often make it appear that intrusion was obtained. The tipping force occurs because connecting a tooth to an archwire produces some amount of initial tipping, especially if adjacent teeth are also attached. In the rare event that no tipping occurs, the tooth would be receiving a direct intrusive force (Fig. 3A) in which no intrusion can take place. We will now see why a moderate or heavy tipping-intrusive force can never yield intrusion.

Hyalinization occurs in the case of tipping forces of approximately one ounce or more.[20] Therefore, in the case of a tipping-intrusive force of such seemingly light magnitude, the immediate result is hyalinization at the crest of the ridge on the pressure side and on the tension side at the apex. Hyalinization means, by definition, that the area is devoid of cells. Therefore, there are no osteoclasts present in order for frontal (surface) resorption to occur, and there are no fibroblasts present to modify the principal alveolar fibers. In such areas these fibers can only remain intact and cannot allow intrusion to occur until undermining (rearward) resorption can take place detaching such fibers. Meanwhile, in all other areas of the periodontal membrane, frontal apposition and resorption occur and new intact principal alveolar fiber connections are completed. This is because it requires much less time for surface apposition and resorption to occur than is required for the slow undermining resorption. When the undermining resorption finally occurs, the tooth makes a sudden, minute tipping movement, but instantly new areas of hyalinization occur in the areas of the recently reorganized intact fibers. These fibers are then trapped in the new areas of hyalinization and thus guard against intrusion throughout a new cycle. Such cycles repeat themselves until the tipping component is dissipated, with numerous areas acting alternately as areas of hyalinization and as areas of surface resorption and apposition. Thus the net result of a moderate or heavy tipping-intrusive force is that no intrusion can occur, for intact principal alveolar fibers are present in one area or another throughout the entire time such a force is acting. When the heavy tipping vector has dissipated itself during the tipping movement and is no longer capable of producing either hyalinization or further movement, the tooth becomes suspended by the undissipated intrusive vector, immobile, in the oblique fiber hammock. We have previously seen that intrusion cannot occur while the hammock is intact (Fig. 3A). Therefore, a heavy tipping-intrusive force cannot achieve intrusion.

The explanation can be simply stated: Intrusion cannot occur in the instance of either a light, noncontinuous tipping-intrusive force or a moderate to heavy tipping-intrusive force because, in either instance, intact principal alveolar fibers are present on the root in one area or another at all times.

Intrusion has been successfully accomplished only by a light, continuous tipping-intrusive force (as in the Begg method) or by a bodily moving, nontipping, lateral-intrusive force (as in the case of Modlin and in Tweed's "en masse" distal-intrusive movement of upper teeth).

This explains why, in Begg's retraction of the upper anterior teeth, the two Class II elastics should not be more than three ounces each, if intrusion is desired. The six ounces or less of total force is distributed as a tipping force to the six teeth. The resulting one ounce or less of tipping force per tooth causes a detachment of the principal alveolar fibers. This allows intrusion to occur as a reaction to the lighter depressive tipback bends. If heavier forces are used, hyalinization occurs around some or all of the teeth; if edgewise brackets are used, hyalinization occurs around those teeth which are the most rigidly attached to the archwire. Hyalinization retards even the tipping movement and absolutely precludes intrusion.

Now for the first time the previously fragmented, and apparently contradictory, histological and clinical findings concerning tooth movement have been combined in an understandable, integral pattern which systematically accounts for all such phenomena. It would then seem simple to understand what happens clinically when the teeth receive the various forces encountered in the major orthodontic techniques. It would be simple were it not for the presence (in most major multibanded techniques) of a hidden force which undoubtedly has never before been suspected and the influence of which has never been appraised. This force will be explained later.

The Pivotal Phenomenon

Jarabak and Fizzell[12] show cephalometrically that a rotational couple on a lower molar, combined with Class III elastics (as in Tweed's distal-tipping bend), causes a rotational axis to be

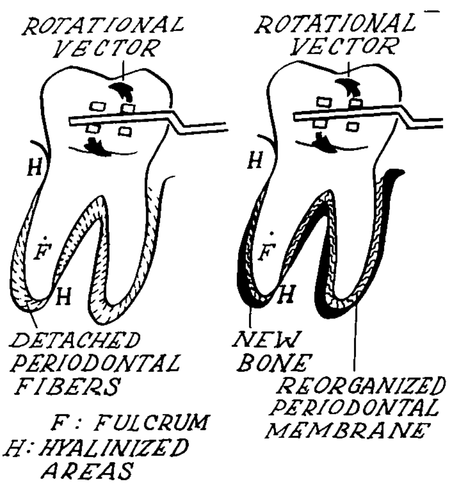

Fig. 7 The pivotal movement.
Left: This represents a lower molar a few days after a moderate to strong distal-tipping force is placed on it.
Right: This represents the tooth some weeks later, after the periodontal membrane is reorganized in all but the hyalinized areas, where undermining resorption is occurring.

established near the middle of the distal root. It follows that the mesial cusps and mesial root also rotate around this axis. The occlusal height of the mesial cusps is thereby increased, even though the tooth often appears to be depressed. This movement will be referred to as the "pivotal" movement and its underlying mechanisms explained.

When a moderate to heavy rotational force acts on a lower molar, it attempts to raise the mesial root using the distal root as a fulcrum (Fig. 7-left). Except for the microscopic, insignificant depressive movement allowed by a straightening of the oblique fibers, the distal root is unable to be depressed and remains at its initial height. The oblique fibers of the mesial root allow the immediate extrusion of this mesial root to the extent that the root ends of these fibers become aimed coronally instead of in their usual apical direction. This allows lateral tensions to exist around the mesial root resulting in the detachment of the periodontal membrane around it. Around the distal root, some of the principal alveolar fibers which initially blocked its intrusion continue to guard against intrusion of this root, due to its undergoing a hyalinizing tipping movement. Hyalinization occurs at the mesial near the apex and on the distal near the crest of the ridge. On the other areas of this distal root, just as on the mesial root, the comparatively rapid surface resorption and apposition occur, followed by reorganization and reattachment of intact fibers (Fig. 7-right). During this time the fibers in the areas of hyalinization have supported the distal root against intrusion, for rearward resorption occurs extremely slowly, and the trapped fibers must remain intact and functional during this time. When undermining resorption finally occurs, the tooth abruptly rotates a little farther around the distal root fulcrum. New areas of hyalinization are immediately established, some being in the areas of the recently reorganized, intact fibers. The mesial root has again moved occlusally and distally, and the previously described cycle of the pivotal phenomenon begins to repeat itself. The constant repeating of this cycle results in the raising and distal positioning of the mesial cusps.

The Class III elastics could conceivably enhance the hyalinization by increasing the tipping force, but their primary contribution to the pivotal phenomenon in the Tweed technique is in moving posteriorly the remaining banded teeth so that they do not block the necessary distal movement of the pivoting molar crown. Jarabak and Fizzell found that, in those cases in which Class III elastics were not worn, the roots of the anchor molar swung mesially and the position of the crown remained relatively unchanged. The pivotal phenomenon with its occluso-distal crown movement, obviously cannot occur if the crown of the anchor molar is barred from moving distally.

Maximum Anchorage in the Tweed Technique

Tweed's tipping of the anchor teeth is covered in many texts and in his manual.[31] The anchorage in this technique is gained through a formerly unsuspected force.

Exclusive of the anchorage gained by headgear and that which is inherent in any teeth, the clinically apparent (prepared) anchorage gained by Tweed is due to the translation of masticatory muscle force into an often completely stationary anchorage.

As in all things, Tweed's method of anchorage is not infallible and in some cases is not achieved. Therefore, to make the explanation easier to follow, we shall omit those cases in which it is difficult to attain. The cases in which it is easiest to achieve and maintain Tweed anchorage are those in which there are present the following factors: (1) a fully erupted lower second molar, (2) a steep lower curve of spee and (3) a small freeway space.

When the Tweed practitioner performs his leveling of the curve of spee and tipping back of the second molars in the lower arch in anchorage preparation, he has extruded lower premolars and the lower first molars as the second molars were undergoing the pivotal movement. When either (1) the tipping occlusally of the lower molar mesial cusps, (2) the resulting extrusion of the premolars, (3) the later incorporation (in maximum anchorage cases) of a lower reversed curve of spee and the resultant further extrusion of the premolars, or (4) any combination of the preceding factors have caused the obliteration of the freeway and a constant stretching of the muscles of mastication, the anchorage can often be stationary. This is because the roots of the anchor teeth are suspended in a hammock of oblique fibers as a reaction to the tension placed in these muscles when they are forced open slightly past the limit of the freeway. The lower first molars or premolars have been forcefully extruded into the upper teeth, wedging the mandible open into the postfreeway and stretching the muscles sufficiently to often elicit a practically constant resistive tension of approximately twelve ounces.

When the freeway has been obliterated and then surpassed, as it is in many of the moderate anchorage cases and most of the maximum anchorage cases treated by the Tweed method, the teeth are forcefully contacting the opposing teeth in or near the premolar areas at all times except for insignificant intervals during which the patient has his teeth apart in talking, yawning, etc. Thus the teeth then are, for all practical purposes, contacting continuously due to the stretch resistance of the masticatory muscles. This force suspends the roots of the anchor teeth in a hammock of oblique fibers (Figs. 8 and 9). The only way to move these anchor teeth mesially is to use sufficient force to bodily move the roots of all teeth mesially against the antagonistic force contained in the oblique fiber hammock. This dynamic suspension of the roots in a tense, fibrous hammock is the mechanism by which Tweed has translated vertical muscle tonus into dynamic horizontal anchorage.

For purposes of explaining hammock anchorage, we will arbitrarily use ten ounces as the amount of force with which the teeth are being held together, and consider the hammock effect as if it occurred on one single root of one

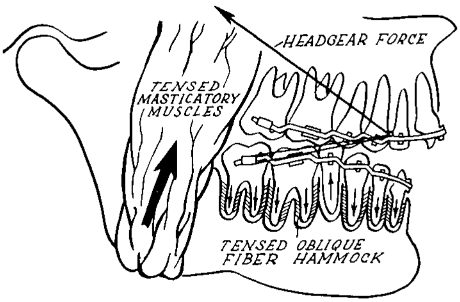

Fig. 8 Tweed anchorage.

lower tooth (Fig. 9). Ten ounces of vertical force are acting on the root of the tooth which means that the distal fibers and the mesial fibers each have vertical components of five ounces. As X= y cot A, and angle A is approximately 45 degrees,[8,14] the cotangent of A is approximately one. Thus the horizontal component of force is five ounces each in the mesial and distal oblique fibers. Therefore, a force, to be strong enough to move the teeth even minutely, would have to be powerful enough to take the weight off the mesial fiber, thereby leaving the full vertical component (ten ounces) on the distal fiber. The distal fiber would then contain a horizontal vector of ten ounces which would have to be exceeded by the mesial elastics in order to achieve even a minute displacing of the anchor root. Only when the root has moved mesially could resorption begin on the mesial wall, resulting in a breakdown of the hammock and the loss of anchorage.

Force is equal to pressure multiplied by area (F = P x A).[24] Therefore, when computing the hammock portion of the total anchorage in one arch, it is unnecessary to consider whether one or more roots or teeth are involved in the hammock. Hypothetically speaking, if only one root in that arch were acted on by the almost constant force produced by the masticatory muscles, this one root would contain the full force of the muscle tonus. In other words, to overcome the anchorage resistance contained in the hammock anchorage of one arch when two quantums of vertical force act on one root, the magnitude of a minimal mesially displacing force would be identical to the amount of mesial force required to overcome the resistance of two quantums of force acting vertically through two roots. This is why, in Figure 9, it is valid to show schematically only one mesial and one distal fiber of only one root of one anchor tooth as a composite of all the fibers of the anchor teeth of one arch which are suspended in the oblique fiber hammock.

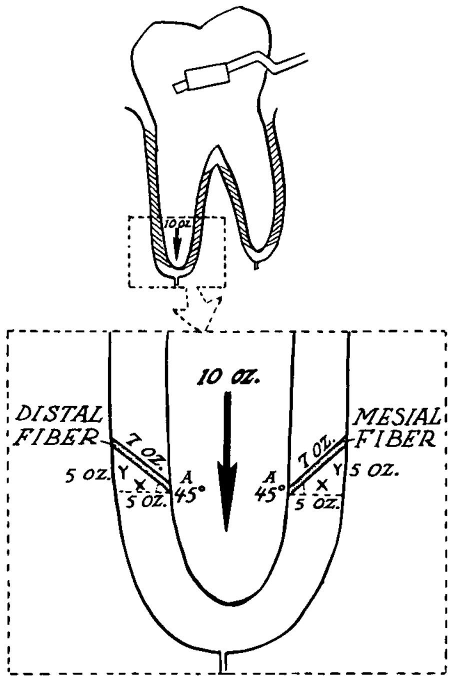

Fig. 9 Schematic Diagram of Hammock Anchorage x: Horizontal vector y: Vertical vector A: Angle (45°) at which oblique fiber attaches from cementum to bone.

In actual cases treated by the Tweed technique, this ten ounces of hammock anchorage would have added to it whatever amount of anchorage exists inherently in any twelve to fourteen lower teeth. We will later see that when the freeway has disappeared, the elastic force in the Tweed method is diverted into two vectors subtracting considerably from the mesial pull. Therefore, when there is ten ounces of vertical hammock force, the elastic force could often be considerably more than ten ounces without its mesial vector being sufficient to overcome the hammock anchorage.

In Figure 8 we see Tweed anchorage as it is employed in the classical distal "en masse" movement in a Class II extraction patient. The freeway has been surpassed by the distal tipping of the molars and the reversed curve of spee, which have extruded the lower premolars into the postfreeway and the opposing teeth. The relaxed state of the masticatory muscles no longer exists, as these muscles are now constantly resisting the extrusive force which is attempting to pry open the mandible. As the other lower teeth attempt to forcefully extrude the lower premolars against the upper arch, these lower teeth are forcefully suspended in a hammock of taut oblique fibers. When completely effective, this hammock renders the lower teeth stationary against the mesial elastic force.

This same hammock anchorage is utilized in the upper arch during some procedures. It is absent during distal "en masse" movement because the force of the headgear (usually combined with Class II elastics) is enough to overcome and destroy the upper hammock. This distal force then moves the roots of the upper teeth against the distal alveolar walls, and resorption and orthodontic movement occur. The lower teeth remain stationary unless the force of the Class II elastics is strong enough to break down the lower arch hammock, in which event the lower anchorage fails. This can be detected at a subsequent visit, however, and alterations can be made to restore the hammock anchorage.

If the hammock is not achieved (i.e., a freeway is still present) or if it is of an insufficient magnitude to successfully resist the forces present, the anchor molars become loose. We would expect this in a tooth which is being moved bodily mesially, for there would be a temporary detachment of the fibers around its roots. However, the fibers and consequently the tooth would remain firm when maintained in the dynamic equilibrium of an adequate hammock mechanism. In regard to such looseness occurring in anchor molars, Tweed writes:[31]

> The mandibular dental arch is closely inspected (when the patient returns after wearing Class II elastics in maximum anchorage cases). In case of the slightest mobility in the terminal molars, the distal tip-back bend is increased and a slight amount of progressive lingual crown torque is incorporated into the legs of the archwire . . . Also, during this period of treatment, the section of the archwires, both maxillary and mandibular, between the cuspids and the first bicuspids, should be altered and lengthened, in such manner as to elongate all four first bicuspid teeth . . .

Increased tipback bends and "elongation" of upper and lower premolars obviously encroach on the vertical dimension. Lingual crown torque on the lower posterior teeth causes the buccal cusps of these teeth to contact farther lingually the buccal inclines of the upper posterior teeth, encroaching further on the vertical dimension. The foregoing words of Tweed, then, are actually advocating that a failing anchorage be bolstered by procedures which have one common element, that of further encroachment on the vertical dimension. Such procedures merely obliterate the freeway if this has not already occurred, or else they cause a further stretching of the muscles in the postfreeway.

Strang writes further:[27]

> The mandibular second molars usually erupt on occlusal planes that are above those of the first molar teeth and are also positioned in mesial axial inclination. Consequently, when distal tipping bends are placed in the archwire, the mesial portion of each second molar is elevated, primarily to a level with the distal portion of these teeth. As this mesial section moves occlusally, it raises the first molar, also and, in turn, this elevating force is transferred to the premolar teeth.

Strang is pointing out that the high occlusal level of the lower second molars results from their ability to elevate the premolars to a greater extent than can the lower first molars. It therefore naturally follows that they can also obliterate the freeway much more easily. Therefore, hammock anchorage is usually not achieved unless the second molar is banded which is primarily why this tooth has been credited by many with having anchorage qualities superior to the larger first molar.

Anchorage in the Begg Technique

Most operators feel that "light forces" and "differential forces"[4] are expressions which are somewhat inadequate to fully explain the clinically apparent anchorage often exhibited by the Begg method.

Like Tweed, Begg has translated masticatory muscle force into an extremely effective anchorage mechanism. In order to demonstrate how he accomplishes this, let us examine those cases in which the principle is easily demonstrated, those of Class II, Division 1 four premolar extraction. After explaining the mechanism in these cases, we will then contrast the results with the less successful cases, which are those of nonextraction and those with the combination of a deep bite and small freeway.

Class II, Division I First Premolar Extraction Cases

The anchorage is often extremely stable in the Begg method of treatment of these cases, once the freeway has been obliterated and the muscles have been put "on the stretch" (Fig. 10). This usually occurs in late Stage I and often remains into Stage III. The encroachment on the muscles, which occurs in most of these cases, is due to (1) the extrusion of the lower anchor molar[16,21] to the limit of the freeway and (2) the subsequent imperceptible prying open of the mandible as a result of occlusodistally tipping these contacting molars by their undergoing the pivotal movement. How are these results achieved?

In the typical Class II, Division 1 extraction patient, the lower anchor molars are extruded as they come occlusomesially in Stage I. The lower second premolars tip into the extraction spaces allowing the lower first molars to achieve this occlusomesial movement in attaining Class I relation with the upper anchor molars. The occlusal movement of the lower anchor molars soon obliterates the freeway (unless it was large), causing these molars to remain in virtually constant contact with the upper anchor molars. The upper molars thereupon begin dissipating the mesial elastic force, which formerly acted only on the lower molars. The lower molars have by then come closer to the anchorage bend. This proximity results in an effectively stronger rotational force which, resisted now by only a portion of the resisting mesial force of the elastics, begins the pivotal movement in each anchor molar. This then pries the mandible open, past the limits of the freeway and slightly into the postfreeway. The resistance to stretch of the muscles then constantly counteracts this force, establishing and maintaining the hammock effect around

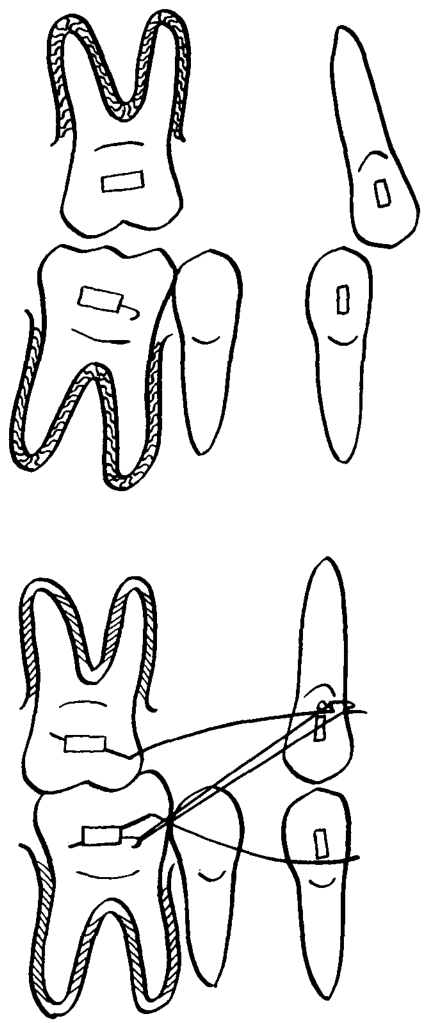

Fig. 10 Above: Begg patient at time of banding, with normal freeway.
Below: During late Stage I of Begg treatment, at which time the freeway has disappeared.

the anchor molar roots. By virtue of this hammock mechanism, the anchorage can often be stationary for long periods.

The virtually constant forceful intercuspation of the anchor molars results in the total hammock anchorage being approximately doubled, for the lower molar cannot move mesially without the upper doing likewise, unless the hammock breaks down. This means that a substantial portion of the hammock effect of the upper anchor molar is added to that of the lower molar in determining the total resistance of this lower molar to forward movement. Moreover, as in the Tweed method, once there is no freeway, the elastic force is dissipated by two vectors, lessening the mesial pull on the anchor molars.

This readily clarifies why the lower molar often moves forward rapidly into a Class I relationship early in treatment and then remains stationary,[33] under strong mesial elastic forces, until the third stage. In the third stage, the powerful torquing archwire is usually strong enough to cause the breakdown of the hammock.

Leno[16] found that the anchor molars at the end of Stage I had extruded an average of 3.0 mm, and Rocke[21] found a practically identical figure (3.1 mm) at the end of Stage II. This can mean only that the lower molar was rapidly extruded until the freeway was obliterated at some point in Stage I, and that it was extruded little, if any, from that time onward.

Nonextraction Cases

The sequence of events is different in the instance of the nonextraction patients, most of whom are Class I. The lower second premolar cannot tip mesially due to contact with the lower first premolar. Further, the proximity of roots and crowns in such patients does not allow the elastics to move the lower anchor molars forward sufficiently to complement the tipback bends in their attempt at extruding these teeth into contact with the upper molars. This is the major reason why the bite is sometimes difficult to open by the Begg method in the typical nonextraction case, even if there is sufficient freeway. It is well known that anchorage is often unsatisfactory in such cases under the Begg method, and the retention of a freeway easily explains why. Even when the freeway is obliterated in such patients, it has occurred at the expense of having already lost considerable anchorage in what is usually a maximum anchorage situation.

First Molar Extraction Cases

It is easier to obliterate the freeway when the lower second molar is the anchor tooth, due to its mesial inclination, nearness to the hinge-axis and being situated more occlusally than the first molar. The first molar's absence also makes it very easy for the second molar to migrate occlusomesially until such time as it abolishes the freeway. Often the pivotal phenomenon alone can almost immediately obliterate the freeway with this tooth, making a Class II molar correction extremely difficult.

Patients With a Small Freeway

In the case of the patient with a deep overbite and small freeway, sufficient bite opening is often impossible. These patients yield unsatisfactory results when treated by any present orthodontic method. The loss of freeway is attained by such a small extrusion of the lower molars that sufficient bite opening does not occur. When such conditions exist in the Class II, Division 2 patient, the usual small amount of tipping-intrusion of the upper and lower anterior teeth is also unsuccessful. This is because the initial small freeway has not allowed molar extrusion to progress to the point at which the bite is opened sufficiently. As the upper and lower anterior teeth are in contact with each other, tipping is ruled out. In this technique if tipping is precluded, intrusion is impossible. Thus the bite remains deep unless the patient is treated through a very long period of growth in the condylar area, gradually lowering the mandible as the anterior teeth are kept from erupting.

However, if the Class II, Division 2 patient has a large freeway, the bite can be opened very easily by the molar extrusion, and an ideal result can be achieved.

Second and Third Stages of Treatment

In the second stage of treatment the lower molars usually do not move mesially at all, as shown cephalometrically. This means that often these lower anchor molars, which once moved mesially very rapidly in response to light forces (in achieving Class I molar relationship during Stage I), now remain stationary while resisting a force which is as strong or stronger than that of Stage I. This can be logically explained only by the oblique fibers, through variations of the pivotal phenomenon and the oblique fiber hammock.

In the case of the patient whose freeway disappears during treatment, it is perhaps impossible to appraise the total factors which determine whether or not through Stages II and III the anchorage holds staunchly, holds intermittently (resulting in moderate loss) or is somewhat freely lost. Some of the possible factors are the following:

(1) Either slight or major changes in the tipback bend angulation, especially the major reduction in Stage III.

(2) The amount of elastic force used in various phases.

(3) The strength of the powerful torquing arch in Stage III, in acting to draw the upper anchor molars mesially and thus (by the virtually constant intercuspation) to pull the lower anchor molar mesially also.

(4) The occlusal anatomy of the anchor molars which affects the strength of their interlocking.

(5) Clenching habits.

(6) Additional growth occurring in

the condylar area which would tend to return freeway.

(7) Whether the patient is a severe mouthbreather, who almost constantly has his teeth separated past the freeway and out of contact.

(8) Whether other teeth are contacting, especially the anterior teeth and the erupting unbanded second molars, and are thus taking some of the hammock-producing force away from the anchor molars.

(9) The amount of the total elastic force which is diverted into a vertical vector, thus detracting from the horizontal mesially displacing vector.

(10) The intrusive vector delivered to each molar by the arm of the cuspid uprighting springs which attach immediately mesial to all anchor molars, and the intrusive force delivered to the upper anchor molars by the arm of the upper torquing archwire.

When Freeway Remains Throughout Treatment

The study contained in the appendix shows that in some of the Begg method patients the disappearance of the freeway probably never occurs. Most of these patients initially had a large freeway or were nonextraction patients. Such patients can certainly be expected to lose more anchorage than would be lost if the oblique fiber hammock were operative. These probably form the bulk of the Begg method patients in whom the anchorage is decidedly unsatisfactory.

Return of Freeway

It should be mentioned that all cases which were examined after treatment were found to have a freeway. This is why Williams, in a cephalometric appraisal of the Begg technique, found that the mandibular plane angle becomes steeper during the first two stages of treatment, then returns to or passes its original position in the third and posttreatment stages.

There are several possible factors which could account for a return of freeway. One factor, which is applicable to the Begg method patients, is the reduction of the anchorage bend in the third stage. This could allow the crowns of all banded teeth to move anteriorly in response to the strong torquing archwire. The molars would then have this lateral movement modified by the lighter intrusive vector from the muscles. When a tooth is undergoing bodily lateral movement while simultaneously receiving a depressive vector, it is indirectly depressed.

A factor applicable to many of the Class II Tweed patients would be the recommended overtreatment to a slight Class III condition. In the distal "en masse" (lateral) movement of the upper arch, the periodontal membrane is of course detached around these upper teeth. This detachment allows the masticatory muscle force, in conjunction with high-pull headgear, to simultaneously depress the upper posterior teeth as they are moved along the occlusal inclines of the lower teeth in arriving at the cusp-to-cusp relationship. After treatment the cusps return toward Class I interdigitation, thereby contacting the opposing teeth in areas of lesser occlusal height, returning freeway.

Later the freeway can often be increased by another factor. Growth could occur in the condylar area in those patients who have not passed the age wherein such growth is still possible, lowering the mandible. This would apply to both Tweed and Begg methods.

The Mouthbreather

Many observant operators are aware of the loss of anchorage and the extreme rotation of the mandible which occurs in the severe mouthbreathing patient under many methods of treatment, including the Begg and the unmodified classical Tweed method. In some of these patients the mandibular plane angle has been opened by treatment to such a degree that their formerly adequate lips have seemingly become too short to close. The extreme disappointment attending such cases makes it necessary to include here the explanation of the underlying cause.

In the normal breather the masticatory muscles become slightly stretched and act to block further extrusion, once the freeway has disappeared. The mouthbreather, however, has his mouth almost constantly open considerably past the freeway. Therefore, in these patients the end of the freeway is not the limit as to how far the operator is able to extrude the posterior teeth and open the mandibular plane angle. The limit is actually the angle at which the patient is constantly open in breathing, which is often from six to twelve degrees more than the mandibular plane angle observed on the pretreatment cephalogram. In cases where the teeth are extruded to this limit, the patient is actually trapped in his former open posture, his lips unable to again close without strain.

When contrasted with the problems attending such severe mandibular rotation, it seems almost anticlimactic to note that the mouthbreather, by his constantly being open past the freeway, has robbed himself of the vertical muscular force necessary for hammock anchorage.

Summary and Conclusions

Most information contained in this paper has been generally well-known and accepted. This study has merely combined the formerly fragmentary information, plus the discovery of a previously unsuspected force, into a thoroughly integral system which, by extension, encompasses all histological and clinical aspects of normal orthodontic tooth movement and anchorage.

Being guided initially by the fragmentary information, it was postulated that in the attainment of anchorage in two major orthodontic techniques, the freeway had disappeared and that the anchor units were held in a virtually constant forceful contact in cases in which this mechanism existed. The assumption was corroborated by force measurements on more than one hundred patients.

Appendix

Through correlating information which is already generally accepted, an explanation was set forth of the factors involved in the attainment of anchorage in certain techniques and tooth movements in any techniques. This explanation attributed to the oblique fiber the role of primary factor ultimately governing anchorage and tooth movement. On the basis of this explanation, it was postulated that in some manner an intrusive force was acting constantly on the lower anchor molars throughout the period in which the clinically apparent anchorage was maintained in certain techniques. It was felt that if a stretching of the masticatory muscles was found to occur as a result of the obliteration of freeway by the various posterior extrusions, the vertical force could therein be found. A study was undertaken to determine whether or not such was the case.

Methods and Materials

The initial step was to ascertain by subjective methods whether or not the freeway appeared to be absent in the Begg method patients at the Fairleigh Dickinson University orthodontic clinic and in private practices in the vicinity. A preliminary survey indicated such was the case. The next steps were (1) to determine more objectively and conclusively that the freeway was actually absent in these patients and, if so, (2) to ascertain with what degree of force these posterior teeth were being held in contact in the postfreeway.

It was felt that these objectives could be accomplished simultaneously by an instrument which would register the amount of force needed to separate the teeth while the masticatory muscles were as relaxed as possible (Fig. 11).

Each subject was adjusted to an upright position in the chair, and then subjected to certain speaking tests and questions in order to ascertain the presence or absence of freeway. It was then noted whether the patient was being treated orthodontically and, if he was, under what method. If a subject had been wearing elastics before the appointment, he replaced them and the testing was repeated. If he definitely felt that the teeth contacted when he was relaxed or when he was speaking, a measurement was attempted. One was attempted also on those patients who were uncertain concerning these points.

The measuring instrument was placed horizontally so that points A and G engaged the upper and lower archwires. While the patient was distracted, knob D was turned, increasing the tension in spring E until the teeth were seen to separate. The instrument was then removed and a Richmond strain gauge was placed on point G. The gauge was made to draw point G toward point A until the same distance prevailed as that which had existed initially between the upper and lower archwires, discernible by scale B. The resulting force reading on the strain gauge was taken as the amount of force required to separate the teeth of the subject. If a freeway was present the teeth were already separated, and no reading was possible.

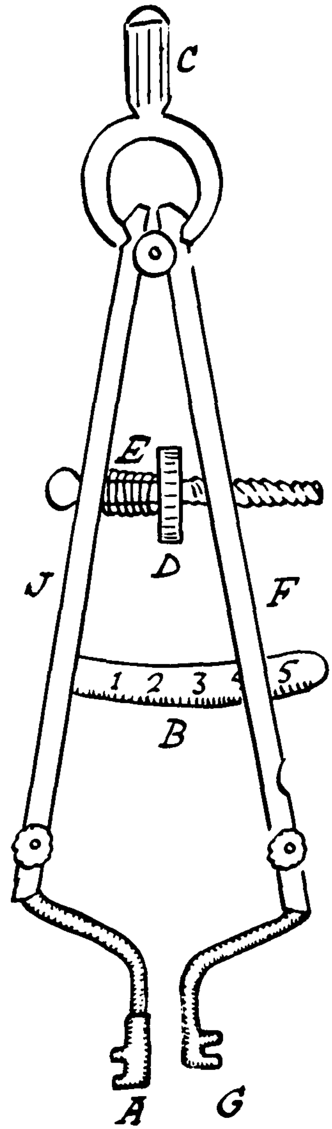

Fig. 11 Instrument used to ascertain muscle force in hammock anchorage.

On each subject with no freeway, three consecutively performed force readings were taken. The lowest of the three readings was recorded as the amount of force being constantly exerted by the masticatory muscles in holding the lower teeth in contact with the upper teeth. If the subject's lowest reading was one-third less than his highest, he was considered unable to relax sufficiently to obtain a representative reading. Only about five per cent of the subjects came under this category.

An increase in the vertical muscular force was found to occur in practically every case when Class II elastics were placed in those patients with no freeway. Further, the freeway disappeared, for practical purposes, in some patients who exhibited one when not wearing elastics. This could well result from the mesial pull of the elastics on the mandible. As the mandible is drawn slightly forward, the masticatory muscles would react to the resultant stretching by increasing their tonus. As the elastics draw the mandible forward slightly, the occluding lower cusps move mesially to more occlusally positioned inclines of the opposing upper cusps. This would wedge the mandible apart, also causing an increase in tonus.

In the geographical areas in which the tests were conducted, patients were found in sufficient quantity to appraise the presence or absence of freeway under the Begg method. A limited but adequate number were found being treated by the Tweed method.

Findings

We have divided the results into (1) the control group, (2) those treated by the Begg method and (3) those being treated by the Tweed technique.

Control Group

The patients of the control group were those who did not fall into the classifications of active Begg or Tweed treatment. They were seen at the Fairleigh Dickinson University orthodontic clinic and the offices of interested orthodontists.

The patients in this group were (1) those seated for diagnosis or separation to begin treatment, (2) patients who had completed treatment, (3) those who were being treated by the Bull edgewise method, (4) patients being treated by strictly extraoral force methods on the upper arch only, (5) those who were undergoing a "modified Begg" method (in the upper arch only), and (6) patients being treated for cross-bites only, with lingual arches, etc.

Only one of the forty-two in the control group was determined to have no freeway. She was undergoing an edgewise method of treatment and previously had a very steep curve of spee. A final reading of 7 ounces was obtained, meaning that her teeth were contacting almost constantly with that much force. Another edgewise patient had been adjudged, from preliminary indications, to have no freeway. He too had initially possessed a steep curve of spee, but an interruption in the testing procedure resulted in the inability to verify the preliminary indication.

It initially came as quite a surprise that none of the strictly Bull method patients had lost their freeway sufficiently to obtain a positive reading, but the number tested who were under this method of treatment (twenty-six) was adequate to suggest that this is generally true. The presence of a freeway was especially surprising of those Bull patients who had originally exhibited steep curves of spee. However, it was remembered that this technique is one in which the lower molars usually are constantly being drawn bodily forward by the powerful Bull loops, closing extraction spaces. If freeway disappears, any resulting vertical muscular force would quickly disappear as it depresses the mesially (laterally) moving molars. The mandibular plane angle at the end of treatment for patients in any edgewise technique shows approximately the same increase as those treated by the Begg method. Therefore, it can readily be surmised that the freeway remaining for these patients at the end of treatment is of an extremely minimal amount.

Begg Method

Of those Begg patients under active treatment on whom a reliable reading was obtained, 72% had no freeway at the time. Undoubtedly, of those who possessed a freeway, some would have been found to have none if tested a few appointments earlier or a few appointments later. Still others probably never did or never would completely lose their freeway at any time. The latter are undoubtedly representative of those Begg patients in whom the anchorage is inadequate.

Of the patients in Stage I who had no freeway, the average force reading was 7.5 ounces. The lowest reading was 0.75 ounces, and the highest was 15.0 ounces. The average elastic force in these patients was 4.5 ounces.

Of the patients without a freeway in Stage II, the average reading was 4.5 ounces. The highest was 6.0 ounces and the lowest was 0.75 ounces. Unfortunately, the total elastic force was not recorded for these patients in Stage II.

The force readings averaged 7.0 ounces for Stage III patients without a freeway. The highest reading was 18.0 ounces and the lowest was 2.0 ounces.

To many it probably seems illogical to think that there could be this constant closing force exerted on the mandible, especially when one sees how effortless it is for these patients to talk. However, this force of tonus instantaneously ceases when the opposing (mandibular depressing) muscles act, as in talking, yawning, etc. Houssay[11] has pointed this out:

> In somatic movements, suppression of activity (i.e., inhibition) in the antagonistic muscles is as important as stimulation of the activity of the protagonists for accurate and smooth performance of movements . . . Inhibitory effects can take place with great rapidity, and the inhibited muscle relaxes at the same speed at which it contracts.

This study has shown, beyond reasonable doubt, that the majority of patients treated by this method have lost their freeway at some period in Stage I and often have not regained it until after treatment is terminated. Forces of tonus were found which exceeded the amount needed in order to enable the anchor molars to remain stationary throughout the latter part of Stage I. The testing procedure and the size of the sample were felt to be adequate to demonstrate these points.

It is felt that many who were past early Stage I and not yet into Stage III but still retained a freeway, were either nonextraction patients or initially had a large freeway. Unfortunately, this information was not obtained.

Tweed Method

The results reveal beyond reasonable doubt that in the case of many patients treated by the Tweed method, there is sufficient vertical force to yield stationary anchorage through the oblique fiber hammock.

In every case in which lower second molars were banded, there was no freeway, whereas patients retained a freeway in every case in which this tooth was not banded. Therefore, in our discussion of the Tweed method results we will consider only those patients with banded lower second molars.

The average force reading when not wearing elastics was 6.5 ounces. For those wearing elastics, the average force reading was 10.2 ounces, with the maximum reading being 12.5 ounces.

Once the freeway has disappeared, the Class II elastic force on the lower arch is divided into two vectors, one mesial and one vertical. The placing of elastics increases our measurement of the masticatory muscle tonus. This increase varies in our sample from 12% to 80% of the total amount of elastic force on the individual patient. Therefore some of this force is spent in straining mesially on the anchorage, but much of it is translated by the cuspal inclined planes into the vertical force which wedges the mandible open. In other words, these inclined planes direct from approximately 12% to 80% of the force of the elastics into vertical channels leaving only a portion of it to pull mesially against the hammock anchorage.

In one Tweed patient, for example, an increase of 3 ounces in the tonus occurred when a total of 10 ounces of elastic force was present. As these 3 ounces were converted into vertical force, we can subtract it from the total 10 ounces of elastic pressure. We then find that the effective elastic force component pulling mesially on the lower arch is actually only 7 ounces. The 10 ounce hammock anchorage recorded for this patient is certainly sufficient to withstand the 7 ounce mesial pull and allow the lower anchorage to remain stationary.

Discussion

The forces producing the hammock anchorage in the Tweed patients are much more controlled and less subject to upsetting influences than are those of the Begg patients. The hammock anchorage can be explained step by step and probably appraised reasonably well throughout all the stages of Tweed treatment. This is certainly not true of the Begg method patients after Stage I.

It was surprising that the maximum readings of Tweed patients were not considerably higher than those of the Begg patients. One would naturally assume that the edgewise wire, being larger, would result in higher readings than would the light wire of the Begg method. However, after further reflection, one can see that the force which is stretching the muscles in the Tweed technique is one which "pushes" the premolars against the opposing arch. Certainly this "pushing" or "lifting" mechanism would not be as efficient in prying the jaws apart as would the lever type of action of the Begg method. Here the force arm is a long lever arm extending from the cuspid bracket to the distal of the molar tube. The work arm extends from the mesial end of the tube to the distal. The depressive force at the cuspid bracket could easily be considered reciprocally as if the cuspid were lifting a lever in raising the mesial cusps of the anchor molar against the resistance of the muscles. As the length of the force arm, from the cuspid hook to the distal of the tube, is approximately seven times the length of the work arm, from the mesial of the tube to the distal of the tube, it follows that it would require a depressive force (derived from the tipback bend) of merely one and one-half ounces at the area of each of the two cuspid hooks in order to yield a work force (at the mesial of the molar tube) of approximately ten ounces in each of the right and left lower molars. It is then only logical that we would find approximately fifteen ounces of force prying the mandible apart in some of the Begg patients in Stage I.

This study was not designed to measure the precise amount of force required to separate the teeth of these patients with no freeway. Rather, it was to demonstrate that a force was actually required and that this force was of a magnitude sufficient to demonstrate the principle of hammock anchorage. This objective was undoubtedly accomplished.

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