ANCHORAGE

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INTRODUCTION

Orthodontics is concerned with moving teeth through bone. It is well known that any applied force will move a tooth. Applying the force exactly where it is desired becomes the problem. Mechanical models, along with Newton's third law, which indicates that for every action, there is an equal and opposite reaction, clearly demonstrates the problem. It is difficult to move one dental unit while leaving others undisturbed. This study is concerned primarily with the utility or distribution of forces in order to move only the desired teeth while leaving the others in their original positions. There are extra oral methods of enhancing anchorage and also intra-oral methods. This study will be primarily concerned with these intra-oral methods.

Anchorage, as related to orthodontics, has been defined as: "The ability of certain dental units that by virtue of their inherent stability combined with their peculiar and favorable relationship to the mechanism by which the teeth are moved, are capable of being used as the base from which the power, inherent in the appliance, can take its origin".[1]

The degree of resistance offered by the various dental units varies with the size, shape, and location of them. The method of appliance attachment and the direction of applied force are factors which play a role in anchorage. It takes less force to tip a given tooth than to move it bodily. Individual variation in metabolism may be as important as any other single variable.

Some elaborate classification systems have been used in the past, but a system such as Angle[2] used was most common. He classified anchorage as simple, stationary, reciprocal, intermaxillary, and occipital.

When considering anchorage concepts relative to clinical orthodontics, several methods are used to enhance anchorage.

Extra oral sources of anchorage may be utilized. Where extraction of teeth is not necessary, one theory holds that an undistrubed tooth is the best source of anchorage.

When crowding is so severe as to make extraction of teeth necessary, the concept becomes more specialized. It becomes desirable to retract the cuspid while holding the molar in its original position. Some methods utilized for this are as follows:

(1) The teeth of the buccal segments are tipped back prior to cuspid retraction.

(2) Molars are tipped back and the roots are torqued into the buccal plate.

(3) Differential and optimal force theories are utilized.

(4) Using some tissue born anchorage from palatal plates.

(5) Tying several teeth together and pitting the unit against, for example, the cuspid.

Tweed states that "anchorage preparation is the most important step in orthodontic treatment. The goal of anchorage preparation is to place the teeth in the buccal segments of the mandibular denture in upright positions with the terminal molars tipped back like tent stakes in the sand so that the pull of the class II elastics, when related to the long axis of the terminal molar, does not exceed 90° when the mouth is functioning, the mandibular denture will be more stable and resist forward displacement. If mesial movement does occur, it will be slow bodily movement of the entire mandibular denture. On the other hand, when we fail to prepare anchorage or leave the anchor molars in their mesially inclined, undisturbed positions, the action of the class II elastics is to pull upward and forward."[3]

Chuck[4] states that it enhances anchorage to torque the roots of the lower molars into the dense bone of the buccal plate.

The various theories of differential and optimal force are closely related to anchorage.[38,39,] They are attempts to gain anchorage by using the correct amount of force to move only the units desired. For example, during cuspid retraction, it is believed that a certain force will move the cuspid distally while the molars stay in their original positions. A greater force would move the bicuspid and molar forward but not retract the cuspid. This is explained biologically by the undermining resorption vs frontal resorption theories.[5]

These concepts are appealing to practitioners and, indeed, entire treatment philosophies are based on them.[6,7,8,]

Recent studies tend to indicate that the differential or optimal force theories are not valid. In general, the more force applied, the faster teeth moved. The individual variation was perhaps more striking than any other finding.[9,10,11,12,]

Brodie[13] feels that an undisturbed tooth is the best source of anchorage. He feels that tipping back a tooth only starts a cellular response, which enhances future forward movement of that tooth. He states that the goal should be to enlist as many fibers as possible against the force we are going to apply. This implies the use of a device which will tense simultaneously all the fibers on the tension side.

Dewell[14] and Lewis[15] feel that tissue bearing anchorage can be utilized especially to start tipping back upper cuspids without allowing the molars to come forward.

Burstone[16] creates what he calls an anchorage unit by tying the posterior segments together. He then pits this unit against the cuspids, feeling that differential root area will not allow the unit to come forward.

It is evident that many ideas are being utilized, some in direct opposition to others, mostly in the basis of clinical observation. Orthodontic thinking has evolved very slowly and this probably stems from a tendency to accept explanation on the basis of faith, rather than on reason.

Eric Hoffer[17] states: "The substitute for self confidence is faith, the substitute for self esteem is pride, and the substitute for individual balance is fusion with others into a compact group." He also says: "We can be satisfied with a moderately good opinion of ourselves, and with moderate confidence in ourselves but the faith we have in a holy cause has to be extravagant and uncompromising, and the pride we derive from identification with a nation, race, leader, or party is extreme and overbearing.

Examples in dentistry of this phenomenon may be found in the cultism built around an individual, an appliance or an idealistic standard.

Edward H. Angle[2] for many years accepted the extraction of teeth as sometimes necessary in orthodontic treatment. About the time he published the 7th edition of his text book, he became slightly critical of any orthodontic treatment, utilizing extraction procedures. He inferred that everyone has the genetic potential to have 32 teeth in perfect alinement. Create the ideal dental environment and "proper growth" will follow. A large percentage of orthodontists accepted such dogma without recognizing the conflict with Mendelian genetics.

A more recent example involves Tweed[18,19], who, after several years of practicing using Angle's methods, and many failures, (in his own words), decided to break away from Angle's principles. He started extracting teeth as a means of achieving long term stable results. Give Tweed credit for finally breaking the yoke, but ironically, Tweed's followers have elevated him on to the same type pedestal that Angle was on. They have let faith replace critical evaluation techniques.

Many orthodontists are totally convinced that their mechanical methods are the only "real" way to treat. This becomes very evident when looking at certain techniques.[20,21,22,23] Faith in the appliance to alter the genetic potential distorts their view of other techniques.

It has been easier for orthodontists to look with hindsight and say: "Look at the beautiful face I have created with my treatment," than to admit that they cannot separate treatment effects from growth effects. It doesn't necessarily follow that changes noted during treatment are caused by treatment. The changes may be occurring in spite of treatment.

SELECTED REVIEW OF LITERATURE

The main purpose of this study is to test the concept that tipping back buccal segments enhances anchorage.

Some of the explanations for employing tip back anchorage are: (1) osteoid formation on the mesial, (2) varied osteoclastic response, (3) bone bending and mechanical factors (4) direct testing of tip back anchorage.

In a consideration of the osteoid formation theory, it is important to note that the first formation product of osteoclast activity is unmineralized bone matrix known as osteoid. When the buccal segments are tipped posteriorly the main site of osteoid formation is on the mesial alveolar surfaces. It is thought that this formation retards the rate of forward movement when that buccal segment is subsequently used as an anchor unit during cuspid retraction in an orthodontic extraction case. This theory arose due to the fact that there is no known biologic mechanism for the removal of unmineralized bone matrix. When attempting to analyze the effect of the presence of osteoid tissue on the mesial of a tipped-back molar, it is desirable to take a close look at the nature of osteoid per se.

According to Weinmann and Sicher[24] the first sign of bone formation is a condensation of the semi-fluid substance of the connective tissue around and between the fibrils. This change in the chemical composition of the cementing substance leads to a masking of the embedded fibrils. The organic substance thus formed is called osteoid tissue. Some of the cells of the connective tissue are enclosed in the osteoid tissue which calcifies later. An undefined chemical change seems to occur around this time as indicated by the fact that osteoid stains differently than decalcified bone matrix. Osteoid is highly resistant to resorption.

Other authors studying pathological conditions have suggested that osteoid tissue is resistant to osteoclastic resorption. Frost[25] states that osteoclasia of unmineralized cartilage or bone is so rare that it is inferred that mineral is in some way necessary for the physical chemistry of resorption. If osteoid tissue is unmineralized, it remains present in the bone.

In many osteomalacias, this tissue accumulates in the skeleton and osteoclasts find less and less mineralized bone to resorb. Serum calcium drops which causes increased parathormone output which lowers serum phosphate levels through renal secretion, creating the typical histologic and chemical features of osteomalacia.[25]

Vitamin D deficiency does not allow mineralization of the matrix to occur. Only osteoid tissue is formed. The vitamin D regulates the Ca - P metabolism by maintaining the absolute level and the physiologic ratio of these two minerals.[24]

Oliver[26] found wide osteoid seams in the alveolar processes of rats on a vitamin D and calcium deficient diets. This condition is also found in animals with rickets and osteomalacias.

Secondly, consider Brodie's concept that the cellular response may vary depending upon the force application and direction. Brodie[13] suggests that a tipping force on a tooth sets up rapid and progressive bone changes from the crest to the apex.

It is possible that the osteoclasts do not respond all in the same manner. Frost[25] suggests there may be more than one type of osteoclast. Hancox[27] states that the evidence that osteoclasts erode bone is partly circumstantial. His theory is that in response to stimuli emanating from bone, osteoclasts are formed from the coalescence of their precursers, probably wandering cells, and move along a tropic gradient to their locus of action. They flatten out against the bone and secrete something which liquifies the ground substance, releasing bone salts which may be dissolved by an acid. The fibrillar are exposed and form the classical brush border, which is slowly digested away by the cell which continues to pour out secretion between the fibrillae so that the process of erosion is continuous. It may end by bein carried away in the blood stream or dying locally.

Setting up anchorage may be justified as a mechanical means of preventing bone bending. More bone bending would occur in response to a tipping movement than in response to a dodily movement. Basset et al[28, 29, 30,] in discussing electrical effect in bone, reminds us of Wolff's law which states that mechanical stress and bone structure are directly related. When bone is subjected to stress, the resulting produces a piezo electric effect. Bassett feels that bone functions as a transducer, converting mechanical energy to electrical energy. He suggests that stress generated electrical phenomena are capable of directing the activity of bone cells.

It is proposed that mechanical deformation applied to the multiple-apatite-collagen interface, which is a semi conductor junction, produces an electrical signal, which in turn stimulates differential cellular responses and causes the oriented deposition of newly formed collagen fibers to produce a structural change in bone, enabling it to better resist the applied deforming force. In vitro studies showed the electricity generated was roughly in direct proportion to the amount of deformation.

Direct testing of tipped back anchorage has been done by Kreitman, Reitan and Rosehnal.

Some increase in arch length appears to be achieved by setting up anchorage. Kreitman[31] tested anchorage theories relative to cuspid retraction in extraction cases. He "set up" anchorage as advocated by Tweed[19] on one side of the mouth both maxillary and mandibular. The other two quadrants were used as controls. He found that the molar teeth that were tipped back in the maxillary arch migrated further mesially during cuspid retraction than did the non-tipped control. In the mandibular arch, he found that after retraction, the crowns of the anchorage prepared teeth were further distal than the crowns of the non-anchoraged prepared group. The roots of the anchoraged prepared teeth were further mesial though. Also, he found that the crowns of the anchorage prepared side came forward faster than did the crowns of the non-anchorage side.

Reitan's[32] study on reversed tooth movement is a specific attempt to relate osteoid formation to anchorage preparation. In this study, teeth were moved either buccally or lingually and then back. Sections of tooth and supporting structures were studied histologically as well as clinically.

Seventy grams of force was used to move these teeth over 8 days experimental time. From previous experiments, he noted that 8 days was adequate for new osteoid formation.

Reitan concluded that osteoid does cause a delay in the onset of direct resorption, but only in experiments of short duration. This was for 3 days or less which is not clinically significant in an orthodontic treatment lasting 1 1/2 to 3 years. He also concludes that greater potential for mobility exists and the slightly calcified bone resorbs more readily than mature bone. The presence of the many young connective tissue cells facilitates the start of tooth movement.

Reitan[33, 34, 35,] noted in his experiments on dogs that on the pressure side there was a decreased number of cells accompanied by increased bone resorption. On the tension side the cell number increased, while new osteoid was being formed. These findings are not consistant with the findings of Baumrind[36] and Gianelly et al[37] who worked with rats and could detect no difference in cell number on the pressure and tension sides.

During tooth movement, Reitan also noted osteoid formed on both the pressure and tension sides. Osteoid seemed to persist for a longer period of time, incident to an intermittant force than incident to the application of a continuous force. The resorption of the bundle bone layer was characterized by the formation of a strikingly larger number of osteoclasts. In some cases, a circumscribed compressed area was observed consisting of semi-hyalinized fibers and subjacent to this a compressed layer of osteoid. The adjacent areas were filled with large osteoclasts undermining the remaining bundle bone. These findings were taken to indicate that slightly calcified bundle bone subjected to pressure will be resorbed more readily than old lamellated bone.

Rosehnal[40] investigated the problem of whether or not osteoid tissue actually retards tooth movement. He moved the mandibular 1st molars of hamsters distally after removing all teeth which occluded with them. His approach was very similar to Reitan's reversed tooth movement study. He found that the posterior tooth movement with the osteoid formation on the mesial did not increase the tissues' resistance to subsequent anterior tooth movement. In fact the rate of anterior movement was greater on the anchorage prepared side even though the total anterior movement was the same on the control and prepared sides. Osteoid tissue only remained one day after the stimulating force was removed.

MATERIAL AND METHODS

Nine patients were used in this study, 6 girls and 3 boys, caucasians, ranging from age 12 to age 15. They were selected because the correction of the malocclusion required the removal of all four first bicuspids, and the retraction of the cuspids. Only the lower arch was utilized in order to not jeopardize the position of the maxillary molars for later orthodontic therapy. Each patient agreed to be available for records and appliance adjustments at least once a week for 8-10 consecutive weeks.

The cuspid retraction appliance was designed in an attempt to retract cuspids bodily and without rotation.[41] (Figs. 1-2) Bodily movement without rotation is desirable in a study of this type because theoretically it distributes forces uniformly along the root surfaces, and the unknown force variables of tipping are eliminated. Coil springs (Unitek Pace Multicoil) of known force values were used in an effort to move the teeth with a somewhat uniform and controlled force. The springs were precalibrated on an Instron tensile testing instrument through a definite range of deflection. Force values ranged from 100 grams to 1,000 grams. The springs were then recalibrated after appliance removal to detect any degree of permanent deformation or set, which may have occurred during the experiment.

To provide reliable fixed radiologic landmarks for the measurement of tooth movement, three tantallium implants were placed in the maxilla and three in the mandible of each patient, one in each molar region, and one in the midline.[42]

The analysis of tooth movement was to be evaluated by a three-dimensional cephalometric technique.[43] However, mechanical failures with the x-ray machine half way through treatment made it impractical to employ this technique. As a back up technique, open mouth head films had been taken at the beginning and at the end of the study. For these the head-holder was rotated 25 degrees toward the film so that the posterior segment of each side of the arch was approximately parallel to the film.[10] Vertical .020" stainless steel tubes approximately 3 mm. long were soldered to the mesial of the cuspid and distal to the molar. These vertical tubes were used to hold .020" stainless steel posts when taking radiographs, so that tooth landmarks could be easily distinguished.

To measure the friction in the tooth moving appliance, an apparatus was constructed to duplicate the situation that existed in the mouth when the appliance was cemented and activated.[41] Force values employed consisted of the average of the two coil spring force values minus the effect of vibrating friction.

Prior to construction of the tooth movement appliance, the lower first molar and the second bicuspid on one side were tipped back for a period of approximately 4 weeks using standard orthodontic appliance and a lever arm activated by a oblique vertical (triangular) elastic from the maxillary arch. When this tip-back was achieved the tooth moving appliance was constructed and cemented to place.

One week following cementation of the appliance, the retraction springs were activated for a given force. At each one week interval appointment the springs were measured. If the length of the springs had decreased from the original or known force values (10% maximum) the springs were reactivated (elongated) to the original length.

To determine whether a tooth had moved by t ipping or bodily, the first and last head films were superimposed on the implants. Criteria for selection were:

a) the midline and the molar implants (right or left in compliance with the side) in each quadrant should superimpose within 0.2 mm.

b) the movement of the crown and apex on the same tooth (separately measured from one of the implants) should agree within 0.2 mm.

Impressions of the arch segments were taken at each of the appointments for later reference and evaluation. The final records were taken and the appliances were removed in 8-10 weeks.

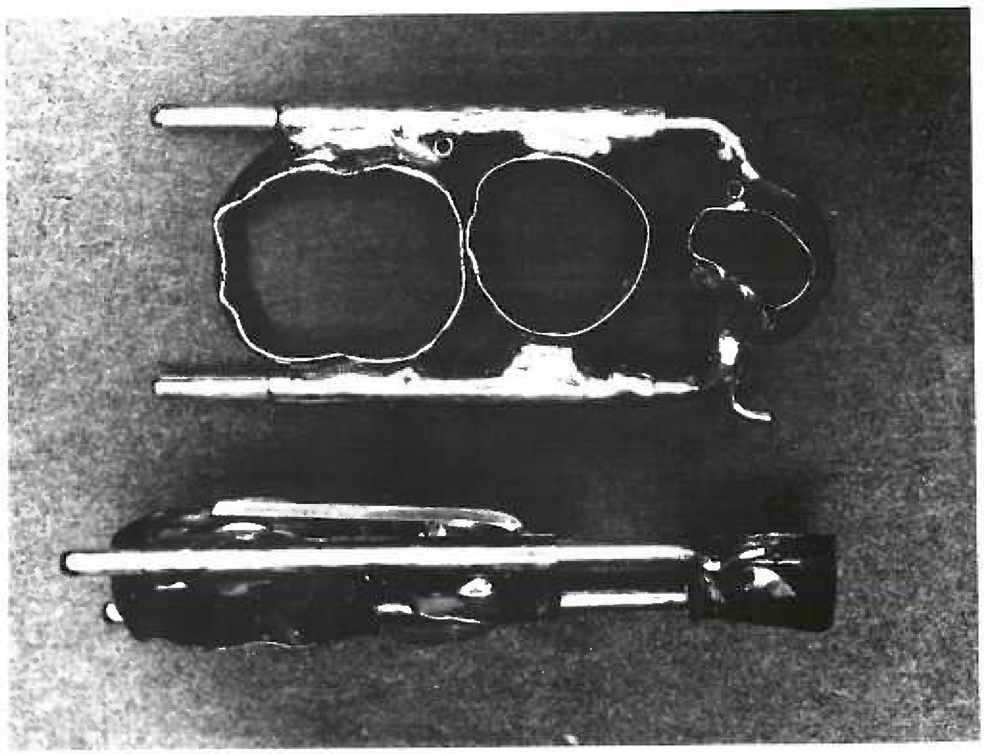
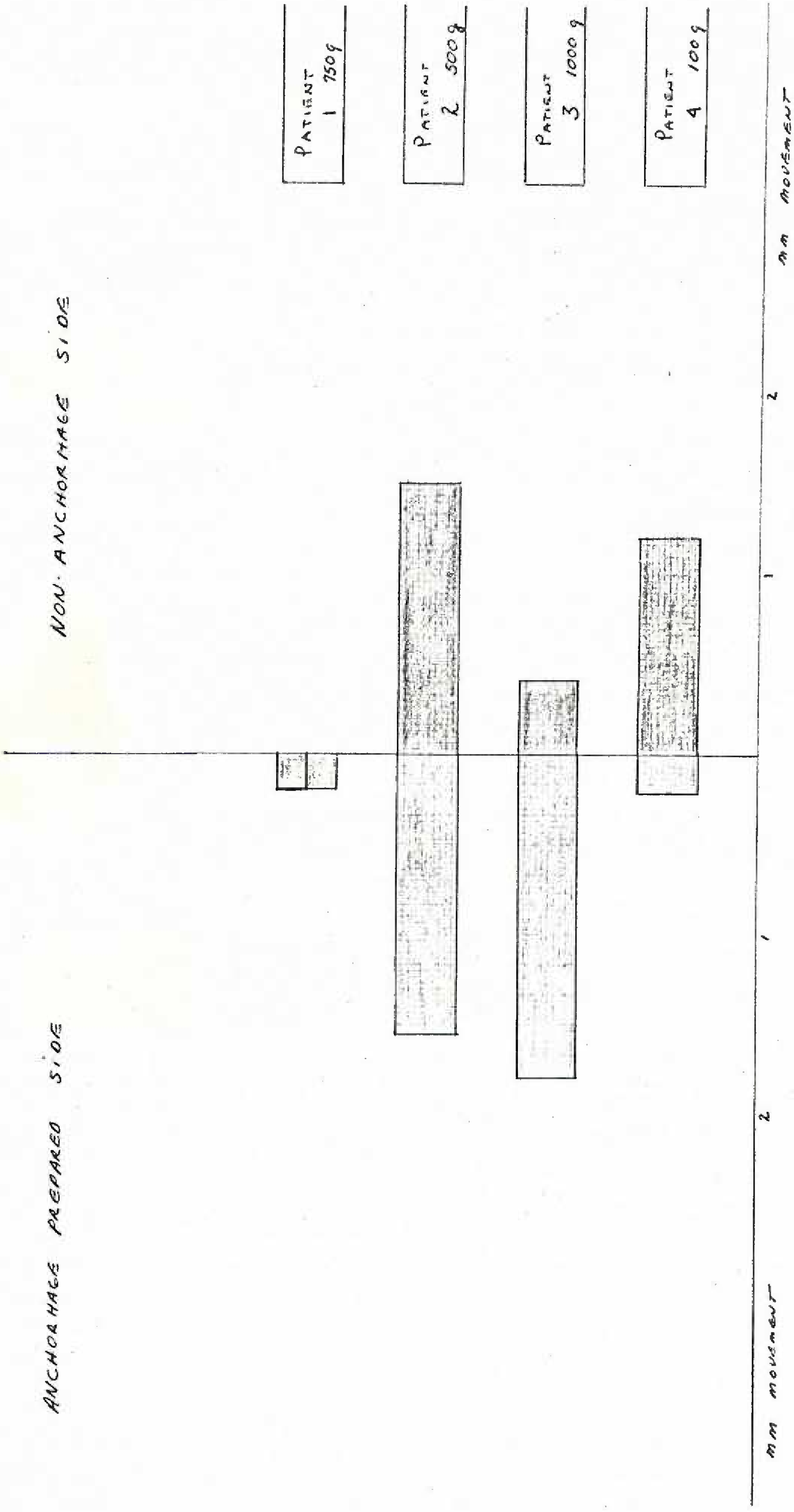


FIGURE I

FIGURE II


NON-ANCHORAGE SIDE
ANCHORAGE PREPARED SIDE
PATIENT 1 750g
PATIENT 2 500g
PATIENT 3 1000g
PATIENT 4 100g
mm MOVEMENT
2
1
1
2
mm MOVEMENT

FINDINGS

Only 8 of 18 quadrants met the standard set forth for bodily movement.

Patients #1 and #2 show no difference in molar bodily movement.

Patients #3 and #4 show difference greater than the error of the method but patient #3 demonstrated the greater movement on the anchorage prepared side, while the greater molar movement on patient #4 occurred on the non-tipped side. The paucity of usable data precludes generalization except to note the lack of supporting evidence for any current anchorage theories.

DISCUSSION

Even though the evidence we tried to collect has been meager, it indicates a lack of support for current anchorage concepts. The discussion, therefore, will be confined primarily to interpretation of the literature.

Reitan[32] did the only human study relating osteoid formation to reversed orthodontic tooth movement and states that osteoid retards the rate of osteoclastic bone resorption. This statement has been quoted as providing a biological basis for tip-back anchorage.[18] What has been overlooked is the fact that osteoid (if it existed at all) was said to be present for only 3 days.[32] The statement that osteoid is more resistant to osteoclastic resorption can be traced to Gottlieb[44] in 1922. No evidence exists to prove this point but it is widely accepted.[5,24,25,38,]

In 1957 Maximow and Bloom[45] stated that "an intermediate stage of uncalcified osseous tissue, or osteoid, is not a necessary step in the formation of bone, but there may be a lag in calcification, even under physiological conditions, owing to local failures in the supply or transport of bone mineral".

Brodie[13] states that the undisturbed tooth is the best source of anchorage. This could be assumed logical if tooth movement progresses as Reitan[33] proposes. An initial compression of periodontal ligament lasting 4-7 days, a hyalinization period lasting 4-60 days, followed by the so-called secondary period during which direct bone resorption occurs with continued tooth movement. The present study as well as others by Hixon et al[9,10] could not document this pattern of tooth movement. Following Reitan's concept would only provide 4-7 days of undisturbed tooth anchorage, hardly meaningful in clinical orthodontics.

Simple tipping movements are said to result in rapid and progressive bone changes from the alveolar crest toward the apex.[13] This bone change may be due to the piezoelectric effect produced when bone is subjected to stress. It is suggested that stress generated electrical phenomena are capable of directing the activity of bone cells.[28] In vitro studies showed that the electricity generated was roughly in direct proportion to the amount of bone deformation.[29, 30,] Any procedure which would prevent mesial tipping of the buccal segments could eliminate bone bending and its accompanying piezo-electric effects. If virtue exists in setting up tip-back anchorage, it is because it helps overcome mechanical weaknesses inherent in the appliance.[10, 41]

Reitan[32] states that teeth move faster through newly formed bone than through old lamellated bone. Kreitman's[31] findings tend to support this contention as he found that the maxillary molars on the tip-backed side moved further forward during cuspid retraction than did the control molars on the other side of the arch. In the lower arch Kreitman found that the lower tipped back molars ended up with the crowns further distally and the roots further mesially after cuspid retraction.

It has been occasionally observed clinically with head gear patients that it may take several months of 24 hours head gear wear to tip an upper molar back, but only about 2 weeks for the molar to relapse to its before treatment position.

These findings indicate that tooth stability may be influenced, not only by prior tooth movement, but also other factors such as supra-crestal gingival fibers. The supra-crestal fibers could account for the increased forward movement rate of the tipped back molars and no actual increase in total forward movement of the molars as noted by Rosehnal.[40]

SUMMARY

While this study was designed to test the concepts of preparing anchorage and then utilizing these dental units in cuspid retraction, little usable data was obtained.

Within their limited scope, individual variation was a consistant finding. It was impossible to find support for any current anchorage concept. On the basis of present evidence, the theory that tip-back anchorage works because of the presence of osteoid is not logical.

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