Bio-Progressive Therapy, Part 6: Forces Used in Bio-Progressive Therapy

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Physiology of Tooth Movement

The orthodontic movement of teeth occurs as a result of the biological response and the physiological reaction to the forces applied by our mechanical procedures. Therefore, when we design our various appliances, it is important to appreciate the forces they generate in a given treatment procedure and the physiological response to those forces. The physiological process of resorption by the osteoclastic cells is the basic activity that allows the bone to change and the tooth to move. Since these osteoclastic cells are carried by the blood to the site of their activity and resultant bone resorption, *the key factor in the efficient movement of teeth seems to be the blood supply that carries these cells and sustains their activity*. When a generous blood supply can be maintained by applying a light force, tooth movement is more efficient. When the blood supply is limited in an area, the osteoclastic activity of bone resorption is limited and the teeth do not move or they move more slowly. Heavy forces that squeeze out the blood cells can limit the physiologic response and markedly effect the rate of tooth movement.

Brian Lee, following the work of Storey and Smith, evaluated the optimum force during cuspid retraction. He measured the surface of the root being exposed to movement-- called the enface surface of the root. In his study he found 150-260 grams per cm2 of exposed root surface to be the range of variation during cuspid retraction. He, therefore, proposed 200 grams per cm2 of enface root surface exposed to movement as the optimum pressure to be applied in efficient tooth movement. Since force per unit area is defined as pressure, then the applied force would vary depending upon the size of the root surface involved and the direction of movement being planned (Fig. 1A, 1B, 1C).

Mesiodistal size of root surface is evaluated when a tooth is being moved antero-posteriorly in the buccal segments or laterally in the anterior area. The buccolingual size of the root surface is evaluated if the tooth is to be moved in the transverse direction. The cross section of the root surface is evaluated when intrusion or extrusion of the teeth is being planned.

Bioprogressive Therapy's evaluation of the applied forces suggests 100 gms per cm2 of enface or exposed root surface as optimum. This is one half the force suggested by Brian Lee and in some instances 10 times lighter than the forces conventionally used in many contemporary treatment situations.

Utility arch mechanics used in the intrusion of lower incisors have shown clinically that the four lower incisors can be intruded very efficiently with forces of 15 to 20 gms per lower incisor or 60 to 80 gms for all four lower incisor teeth (Fig. 2). This force relates consistently with 100 gms per cm2 when we consider the cross section graph for the lower incisor (Fig. 1C), which demonstrates only

.2cm2 of cross section root surface for each tooth. Thus .2cm2 X 100 gm/cm2=20 grams per lower incisor for intrusion. The upper incisors have a root surface cross section that is almost twice as large as the lower incisors and, therefore, the force required for their intrusion is twice as much as the lower arch, approximately 160 grams or 40 grams per each tooth. Analysis of the root surface charts help us to analyze the forces prescribed in different treatment situations. The buccolingual root surface analysis suggests that a force of 40 grams be applied when moving an upper lateral incisor labially into the arch, since its labial surface has .40 cm2 of enface root surface exposed to movement.

When traditional procedures used in edgewise mechanics are evaluated, such as round wires to align incisors or reverse curve of Spee to level (Fig. 3), we find that forces almost 10 times as high as those recommended are currently being used. A force of 400 grams is measured when a .014 round wire is ligated into the lateral incisor brackets. A force of 300 grams is measured at the lower incisor bracket when a "reverse-curved archwire" is tied in through the buccal occlusion to the

cuspids. A vertical open loop in .018 X .022 steel wire can produce 800-1000 grams of force in the retraction of upper or lower cuspids, where only 100-150 grams may be necessary. These heavier forces physically squeeze out the blood supply to the area and limit the biological response so necessary to the physiological alteration of the bone and the efficient movement of the teeth.

Control of Force

Thurow has shown that a force of 650 grams is produced in deflecting an .018 round chrome wire 3mm across a span of ½-inch (13mm) (Fig. 4). When a steel wire is used, the force is almost doubled to over 1000 grams. Thus, in clinical situations when we ligate arch wires across short spans very high forces can result; forces that are well above the optimum so necessary to allow the physiological response for efficient tooth movement.

In order to lessen the force being delivered to a single tooth or group of teeth the concept of a long lever arm is applied. By placing more wire between the teeth the applied force is lowered and the length of time of activation is increased. Thus, the concept of lighter continuous forces that support rather than limit the necessary physiology for efficient tooth movement is presented.

The elastic or proportional limit is the amount of force that can be applied to a given wire before it will take a permanent bend and not return to its original state. The elastic or proportional limit of .016 X .016 Elgiloy wire at a distance of 25mm is approximately 80 grams; the load of bending at 25mm is 25mm X 80 grams or 2000 gram millimeters of force. Shorter distances generate greater forces. When more wire is incorporated, the force is proportionately reduced (Fig. 5).

The utility arch uses a long lever or spanning arch principle to span from the molars to the incisors with distances from 20-40mm depending upon the length of the arch and the malocclusion. The span in the lower arch from the permanent 1st molar to the incisor is 25-30mm and produces the desired 80gms of force necessary to intrude the lower incisors in the leveling process. With the longer distance of 35-40mm in the upper arch, a larger wire (16X22) is necessary to produce the

required 160gms for the upper incisor intrusion.

In order to reduce the applied force to achieve the desired pressure of 100 gms per cm2, Bioprogressive mechanics incorporates more wire in its loop design, thus producing lighter forces that are more continuous in their action. Commonly used simple loops can be evaluated for the amount of wire they contain (Fig. 6).

Loop Design For Force Control

By combining a series of wire lengths and loop designs into compound loops the amount of wire can be greatly increased, thus further reducing the force and increasing the duration of activation. In addition, the compression of the wire during the activation of the loop further enhances its action and prolongs its effectiveness.

Some compound loops designed to compress the wire upon activation are (Fig. 7):

Vertical helical closing loop.Double vertical helical closing loop.Double delta closing loop.L-Loop crossed "T" closing loop.Double vertical helical extended crossed "T" closing loop.

Load deflection rates for each spring show the amount of force produced by each mm of activation (Fig. 8). With this information, the amount of activation needed to produce the proper force required to create a pressure of 100gm per cm2 of root surface involved in the specific clinical situation can be calculated and applied.

The mandibular cuspid retraction spring is a compound spring, a double vertical helical closing

loop. It contains 60mm of wire size 16X16 Blue Elgiloy and produces approximately 75gms of force per mm of activation. A range of variation exists due to loop size and character of the wire. Therefore, 2-3 mm of activation is required to produce the desired force. The cuspid enface distal surface is .75 to 1.0 cm2 requiring 100 to 150gms.

The maxillary cuspid retraction spring is a double vertical helical extended crossed T closing loop spring which contains 70mm of wire. It produces only 50gms per mm of activation because of the additional wire used in its design and all loops are being contracted during its activation. Two to three mm of activation are sufficient for upper cuspid retraction.

The lower contraction utility arch is a compound loop which possesses an L-Loop and expanded crossed T-loops and contains 40mm of wire in its design. It generates 80gms per mm of activation during lower incisor consolidation. Only 2mm of activation are required to produce the necessary force for the prescribed pressure for the four lower incisors.

The double delta retraction loop has 36-50mm of wire in its design and produces around 100gm per mm of activation during upper incisor retraction and arch consolidation. The force generated

here because of less wire is almost double that produced by the maxillary cuspid retraction spring. However, it is applied to the four maxillary incisors, which requires more force application than for the single cuspid.

Thus, each tooth for its efficient movement requires an optimum applied force in order to produce the desired pressure in the various directions of movement. Springs are designed using various compound loops with load deflection rates that can be applied to produce the needed force (Fig. 9). The horizontal T-loop containing 25mm of wire can be used to align, rotate, extrude or intrude, and gather the 5-6mm between teeth on a continuous archwire (Fig. 10).

The total movement of teeth cannot be simulated by metal teeth in a wax typodont. The root surface theory of tooth movement works well for the individual teeth, but when interarch mechanics and reciprocal factors are analyzed, it becomes apparent that other factors need to be considered in the total evaluation of teeth movement. One of the major factors is the character of the bone through which the teeth are being moved. Since the movement of teeth requires the cellular change of the supporting bone, the physical characteristics of the supporting bone must be appreciated and analyzed.

Concept of Cortical Bone Anchorage

While the character of bone at the cellular level is all the same, when we examine the gross physical structure we are dealing with two very different physical characteristics. On the one side is a very dense laminated avascular cortical bone which gives strength to the jaw structure and supports the teeth; while the opposite characteristics are to be found in loosely knit open spaces of the cancellous or trabecular bone (Fig. 11). These open spaces have less bone to be altered and are extremely vascular and therefore carry the necessary elements for bone change in open spaces that are even more susceptible to alteration. Since an adequate blood supply that produces the cellular change is vital to move a tooth, we should strive to maintain a generous blood supply and move teeth into the less dense, more vascular trabecular bone and avoid the denser, avascular cortical bone.

The concept of cortical bone anchorage implies that, to anchor a tooth, its roots are placed in proximity to the dense cortical bone under a heavy force that will further squeeze out the already limited blood supply and thus anchor the tooth by restricting the physiological activity in an area of dense laminated bone. Because of its density and limited blood supply, the cortical bone resists change and tooth movement is limited. On the other hand, when we desire to move a tooth, we should seek out that route through the less dense trabecular bone where under a light force a generous blood supply can be maintained that will produce the physiological osteoclastic reaction of bone resorption that is needed for the efficient movement of teeth. For efficient movement our mechanical procedures should steer the roots away from the denser cortical bone and through the less dense channels of the vascular trabecular bone.

Since each tooth is supported by cortical bone, an understanding of this bony structure and

support is necessary in order either to move the roots into the cortical bone to anchor them or to avoid the cortical bone, if possible, for their efficient movement. Each jaw and each tooth will be analyzed under different clinical needs in order to show the practical application of these factors to clinical treatment.

Lower Incisors-- Cuspids-- Bicuspids

Beginning in the lower arch, the lower incisors, cuspids, and 1st bicuspids are supported on the lingual by the cortical bone of the planum alveolar (Fig. 12) . Their various movements must respect this denser cortical bone. During lower incisor intrusion their roots need to avoid the lingual cortical bone and be moved buccally away from this denser heavier support. In order to avoid this lingual cortical bone support, the lower utility arch applies 15° to 20° of buccal root torque in its activation for intrusion of the lower incisors (Fig. 13). Round wire leveling on the other hand tends to tip the incisor roots into this cortical bone support, locking the roots tips and limiting their intrusive movement. A force comparison finds the utility arch with its long lever arm applies 80 grams, while the short span of round wire can guarantee 300 grams. By avoiding the cortical bone, we free their movement under a light continuous force, or we can anchor the roots into the cortical bone under a heavier force. During lower cuspid retraction the cuspid roots must avoid this denser cortical bone on the lingual and be moved around the corner in the initial stages of their retraction in order to stay in the trough of trabecular bone (Fig. 14). When cuspid roots contact this lingual cortical bone they strain the anchorage support and are more susceptible to tipping around this denser bony fulcrum, tipping wherein the crown is extended distally and the root tip comes forward often into or through the labial cortical bone.

In extraction treatment the cuspids are first retracted on sectional arches in order to keep the cuspid roots in the trough of trabecular bone and thus round the corner by avoiding the dense lingual alveolar or cortical bone. During the next step of lower incisor consolidation the incisor roots must now be moved through the supporting cortical bone and allow for its remodeling. In order to allow the physiology to remodel the denser cortical bone, even lighter more continuous forces need to be applied (Fig. 15). If heavier forces are applied to the incisor retraction, then the roots being adjacent to the cortical bone become anchored. This anchoring into the cortical bone will strain the molar anchorage as well as tip and extrude the incisors around the planum alveolar cortical bone fulcrum. This tipping and extrusion of the incisors creates the incisor overbite problems often associated with the extraction mechanics.

There are three main aspects of tooth movement and cortical bone support:

1. Avoid the cortical bone support where possible and direct the roots through the less dense more vascular trabecular bone. The forces here are kept light to encourage a good blood supply necessary for the physiological response and efficient tooth movement.
2. Anchor teeth by placing their roots adjacent to the denser cortical bone under a heavy force that will push out the blood supply and lessen the physiological response necessary to bone change and tooth movement. The concept of cortical bone

anchorage is to stabilize the roots into cortical bone.

3. When the treatment objectives require that we move teeth through the supporting cortical bone,

where the dense bone cannot be avoided but must be remodeled, the forces must be kept even lighter to respect the character of the bone and its limited blood supply and physiological response. A heavy force returns to our second response of anchorage and limited change. This aspect becomes critical in adult treatment where even the cribriform plate of the socket wall is more dense, like the cortical bone, and demands a lighter force initially to allow an adequate blood supply for tooth movement. Tooth movement in adult treatment will be slower in the initial stages because of the density of the bone. After the initial change and bone alteration, the movements are more similar to our younger patients' treatment progress.

Lower Bicuspids and Molars

The lower 2nd bicuspids and molars are supported from the buccal by the cortical bone which runs along their buccal surface into the external oblique ridge. To anchor the lower molars, the roots are expanded and torqued into this denser avascular cortical bone. As viewed in the skull material this bone is not bulky, but is more compact and dense in its structure over the buccal surface of the molar roots (Fig. 16). This density limits the blood supply and thus the movement by the limited change in the bone.

Clinical observations of lower molar anchorage have demonstrated that when the lingual cusps are kept down (roots expanded and torqued buccally) good molar anchorage is being maintained. When the molars become upright and extrude then their roots are moving away from the cortical bone support and their anchorage is lessened. Lower molars first become upright and then more forward in anchorage loss cases. In order to minimize the molar anchorage when we desire to bring the molars forward, the teeth need to be kept upright so that the roots can be moved lingually away from the denser cortical bone (Fig. 17). Expansion and buccal root torque is minimized in order to keep the molar upright and allow movement. Round wire in the molar tube and a continuous force will assist in its forward movement.

To distalize or upright tipped or impacted lower 2nd and 3rd molars requires treatment procedures that apply a light continuous force. Loop designs or springs that will remain attached to the molars are difficult to apply because of their remote location, but these teeth can be moved when a light force is continuous in its application. A longer time for this movement is required to allow alteration of the bone to occur. Bioprogressive Therapy states that any tooth can be moved in any direction with the proper application of pressure (force per unit area).

Teeth in Maxilla

The maxilla differs from the mandible in its supporting cortical bone structure. The mandible is similar to a long bone with the cortical bone support running the length of the U-shaped, curved lower jaw. The cortical bone structure forms around its tubular shape on into the alveolar, coronoid, and condylar processes. The maxilla by contrast is a laminated structure with cortical bone supporting four cavities: the nasal, orbital, oral, and sinus cavities (Fig. 18). These cavities are lined with cortical bone that give them support. This support as well as the cortical bone covering the body of the maxilla gives it its total support and influences the teeth in their movements. The roots

of the maxillary teeth being adjacent to these cavities are subject to the influence of the cortical bone that lines them. The teeth in the maxilla are supported within the alveolar process with cortical bone on the palatal or lingual surface and also along the buccal or labial surface. Movement of teeth within the maxilla requires that we consider where the roots are located in relationship to the cortical bone supporting the cavities as well as the alveolar process.

Maxillary Incisors

The maxillary incisors are best intruded along their long axis into the broadest area of the alveolar process. If the root tips are forward, as in a Class II division 2 malocclusion, the crowns must be advanced and the roots retracted before intrusion so that they can avoid the cortical bone around Pt A in the maxilla (Fig. 19). Intrusion must also respect the floor of the nasal cavity in those types with a low facial height. The initial moves in utility arch mechanics for intrusion of the upper incisors often must first advance the crowns in order to better locate the root tip away from the interference of the labial cortical bone.

Maxillary Cuspids

The cuspids on the corner are similar to the corner problem exhibited in the lower arch and treatment requires that the cuspids be brought around the corner in their retraction and alignment. The cuspid root tip is often precariously located between the constricting alveolar process on the buccal-lingual corner, the canine fossa, and the cortical bone lining the lateral corner of the nasal aperture (Fig. 20). If too much tipping is allowed the root tip can become exposed through the buccal cortical bone and then its uprighting and torquing alignment can be made extremely difficult. To keep the upper cuspids in the trough of trabecular bone the cortical bone on the lingual and labial plates of the alveolar process need to be respected and the roots guided around the corner in their retraction. Forces applied to the lingual of the cuspid crown in the initial retraction movements will often tip the roots buccally from the corner fulcrum of cortical bone. Lingual string should not be used in the initial stages (Fig. 21).

Maxillary Bicuspids and Molars

The bicuspids are supported in the alveolar process between the buccal and lingual cortical plates. The roots of 2nd bicuspids, along with roots of the molars, are often involved with the cortical bone lining the floor of the sinus. During intrusion of teeth in this area we must appreciate the sinus and its location in relation to the root tips. Intrusion forces must be kept light and continuous since they are being directed through cortical bone in the floor of the sinus.

The maxillary molars with their three roots extend into the cortical bone of the sinus floor and are located at the base of the key ridge to the zygomatic process (Fig. 22). They are anchored by being expanded and rotated into the buccal cortical bone. Headgear therapy that applies heavy forces, above 500gms, expands the molars into the cortical bone where they become "anchored". The molars thus anchored allow orthopedic alteration to occur wherein the whole maxilla is altered at the adjustment sites in the sutures. This was explained in the previous article on orthopedic

alteration.

When all of the maxillary teeth are banded and tied together along an arch, the heavy force from the headgear is being distributed through the roots of all the teeth and results in orthodontic tooth movement. When maxillary orthopedics is desired, only the molars or buccal occlusion should be involved in order to create the anchoring of the molar which then acts as a handle for orthopedic control of the maxilla and adjustment at the distant suture sites. When heavy lateral orthopedic forces are applied, the teeth in the maxillary buccal segments become anchored and much of the adjustment occurs in the midpalatal suture, as is the case of palatal separating appliances. The quad helix expansion appliance and expanded headgear encourages this same reaction when properly applied. This occurs when the incisors are not banded and the midpalatal suture is allowed to adjust to the applied orthopedic forces. When it is desirable to distalize only the upper molar and not orthopedically alter the jaw, then the molar should be kept narrower in the trabecular trough area and the forces lighter and more continuous for orthodontic movements. Under certain circumstances teeth in the maxilla must be moved through the dense cortical bone. The retraction and torquing of the incisors after they have been intruded is a movement that requires this remodeling of the palatal cortical bone. Arches with long arms extending from the stabilized molars allow us to apply forces that are light and continuous during these critical incisor retraction and torquing moves.

The movement of impacted cuspids into the arch, either through the buccal vestible or across the palatal vault, requires our respect for the cortical bone through which they must move (Fig. 23). This denser bone must be resorbed under a very light continuous force in order to encourage the osteoclastic action of the blood cells against the cortical bone. When a heavy force is applied, the cuspid may appear to be ankylosed and not move. Surgically channeling of this denser bone will facilitate their movement. However, care of the periodontal attachment must be taken during this type of surgical procedure.

Musculature Anchorage

The facial type described by the cephalometric morphology reflects the musculature which supports the occlusion. Where the musculature is strong as characterized by the deep bite, low mandibular plane, brachyfacial type, the teeth demonstrate a "natural anchorage". In the open bite vertical dolichofacial patterns, the musculature seems weaker and less able to overcome the molar-extruding and bite-opening effect of our treatment mechanics. Two cephalometric measurements that begin at Xi point in the center of the ramus of the mandible are specifically related with the structures involved and are proving to be excellent describers of the mandibular morphology and its musculature function (Fig. 24).

These measurements are directly related to the internal mandibular morphology and not to some distant cranial base landmarks. The lower face height angle is an angular reflection of the musculature function between the upper and lower jaws. While the mandibular arc angle describes the internal structure of the mandible and its function. The lower facial height angle averages 47° with a standard deviation of ±4°, while the mandibular arc angle is 27° ±4°. Variations outside of

one standard deviation represent cases that require our attention in planning anchorage and treatment mechanics, including headgear types and lower molar torque.

Summary

In considering the efficient movement of teeth Bioprogressive Therapy suggests we consider four areas:

1. Size of the Root Surface Involved

The enface surface of the root exposed to movement is the area to be considered in selecting the proper amount of force needed. The surface area will vary depending on the direction and the root surface involved. Intrusion movements need to evaluate the cross section area of the root. Buccolingual or mesiodistal surfaces are used in calculating the amount of force required for the anterior-posterior movements or the transverse movements of the individual teeth.

2. Amount of Applied Force

The amount of applied force depends upon the size of the root involved, when considering the optimum pressure of 100 grams per square centimeter of enface root surface; pressure being defined as force per unit area. Where the area is known, the application of the long lever arm and additional wire in the loop design can reduce the applied force, allowing it to be lighter and more continuous. This application of a lighter continuous force sustains the blood supply needed to support the physiological response .

3. Cortical Bone Support

Each tooth is supported by cortical bone which must be evaluated in the efficient movement of teeth. To move a tooth efficiently we avoid, whenever possible, the dense avascular cortical bone and move through the open spaces of the cancellous trabecular bone. When anchorage of a tooth or group of teeth is desired in reciprocal mechanics, the roots of the teeth are positioned against the denser cortical bone under a heavier force. This heavier force and avascular bone limits the blood supply which is necessary to change the bone and allow movement.

4. Muscular Support-- Reflected by the Facial Type

Strong muscles of mastication give additional anchorage to those teeth in the jaws of the brachyfacial type, while the vertical open bite patterns seem to demonstrate weaker muscles in the dolichofacial type. These facial types which show variations in muscular functions can be identified by variations recorded in their cephalometric morphology. Lower facial height angle and the mandibular arc angle are strong indicators of facial type and muscular function.

(TO BE CONTINUED IN NEXT ISSUE)

FIGURES

Fig. 1a

Fig. 1A The size of the enface root surface exposed to anterior-posterior movements (mesiodistal surface of buccal segments and labiolingual surface of anteriors) is measured in square centimeters. Each tooth can be evaluated as to

the necessary force, based on its root surface involved. These are shown for 200, 150, and 100 grams per cm2.

Bioprogressive Therapy recommends 100-150 grams per cm2 of enface root surface.

Fig. 1b

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Figures

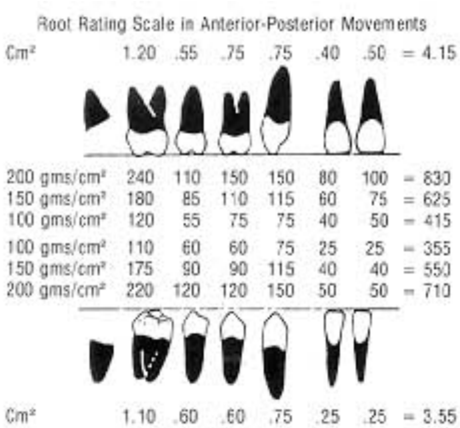

Fig. 1a The size of the enface root surface exposed to anterior-posterior movements (mesiodistal surface of buccal segments and labiolingual surface of anteriors) is measured in square centimeters. Each tooth can be evaluated as to the necessary force, based on its root surface involved. These are shown for 200, 150, and 100 grams per cm2. Bioprogressive Therapy recommends 100-150 grams per cm2 of enface root surface.

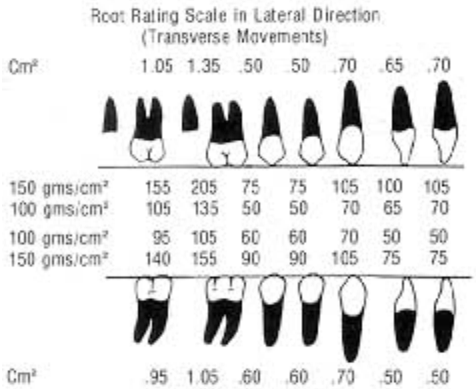

Fig. 1b Rating scale of root surface exposed to transverse movements of the teeth (buccolingual surfaces of the buccal segments and mesiodistal surfaces of the incisors) is shown expressed in cm2, with forces needed at 150 and 100 grams per cm2 of enface root surface.

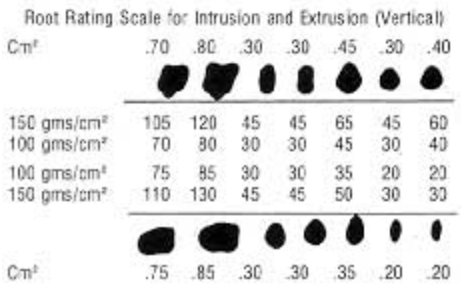

Fig. 1c Rating scale for the intrusion of teeth measures the greatest cross section of the tooth surface in cm2. Required forces are shown at 150 and 100 gms/ cm2 Lower incisors show .20cm2 of enface root surface, while upper incisors show .40cm2.

Fig. 2 Utility arch mechanics applies a light force of 60 to 80 grams to the four lower incisors. This force of 15-20 grams per tooth corresponds to 100 grams per cm2 of exposed cross section of root surface.

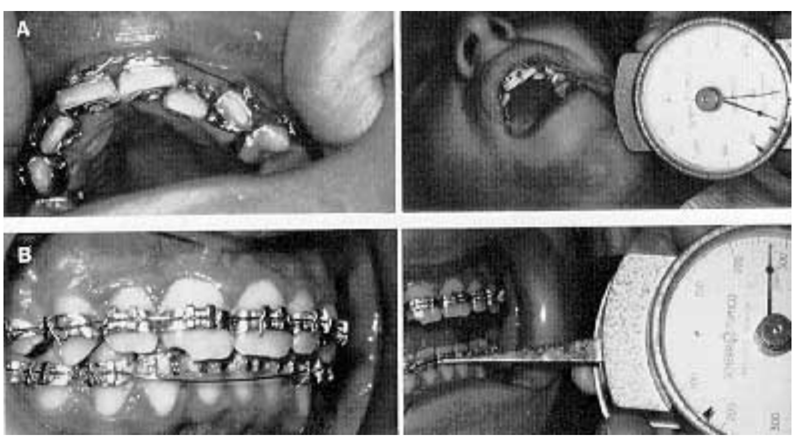

Fig. 3 Heavy forces, approaching ten times those suggested by Bioprogressive Therapy, can be applied even with an .014 round wire when the span of wire is short. A. 400 grams against an upper lateral incisor. B. 300 grams against a lower lateral incisor with a "reverse-curved arch".

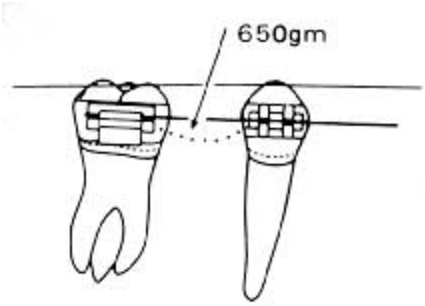

Fig. 4 A 3mm deflection in .018 wire can produce 650 grams of force.

Proportional Limit
.016 x .016 Elgiloy

LENGTH	FORCE OF BENDING
@ 30mm	+ 70 grams
@ 25mm	+ 80 grams
@ 20mm	+ 100 grams
@ 10mm	+ 200 grams
@ 5mm	+ 400 grams
@ 4mm	+ 500 grams
@ 3mm	+ 600 grams

Fig. 5 Greater length of wire reduces force. Values rounded off for clinical estimates.

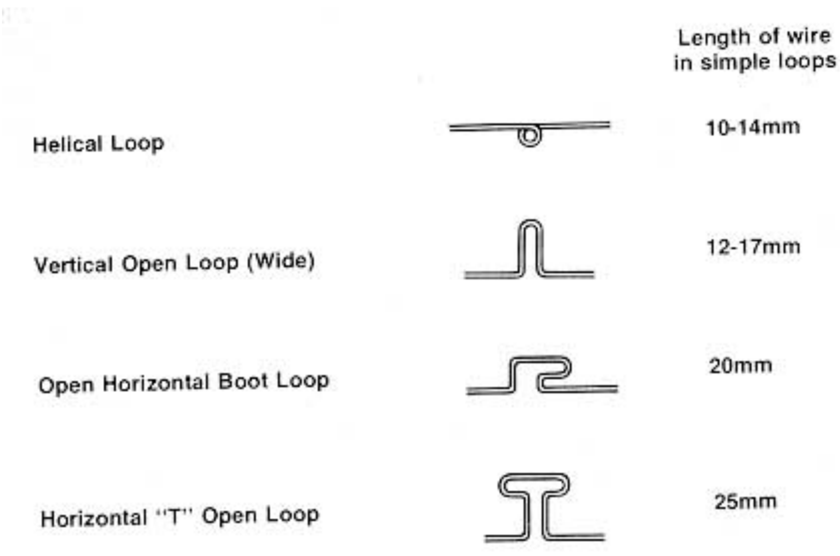

Fig. 6 Simple loop designs incorporate more wire between teeth and reduce the amount of force applied.

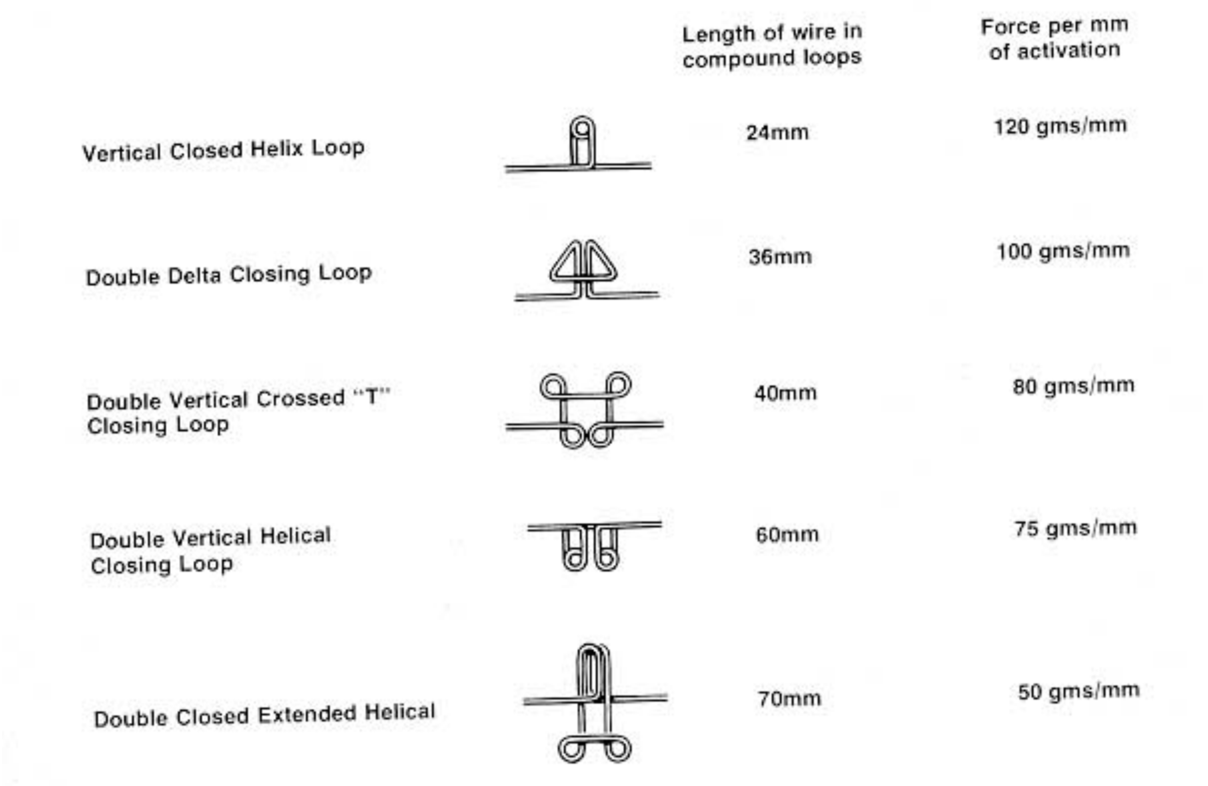

Fig. 7 Compound loop design uses combinations of simple loops and adds additional wire to further reduce the amount of force, while making it more continuous. An added value is to design loops that are compressed during activation.

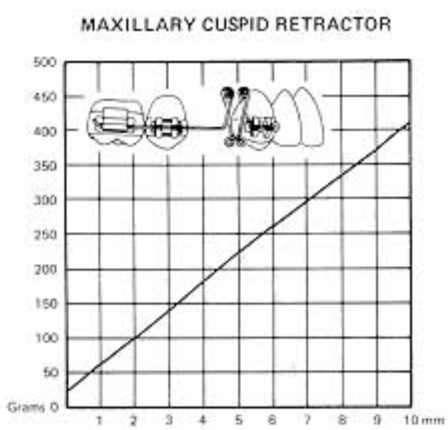

Fig. 8a Force/activation characteristics of looped wires (Load Deflection Rate): The maxillary cuspid retraction spring contains 70mm of wire in its design and produces approximately 50 grams per mm of activation. 3mm of activation is prescribed during maxillary cuspid retraction.

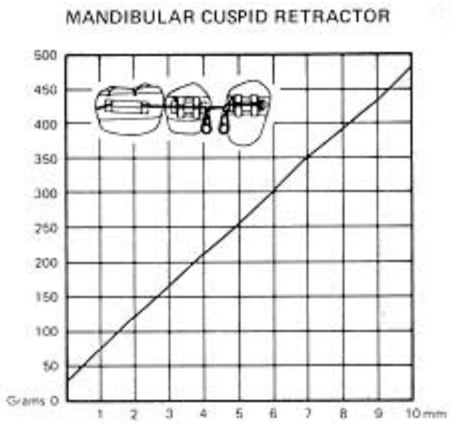

Fig. 8b Force/activation characteristics of looped wires (Load Deflection Rate): The mandibular cuspid retraction spring contains 60mm of wire in its design and produces approximately 75 grams per mm of activation. 2mm of activation is suggested during mandibular cuspid retraction.

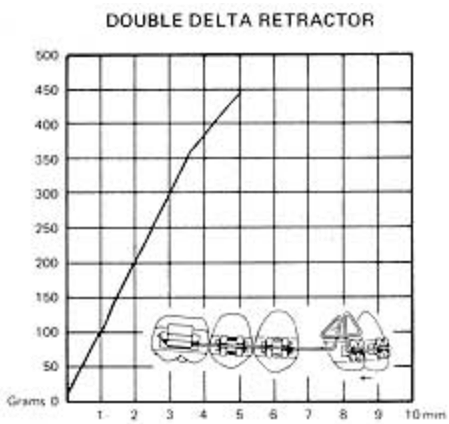

Fig. 8c Force/activation characteristics of looped wires (Load Deflection Rate): The double delta retraction spring used for incisor retraction and arch consolidation contains 36mm of wire and produces approximately 100 grams per mm of activation. This spring design contains only one half the length of wire as the maxillary cuspid retractor and as a result generates twice the amount of force in its activation. 2mm of activation is prescribed during maxillary incisor retraction.

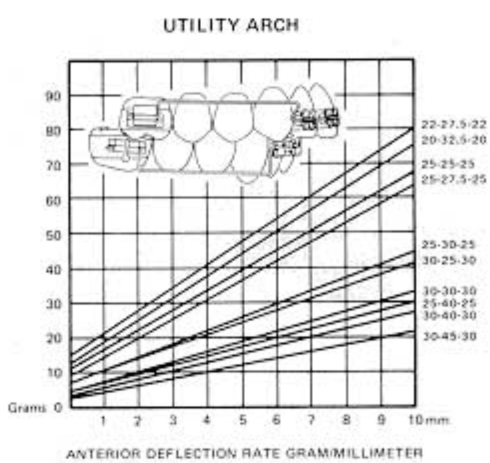

Fig. 8d Force/activation characteristics of looped wires (Load Deflection Rate): Force distribution to the incisors by the utility arch is dependent upon the length of the span from the molars. A measurement of a 10mm deflection of the 20mm span produces 80 grams of force, while the same deflection on a 30mm span produces only 20 grams in the .016x.016 blue elgiloy wire.

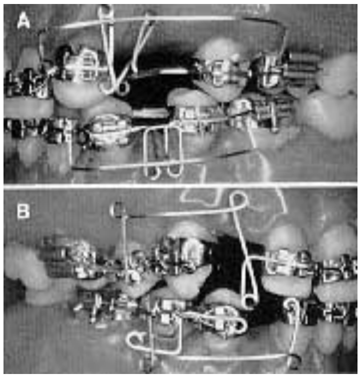

Fig. 9 Combinations of arches and compound loop designs can be structured to reinforce anchorage needs and at the same time take advantage of the basic beginning mechanical moves such as incisor intrusion and cuspid retraction (A). Multiaction mechanics can facilitate efficiency in lower incisor consolidation or upper incisor torquing needs (B).

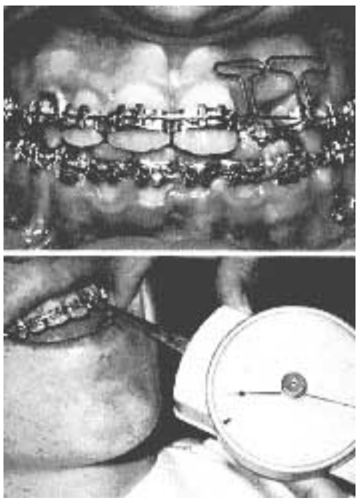

Fig. 10 Horizontal T-loops on each side of a tooth can place 50mm of wire in the arch, which greatly reduces the force and increases its continuous action. 75 grams of force is applied as against 400 grams from a continuous arch.

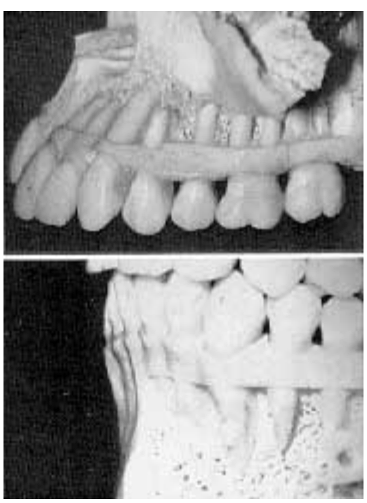

Fig. 11 The physical structure of bone includes dense, avascular, laminated cortical bone and loose, vascular, cancellous trabecular bone.

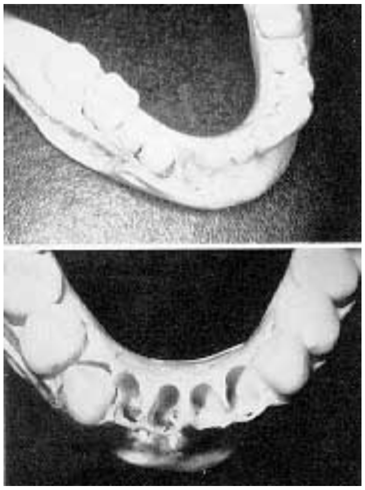

Fig. 12 The lower incisors, cuspids, and first bicuspids are supported on the lingual by cortical bone of the planum alveolar. For efficient incisor intrusion or cuspid retraction, treatment mechanics must respect this denser supporting bone.

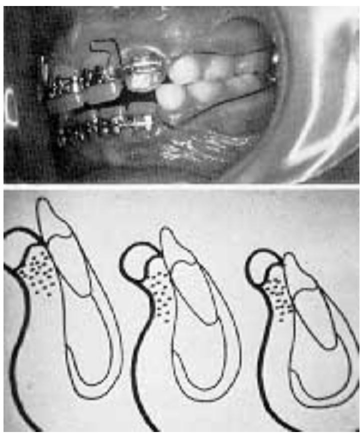

Fig. 13 The utility arch is designed to avoid cortical bone on the lingual surface of the lower incisor roots during their intrusion by placing 15°-20° buccal root torque.

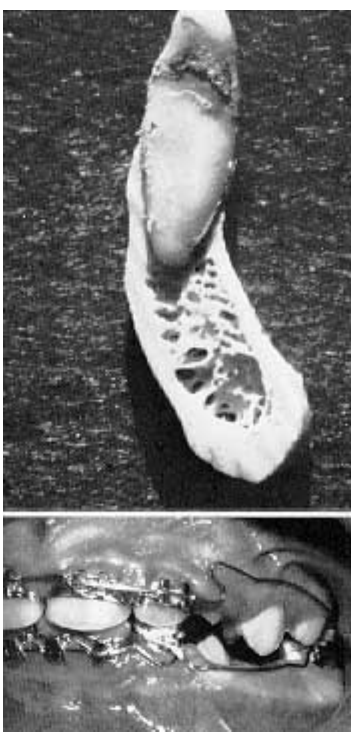

Fig. 14 Lower cuspid intrusion also must avoid the cortical bone for efficiency in movement. Elastic ties to the utility arch allow

it freedom of movement during intrusion.

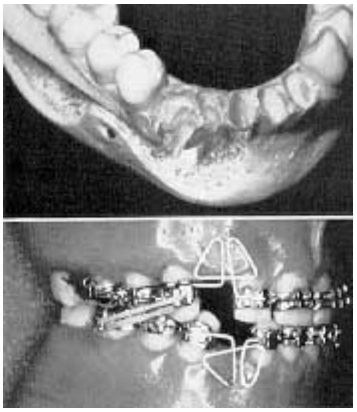

Fig. 15 Lower incisor retraction and consolidation requires remodeling and alteration of the dense cortical bone. Very light forces are necessary to maintain a good blood supply which facilitates the physiological osteoclastic response. Too heavy a force will limit movement.

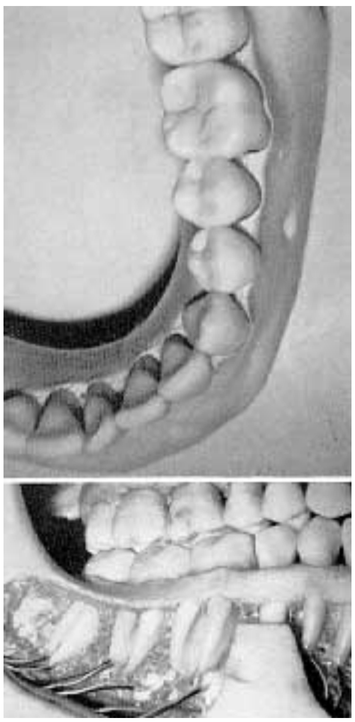

Fig. 16 The lower second bicuspids and molars are supported on the buccal by the less vascular cortical bone. To anchor these teeth, they must be torqued and expanded into this denser bone where, under a heavier force, their movement is more limited.

Fig. 17 To move a molar forward, the tooth must be kept upright, under light continuous force, avoiding the cortical bone support.

Fig. 18 The maxilla supports four cavities? the orbital, nasal, oral, and sinus cavities. The cortical bone support in the maxilla surrounds these cavities as well as the alveolar process containing the teeth.

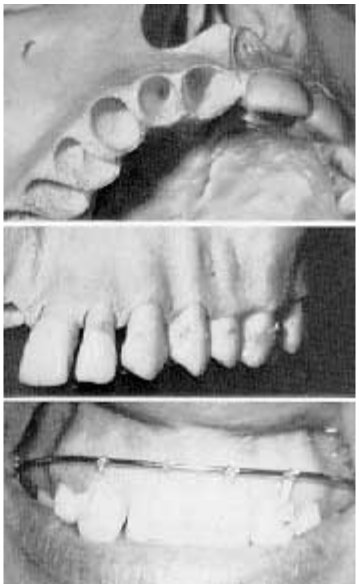

Fig. 19 Upper incisor intrusion should avoid the cortical bone and move into the broadest area of the alveolar process. When the root tip is forward, as in many Class II division 2 malocclusions, the incisor crowns must be tipped forward (root tipped back) before intrusion. A force of approximately 40 grams to each tooth is necessary for their efficient intrusion. Elastic ties to a labial bar can tip the crown and apply a light force.

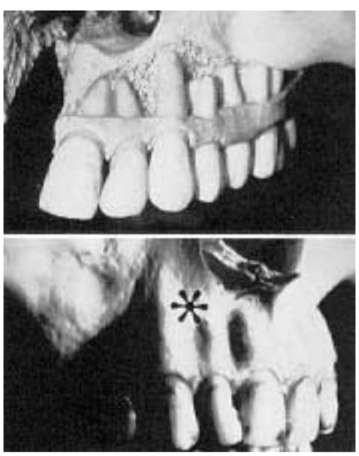

Fig. 20 During maxillary cuspid retraction "around the corner", the treatment must respect the constricted "corrugated" cortical bone on the labial side and the lingual cortical bone at the corner of the nasal aperture.

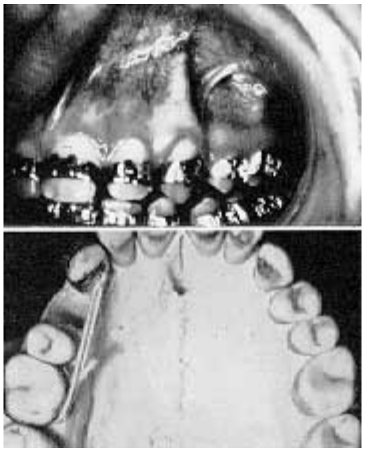

Fig. 21 During the early stages of maxillary cuspid retraction, lingual string should be avoided, because it will cause tipping around the lingual cortical bone of the alveolar process.

Fig. 22 The upper molars are supported at the base of the key ridge of the zygomatic process. Anchorage of the maxillary molars is assisted by expansion into this denser area of support. During maxillary orthopedic treatment, the adjustment occurs at the suture site. A Nance appliance, lingual quad helix, palatal jack screw, or headgear can expand the molars.

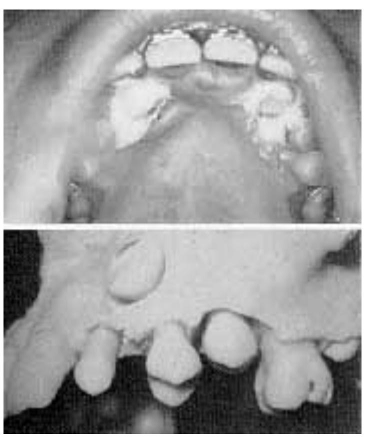

Fig. 23 Cuspids in the buccal vestibule or across the palatal vault must resorb cortical bone in their alignment. Too heavy a force will anchor these teeth and they may seem to be ankylosed.

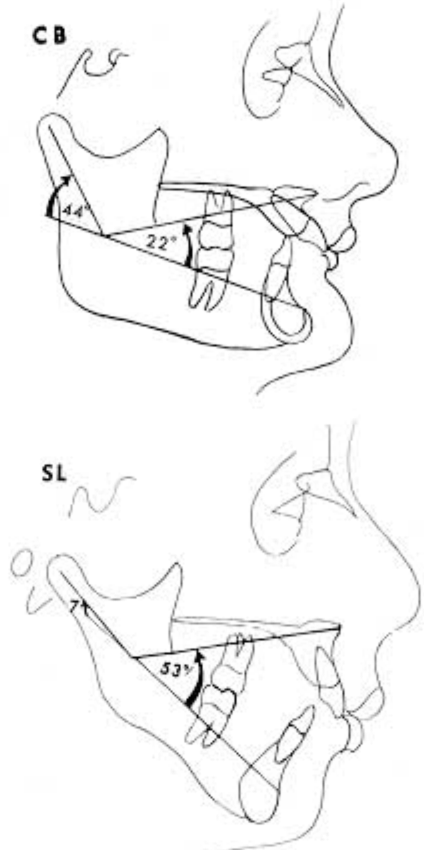

Fig. 24 Cephalometric morphology reflects the musculature that supports the occlusion. The lower facial height angle (norm 47° ± 4°) and the mandibular arc angle (norm 27° ± 4°) are excellent indicators of facial type and muscular anchorage. CB is an extreme deep bite brachyfacial type, while SL is an extreme vertical open bite dolichofacial type. Treatment design, including anchorage planning, must respect the facial type and its muscular anchorage.