Current Concepts of Anchorage Management

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Anchorage is defined by Webster as "a secure hold sufficient to resist a heavy pull." This is a purely mechanical definition, one which does not consider the biological aspects which apply when discussing the concept of anchorage in orthodontics. The consideration of anchorage in orthodontics is intimately involved with the biological response of bone, periodontal membrane and cementum as they react to external mechanical forces applied by the orthodontic appliance. The ability to selectively designate dental units as anchorage units or as being moving units is directly related to the orthodontist's ability to control the biological responses of these tissues to the mechanical forces which are applied to them.

Successful anchorage management, held by many to be the key to successful orthodontic treatment, is the result of an understanding and a successful practical application of sound biomechanical principles. Angle stated the problem this way, "According to the well-known laws of physics, action and reaction are equal and opposite, hence it must follow that the resistance of the anchorage must be *greater* than that offered by the teeth to be moved, otherwise there will be a displacement of the anchorage and failure in the movement of the teeth in the desired direction."

There appear to be two distinct approaches to the management of anchorage in orthodontic treatment. The classical concept of anchorage management relies upon the utilization of auxiliary holding-appliances of one kind or another, or anchorage preparation to provide the means of stability against the force applied to those dental units which are to be moved. Anchorage preparation is the active placement of future anchorage units in the configuration most advantageous for them to be able to resist the anticipated forces to displace them when they are to be utilized as anchorage units. The holding-appliances utilized may offer active posterior traction on the anchorage units to counteract the tendency of these teeth to move as a reaction equal and opposite to the force applied to retract cuspids and/or anterior teeth as, for example, the headgear does, or they may offer rigid passive resistance to the same tendency of the anchorage units to drift anteriorly as, for example, the lingual arch does.

A new concept of anchorage management has been proposed which utilizes no supporting appliances or anchorage preparation but which profits by a careful application of forces by the active treatment appliance to effect a controlled selective anchorage through the employment of differential forces. Under this philosophy a quantitative applied force differential will cause teeth to act either as anchor units or to be moved, depending upon the amount of force applied.

The relative effectiveness of each of these approaches to anchorage management has not been objectively evaluated. It is felt that such information would be useful. To this end the following investigation was undertaken.

Review of the Literature

The importance of anchorage management to the successful accomplishment of orthodontic treatment is attested to by the multiplicity of writings on the subject. A complete review of the literature is impractical to give, so a condensation of the main concepts proposed by the two above-mentioned schools of thought concerning anchorage management will be presented.

The search for successful anchorage management techniques started at the beginning of orthodontic therapy. Discovery and utilization of efficient anchorage units was a primary goal of most of the early pioneers in this specialty. Angle, Case, Strang, Salzmann, Oliver, Renfroe and others referred to anchorage as being comprised of units or components of resistance. They may be a single tooth, a group of teeth, or any available anatomic area which, by the use of an appliance, can be made to offer resistance to movement.

Intraoral sources of anchorage are described as: a) alveolar bone, which resists tooth movement by the arrangement of the alveolar trabeculae; b) the teeth, which oppose movement due to variation in form, size, number, inclination and position of the roots in relation to the direction of movement and position in the bony arch; c) the dental arches, which offer resistance to movement as a unit when teeth are joined together by an appliance and are stabilized to resist movement against the opposing arch; d) palatal and mandibular basal bone, which repel movement when forces are applied against them and e) lip musculature, which can be harnessed to exert an active force to resist movement. Extraoral sources of anchorage are limited to the calvarium and the cervical spine areas. These structures, by offering static opposition to movement to a headgear or cervical strap, provide a means of exerting an active counterforce on the anchorage units against the tendency of these units to be displaced.

Anchorage to be stable must be overwhelmingly more resistant than the teeth being moved. To achieve this stability the following points must be considered: 1) The reactive forces should be distributed over a number of units to reduce their effect on any one unit to a minimum; 2) As many teeth as are available as anchorage units, including the second molars when possible, should be utilized; 3) Adjustments should be incorporated in the appliance to offset the tipping and rotating tendencies of teeth when they are used as units of resistance; 4) Holding arches should be used when adequate stability cannot be obtained with the treatment appliance; 5) Intraoral anchorage can be supplemented with extraoral when holding arches are not used.

One of the basic principles upon which Tweed based his treatment philosophy is that the establishment and maintenance of a stable anchorage is a fundamental factor in successful orthodontic treatment and should be the initial concern of the orthodontist. He originated the "toe-hold" concept of anchorage preparation. In this idea Tweed "re-oriented every tooth in the anchorage section of the denture to an axial position wherein it was best able to mechanically resist the force that would eventually be used in producing the tooth movements required in treatment." This concept departed somewhat from prior biological thinking which stated that an undisturbed tooth would offer a greater resistance value than one which had been disturbed. Clinically, this type of anchorage preparation apparently places the tooth in the best configuration for the greatest mechanical advantage to rebuff a displacement force. With the recognition of the need for distal movement of posterior teeth in some cases, rather than solely the static maintenance of their positions, the use of extraoral anchorage was advocated to a great degree. Presently, extraoral anchorage is being used both as an anchorage mechanism and to accomplish active tooth movement.

The Bull anchorage philosophy maintained that an undisturbed tooth offered the best source of anchorage. The Northwest technique advocates constructing a maxillary holding-appliance to retain stability of the maxillary posterior segments while headgear is often utilized for anchorage support in the mandibular arch.

Many of today's practicing orthodontists do not adhere to the teaching of any one technique concerning anchorage management, but prefer to apply a variation of anchorage mechanisms dictated by the needs of the individual case.

This brief review of the *classical* ideas in anchorage management has attempted to show a few of the anchorage mechanisms that are available and are advocated by different authors. The variations of application and utilization of these mechanisms are many. They all have in common, however, either the use of an auxiliary appliance to support the anchorage units in conjunction with the active treatment appliance, or the preparation of the dental arches to allow them to efficiently resist forces placed upon the anchorage units by the active treatment appliance.

More recently a philosophy of anchorage management has evolved which does not use auxiliary supporting appliances or the preparation of the arches as anchorage units, but utilizes a concurrent application of differential forces by the treatment appliance to effect anchorage management. When considering the behavior of bone to mechanical stress it has been demonstrated by Smith and Storey, Sandstedt, and Schwartz that the changes in the shape and architecture of the involved bone depend upon, among other things, the intensity and duration of the applied stress. The magnitude of mechanical force exerted upon the tissues surrounding the tooth as a result of orthodontic treatment has been a major consideration. Any force exerted in a horizontal direction on the crown of a tooth is transmitted via the periodontal membrane fibers as pressure to the bone in the path of movement and as tension in the wake of the movement. This results in the resorption of bone in the pressure area and, providing that the forces are within the limits of tolerance of the supporting tissue, deposition of bone in the tension area. Oppenheim observed that with heavy forces destruction of bone also occurred in the tension area of the teeth being moved due to extensive rupture of blood vessels. This indicated that there is a limit to the degree of stress which the periodontal membrane and bone can support without destructive resorption. Thus it seems apparent that it is imperative to define the limits of stress tolerance of the tissues in quantitative terms and proceed with mechanotherapy design accordingly.

In general, little attention has been paid to the quantitative determination of what force has been applied by the treatment appliance to move teeth. It was the suggestion of an optimal force for tooth movement that lead Storey and Smith to their study in which they attempted to re-examine Schwartz' idea of optimal force and to quantitate it. They found, in agreement with Schwartz, that there was an optimum range of force for tooth movement. They felt that 150-200 grams should be used to produce a maximum rate of cuspid retraction without disturbing the molar anchor units. By increasing the force above this range, the rate of cuspid movement decreased and finally approached zero. Simultaneously, with an increased force, appreciable movement of the anchor units seems to occur.

Storey and Smith found that a light applied force of 200 grams moved only the cuspid, leaving the posterior teeth stable; an applied force of 500 grams moved only the molar-premolar segments, leaving the cuspid stable, and an applied force of 350 grams simultaneously moved both cuspid and molar segments. They noted that during cuspid retraction the surrounding tissues withstood forces of approximately 150 grams before cuspid movement occurred. A similar behavior was seen in the posterior units where the tissues withstood forces of approximately 300 grams before molar movement occurred. This was the first practical demonstration of the concept of selective application of differential forces to effect a reciprocal anchorage mechanism in treatment. When forces in excess of the optimum range as given to us by Storey and Smith, and Reitan are applied, movement of the tooth practically ceases until undermining resorption takes place in the pressure area permitting movement to take place, while resorption of bone occurs in the tension area at the alveolar crest.

The selectivity of anchorage units through differential force application is apparently a function of root surface-area and bone contact-area. The greater these areas of a tooth or group of teeth, the greater the force required to initiate tooth movement. This relationship of root surface and bone contact-areas to the force required for this initiation of tooth movement enables the selection of teeth as either anchorage (stable) units or moving units. This ability to set up differential forces in a reciprocal manner obviates any need for anchorage preparation or auxiliary support.

Methods and Materials

This investigation was based upon measurements taken from the cephalometric roentgenograms of one hundred patients who had completed orthodontic treatment which required the removal of at least four permanent teeth (usually first premolars). No notation of age, sex, age at initiation of treatment, length of time of treatment or type of malocclusion was made. These patients were divided into two groups: *Group A,* fifty cases selected from the files of the Department of Orthodontics, Eastman Dental Center and from private offices, treated with the edgewise philosophy utilizing auxiliary holding appliances in both arches for anchorage management. *Group B,* fifty cases treated under the Begg philosophy of treatment with no holding appliance in either arch but employing the differential force concept of anchorage management. All of these cases were obtained from records of individuals practicing Begg treatment exclusively.

Lateral head roentgenograms were taken in the accepted manner prior to the initiation of orthodontic treatment and immediately following the completion of orthodontic treatment. They were traced in the accepted manner using established landmarks. Two separate tracings were made for the maxilla and the mandible, both in the preoperative and postoperative films.

Several series of linear and angular measurements were made from these separate tracings. On one of the maxillary tracings the palatal plane was constructed (ANS-PNS) and lines perpendicular to it were drawn to intersect:

(a) the most anterior point on the mesial outline of the first permanent molar crown; the intersection of this line and the palatal plane was designated point Mu.

(b) the middle of the incisal edge of the left central incisor; the intersection of the line and palatal plane was designated point Iu.

(c) through ANS; this point was designated the reference point Ru.

All linear measurements were taken from this tracing (Fig. 1).

On the other maxillary tracing the palatal plane was constructed as above and:

(a) the central axis of the left central incisor was extended to intersect the palatal plane; the anteroinferior angle thus formed was designated angle Iu.

(b) a line was constructed by joining the most anterior point on the mesial of the crown and the most anterior point on the mesial of the mesiobuccal root of the first permanent molar; this line was extended to intersect with the palatal plane; a perpendicular line was constructed at this point of intersection; the angle formed by this perpendicular construction and the mesial line was designated angle Mu.

All angular observations were taken from this tracing as indicated in Figure 2.

On one of the mandibular tracings the mandibular plane was constructed (Go-Gn) and lines perpendicular to it were drawn to intersect:

(a) the most anterior point on the mesial outline of the crown of the first permanent molar; the intersection of this line with the mandibular plane was designated point ML.

(b) the midpoint of the incisal edge of the lower left central incisor; the intersection of this line with the mandibular plane was designated point IL.

(c) the most posterior point on the mandibular symphyseal outline; the intersection of this line with the mandibular plane was designated the reference point RL.

All linear observations were taken from this tracing as indicated in Figure 1.

On the other mandibular tracing the

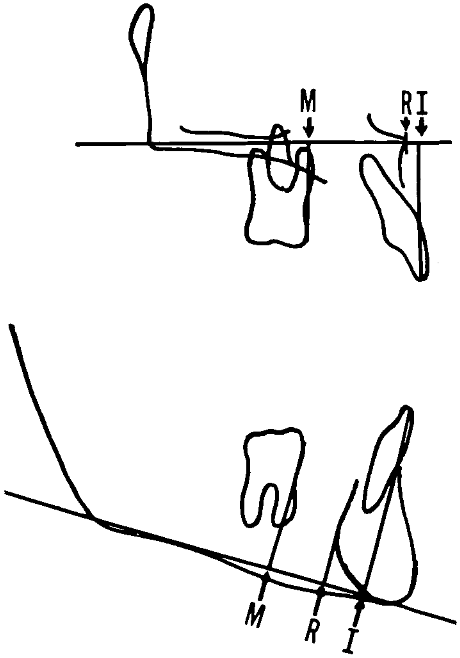

Fig. 1

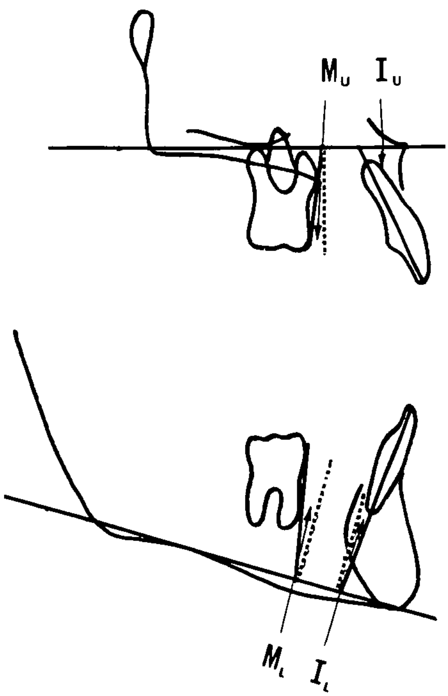

Fig. 2

TABLE I. SUMMARY OF COMPARISONS FOR THE ENTIRE DATA SET

PARAMETER		GROUP	N	MEAN	STD. DEV.	95% CI	86% CI	.05 SIG
MOLAR MOVEMENT (M-R) - (M'-R')	MAXILLA	A	50	1.51 mm	2.59 mm	0.73	0.55	YES
		B	50	2.70 mm	2.16 mm	0.61	0.46	
	MANDIBLE	A	50	1.83 mm	1.79 mm	0.51	0.38	YES
		B	50	3.40 mm	1.96 mm	0.56	0.42	
MOLAR ANGULATION ∠M - ∠M'	MAXILLA	A	46	3.32°	6.06°	1.79	1.34	YES
		B	50	0.09°	6.16°	1.74	1.31	
	MANDIBLE	A	47	-2.83°	7.96°	2.32	1.74	NO
		B	50	0.13°	6.98°	1.98	1.48	
INCISOR MOVEMENT (I-R) - (I'-R')	MAXILLA	A	48	4.52 mm	2.89 mm	0.84	0.63	YES
		B	49	7.12 mm	4.03 mm	1.15	0.86	
	MANDIBLE	A	48	1.83 mm	2.57 mm	0.74	0.56	NO
		B	49	1.64 mm	2.75 mm	0.79	0.59	
INCISOR ANGULATION ∠I - ∠I'	MAXILLA	A	48	-8.71°	8.13°	2.35	1.76	NO
		B	50	-12.10°	10.28°	2.91	2.18	
	MANDIBLE	A	48	-1.74°	7.80°	2.25	1.69	NO
		B	50	-0.81°	8.10°	2.29	1.72	

mandibular plane was drawn as above and:

(a) the central axis of the left central incisor was extended to intersect the mandibular plane. A line perpendicular to the mandibular plane was drawn at this intersection and the angle created called angle IL.

(b) a line connecting the most anterior point of the crown and the most anterior point of the mesial root of the first permanent molar was constructed and extended to intersect the mandibular plane. A line perpendicular to the mandibular plane at this intersection and the angle made with the molar line was designated angle ML.

The success of anchorage management was primarily evaluated by comparing the anteroposterior position of the first permanent molars projected upon the reference plane (point M) and related to the registration point (point R) before and after treatment. The distance the incisors were retracted during treatment was recorded by observation of their position projected upon the reference plane (point I) and related to the registration point (point R) before and after treatment. The nature of any observed molar and/or incisor movement during treatment was evaluated by comparing the axial inclination of these teeth related to the reference plane before and after treatment (Table I). Correlations were investigated between anchorage loss (anterior molar movement) and change in molar inclination, anchorage loss and any change in incisor inclination, and anchorage loss and incisor retraction. These correlations were made for each arch individually (Table II).

Results

Stability of Molar Position

Comparison of molar positions, be-

TABLE II. CORRELATION OF PARAMETERS

	COMPARISON		CORREL. COEFF.	t-VALUE	SIG.
GROUP A	MAXILLARY MOLAR MOVEMENT vs	CHANGE OF MOLAR ANGULATION	.17	1.148	NO
		INCISOR RETRACTION	.03	.188	NO
		CHANGE OF INCISOR ANGULATION	.03	.167	NO
	MANDIBULAR MOLAR MOVEMENT vs	CHANGE OF MOLAR ANGULATION	.24	1.505	NO
		INCISOR RETRACTION	-.30	-2.080	YES
		CHANGE OF INCISOR ANGULATION	.25	1.689	NO
GROUP B	MAXILLARY MOLAR MOVEMENT vs	CHANGE OF MOLAR ANGULATION	.06	.394	NO
		INCISOR RETRACTION	-.28	-1.928	NO
		CHANGE OF INCISOR ANGULATION	-.08	-0.535	NO
	MANDIBULAR MOLAR MOVEMENT vs	CHANGE OF MOLAR ANGULATION	.17	1.098	NO
		INCISOR RETRACTION	-.41	-2.915	YES
		CHANGE OF INCISOR ANGULATION	.18	1.226	NO

fore and after treatment, revealed significantly different amounts of movement of the molars during treatment between the two groups studied. In the maxilla, the mean anterior molar movement was found to be approximately twice as great in the Begg group as in the edgewise, 2.70 mm to 1.51 mm. The same was found for the mandibular comparison, the Begg patients experienced approximately twice as much anterior molar movement as the edgewise, 3.40 mm to 1.83 mm (Fig. 3).

Axial Inclination of Molars

Comparison of axial inclination of molars before and after treatment showed a significant difference between the two samples in the type of movement experienced by the molars as they moved anteriorly. In the maxilla the edgewise group showed a mean mesial tipping of the crown in relation to their roots of 3.32 degrees, while the Begg group showed a similar mesial tipping of 0.09 degrees (bodily movement, for all practical purposes). In the man-

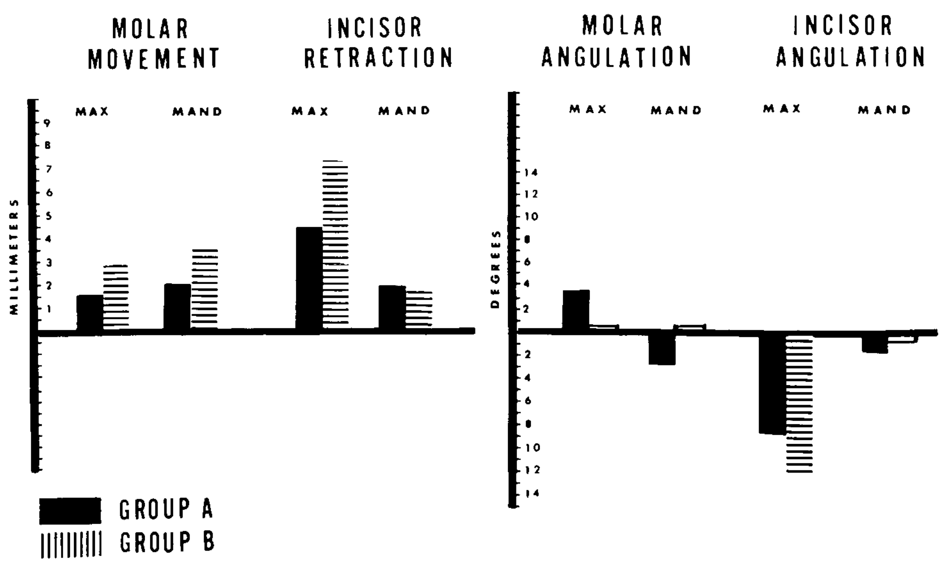

Fig. 3

dible the differences seen were not significant (although fairly close), with a tendency toward distal tipping of the crowns of the molars in relation to the roots of 2.83 degrees in edgewise cases and a 0.13 degree anterior tipping of the crowns in the Begg patients.

Retraction Distance of Incisors

Incisal retraction comparisons showed a significant difference between the two groups in the maxilla. The mean retraction distance was one and one-half times greater with Begg treatment, 7.12 mm, than that in the edgewise group, 4.52 mm. In the mandible the experience was about the same in both groups, 1.83 mm in the edgewise group and 1.64 mm in the Begg.

Axial Inclination of Incisors

A comparison of the axial inclinations of incisors before and after treatment revealed no significant difference in the changes observed between the two samples studied. In the maxilla the differences were fairly close to being significant, however. In both groups the mean change in axial inclination showed a distal tipping of the crowns with a greater tendency shown in the Begg group compared with the edgewise, 12.10 degrees to 8.71. The same distal tipping of the crowns was apparent in the mandibular incisor area, with both groups approximately the same, 1.83 degrees in the edgewise and 1.64 in the Begg.

Correlations of Variables

The only correlation that showed a significant relationship was that relating the amount of incisal retraction with the amount of mesial movement of the molars. This was a negative correlation which indicated that the greater the amount of mesial movement in each case, the less the amount of incisor retraction. This was found to be significant in the mandible in both groups and very close to being significant in the maxilla in the Begg cases.

Discussion

The comparison of these two approaches to anchorage management, supporting appliances vs. differential forces, demonstrated a relatively more successful maintenance of molar position with the use of auxiliary supporting appliances during treatment than with the sole use of differential forces. A greater mesial movement of the molars, both maxillary and mandibular, was seen in those cases treated with differential force application. These data would raise questions as to whether or not selective application of differential forces by the treatment appliance can maintain molar position during treatment as efficiently as the use of auxiliary holding-appliances in conjunction with the active treatment appliance when anchorage maintenance is a critical treatment factor.

The observed change in the axial inclination of the molars during treatment in those cases treated by the Begg appliance showed a relative stability of molar inclination, while those cases treated by the edgewise group showed a mesial tipping of the crowns. This probably indicates the effectiveness of the anchorage tip-back bends mesial to the molar tubes used in Begg treatment in maintaining molar inclination, at least in the maxilla. Although there was no significant difference between the two groups in the change of axial inclination of the molars in the mandible, the tendency appears to be toward stability of the original axial inclination of the molars during treatment of the Begg patients, with a distal tipping of the molars in the edgewise group. This is probably due to the common use of the lip bumper which exerted an active distal force on the crowns of the lower molars in this particular edgewise sample.

The differences observed between the two groups in the amount of incisal retraction in the maxilla appears to cloud the issue of this evaluation of anchorage management, especially in view of the apparent relationship demonstrated between stability of molar position and available space for incisor retraction. This perhaps can be explained by either an imperfect homogeneity of the sample or it may be a reflection of different criteria for tooth removal utilized by the two philosophies of treatment. It is extremely difficult to get a goodly number of cases with exactly the same anchorage requirements, arch length relationships, profile characteristics, etc. Perhaps another study without the absolute measurement of mesial movement would eliminate these conflicting factors. For example, comparisons might be made relative to original arch length, expressing movement as a percentage of the original arch length rather than an absolute measurement.

There was no significant difference between the two groups in the change of axial inclination of the incisors during treatment, although the difference was fairly close to being significant in the maxilla. Here the Begg group showed a greater amount of lingual tipping of the incisors than the edgewise group. This should be evaluated, however, with respect to the different philosophies of treatment, since under the Begg concept the initial movement of anteriors in the first stage of treatment to close extraction spaces is exclusively a lingual tipping.

The correlations of variables demonstrated a relationship between the stability of molar position during treatment and the amount of incisor retraction, which is understandable.

Summary

A cephalometric appraisal of anchorage management in one hundred cases was undertaken. Fifty were treated under an edgewise treatment philosophy, the other fifty cases were handled according to the Begg plan of treatment. The data indicate that molar position in both the mandible and maxilla is more stable during treatment with the utilization of auxiliary supporting appliances than with the utilization of differential force application as the anchorage mechanism. There was a greater amount of mesial tipping of the maxillary molars with the use of auxiliary appliances than with the use of differential forces, but no significant differences found in the mandibular molars. There was a greater amount of maxillary incisal retraction with Begg appliances than edgewise, but no significant difference was found in the mandibular incisal retraction. The changes in the axial inclinations of maxillary or mandibular incisors during treatment were not statistically different. A negative correlation was found between the anterior movement of the mandibular molars and the amount of mandibular incisal retraction.

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