CHANGES IN ROOT FORM AND ROOT RESORPTION.

One of the often mentioned sequels to orthodontic tooth movement is the occurrence of resorption of the roots of the teeth being moved, or an alteration in what would be the final root form and quite a deal or work has been done in investigating these aspects of tissue change.

Movement of the tooth before the root was fully calcified produced a "bending" of the roots with the apical portion tending to remain closer to its point of origin than the rest of the tooth according to Johnson Appleton & Rittershofer. Gottlieb & Orban found shortening and blunting and thickening of the apical end of the roots of the teeth following abnormal occlusal pressure. Kronfeld stated that blunted or shortened root ends following orthodontic movement of teeth to be due to resorption at the apex or to a deformity and distortion of Hertwig's sheath, if the tooth is moved before root formation is completed. Rudolph however, claims that orthodontic treatment is less hazardous to root structure when initiated at an early age and that prolonged treatment is less likely to produce loss of root tip structure in younger children. Phillips agrees with this. "The surface of the root normally has an acellular organic layer of cementoid over the cementum. When orthodontic pressures are applied, this protective cementoid layer may be perforated and semi-lunar areas of resorption appear in the cementum". (Graber)
Fig. 10-1 Excessive pressure has caused resorption of cementum and a cupping out of the dentin where the cementoid layer has been ruptured. Tooth is moving from left to right. In the higher magnification view on right, A shows beginning repair with a cementoid layer, B shows cementoblasts at work and C indicates fiber bundles. (Courtesy Kaare Reitan)
Root resorption in relation to orthodontic therapy has proved quite a contentious subject, but it now is becoming obvious that in this respect the orthodontist is faced with dealing with a large number of inherited factors which are largely outside of his control and it is the individual's response, and the response of individual teeth, which is so variable and has led to such widely differing views in the past. Oppenheim really compounds the problem when he refers to Winkler who stated that "The readiness for the reaction of the organism certainly is not only different in different individuals, but also in the same individual at different times."

Goldman observed spontaneous resorption in crowns and roots of teeth, not even induced from the external surface of the tooth. In some cases the entire root may disappear.

Becks & Grimm found that children who show a tendency to root resorption before treatment to be poor risks. Metabolic disturbances such as endocrine imbalance are active factors in root resorption and Schour suggested that genetic endowment may be a factor.

A resorptive potential seems to be present in the root ends of practically all permanent teeth. This potential seems to vary with different persons and in different teeth of the same person and this variation is the crux of the conflicting reports on this subject, as is the work by Massler & Malone in a survey showing definite evidence of root resorption in 86% of the teeth.
examined. Their survey showed mandibular incisor teeth followed by the maxillary lateral incisor, premolar, central incisor and canine teeth in the order of decreasing frequency. All this was in people who had not undergone any orthodontic therapy.

"The fact remains (Brodie) that, regardless of appliances used, forces exerted, or the duration of the treatment, there are wide variations in tissue tolerance or the susceptibility to resorption.

"The resorbability of the cementum surface is certainly different in different individuals" (Orban) and again "Why, under apparently similar conditions, root resorption occurs in some instances and not in others is still a problem" (Skillen).

"In individuals with high resistance even a great amount of occlusal trauma does not produce resorption of the root. On the other hand, in patients susceptible to root resorption normal mastication or careful orthodontic treatment may occasionally produce progressive root resorption leading finally to complete destruction of the root." (Kronfeld).

In the light of this evidence it is reasonable to assume that root resorption following orthodontic therapy is no proof positive that there exists a cause and effect relationship. That some root resorption is a sequel to orthodontic tooth
Fig. 12, Specimen No. IV. - Resorption on the traction side in high magnification; *P*, tissue of the periodontal membrane; *C*, cementum; *Sc*, secondary cementum.
movement is so, and careful consideration of this is imperative during treatment in an attempt to minimise it, as Orban puts it: "In careful orthodontic treatment cementum resorption if it occurs is usually localised and shallow. Moreover it is readily repaired if the intensity of pressure is reduced and the surrounding connective tissue remains intact. If resorption is extensive it may indicate a systemic disorder, possibly of the endocrine system".

Graber claims that if the forces employed are intermittent or if the treatment is completed, cementoblasts usually fill in the "punched out areas," but the cementum is never quite the same in microscopic appearance as the original structure.

Marshall showed that monkeys on a poor diet had a greater incidence of root resorption, as did those animals suffering from metabolic or infectious diseases.

Insufficient research has yet been accomplished into the various metabolic factors influencing root resorption during orthodontic therapy, even particularly in the extreme cases which sometimes present, but a consideration of local factors which may contribute can be helpful.

When Massler & Malone turned their attention to orthodontically treated teeth they found some root resorption in 93%, (compared with above, or non-orthodontically treated teeth). They reported a moderate degree of resorption in 31.4% and
Fig. 31. Specimen No. VII.—Wire separation: outline picture: crown tipped to the left; a, cementum resorption and two other ones at the apex b and c: A, artifact.

Fig. 32. Specimen No. VII.—Resorption C from Fig. 31 in high magnification: P, tissue of the periodontal membrane; Kr, root canal; C, cementum.
severe resorption (more than half the root resorbed) in 3.4% and their order of frequency was mandibular and maxillary first incisor teeth, the maxillary first molar tooth, the first and second premolar and canine teeth, the mandibular canine tooth and the maxillary and mandibular second molar teeth.

Earlier studies by Ketcham and Oppenheim gave the maxillary central incisor tooth and lateral incisor tooth as the teeth most susceptible to apical root loss. Oppenheim ascribed these as the teeth most affected by orthodontic treatment because of their cosmetic and functional position and because the general conical shape of their roots transmitted appliance forces to the apex, thereby causing a tendency for apical root resorption. Ketcham considered the degree of change was related to the type of appliance used for the orthodontic treatment. This touches on the concept that "jiggling" - the moving of the apex back and forth such as caused by the so-called "daily relapse" as sometimes induced by wearing a removable appliance only at night or moving a tooth intermittently against a constantly present force being generated in or by the dentofacial complex - tends to a greater degree of root resorption. Auxiliary springs have received special mention in this regard by Stuteville who claims that fixed appliances are far safer in this regard.

Hellman stated that the type of appliance is not responsible for root resorption but that the manner in which the appliances
Fig. 23. Specimen No. V.—The same resorption as Fig. 18; C, cementum; a, b, cementum at c the resorption is somewhat deeper; Oc, root of multi nucleated osteoclast.

Fig. 24. Specimen No. V.—Osteoclastic row Oc from Fig. 23 in high magnification; P, one of periodontal membrane; Oc, multinucleated osteoclast; A, artifact.
are used is the determining factor, and again Stuteville hammers the point that sufficient time should elapse between adjustments to allow all the supporting tissues to return to normal.

Rudolph reported that it "is estimated that root resorption occurs in at least 12% of all orthodontic patients presently being treated by competent orthodontists".

Stuteville concluded that root resorption occurs in practically all cases of malocclusion that are treated orthodontically.

Returning to our consideration of local factors, Phillips could not demonstrate any sex difference nor could he find any correlation between the amount of apical root loss and the amount of movement, the age of the patient or the length of the treatment period. He did point out that teeth with previous injuries as shown by teeth with fracture lines or checks in their enamel or distortion of their roots generally show a greater predelection to root resorption. Such teeth would be most commonly the maxillary central and lateral incisor teeth as mentioned earlier. However, he claimed that there is only a very small incidence wherein the degree of root resorption was clinically significant.
Fischer lists some basic principles for the management of root resorption.

1. Timing of orthodontic treatment. Root resorption does not occur in the teeth whose roots were not fully formed when orthodontic treatment was started.

2. Age of the patient. The younger the patient the less the incidence of root resorption. Whenever possible cases should be treated in the mixed dentition before the roots of the permanent teeth are fully formed.

3. Length of active treatment. The extent of root resorption is directly proportional to the duration of appliance therapy. The shorter the period of treatment the less the extent of root resorption.

He considers that these have reduced considerably the incidence and extent of root resorption in his practice, and concedes that the natural variation in tissue tolerance to orthodontic pressure is always an unknown, which cannot be assessed until after the damage, if any, is done.

To finish off this section dealing with root resorption reference to the work by Huettner & Whitman on the Macaque Rhesus Monkey which they show as having a similar dentition to that of the human is in order. They have listed a number of commonly attempted orthodontic movements and have classified them in relation to their resultant effects with respect to root resorption. They showed that elongation of a tooth
altered the direction of the periodontal fibres and there was no serious root resorption. Tipping of a tooth usually led to only minute root resorption. Bodily movement of a tooth through the bone gave rise to minimal root damage. Rotation of a tooth showed only slight root damage. Depression of a tooth into the alveolus led to a severe compression of the periodontal membrane particularly at the apices but resorption of the cementum was slight in degree. Note that Graber lists this movement as the least successful in terms of absolute tooth movement. Producing a torque on a tooth was rated as a severely damaging orthodontic tooth movement but not as damaging as "tipping back" or producing so called second order bends in the posterior teeth, a method that had been advocated in the belief that it increased anchorage, particularly in the lower arch. This movement was listed as the one leading to the most severe root resorptions, and was finally condemned as not preventing mesial movements of the posterior segments.

At all times it has been stressed that light forces lead to the least amount of damage, and careful treatment planning before actual therapy starts is essential to minimise any necessity to reverse tooth movement, once commenced.
CHANGES IN THE PULP.

Impairment of blood supply.

A further tissue in which untoward changes can be generated is the pulp of the tooth. The danger lies in impairment of the nutrition of the pulpal tissues through undue tension on the apical vessels. Salzmann mentioned this only in relation to the use of excessive force but Simpson claimed that even slight forces applied to the apex led to a condition of stasis in the pulpal vessels. Mild forces (Graber) cause hyperemia of the pulp tissue. Patients sometimes have a sensitivity to thermal changes in conjunction with a pulpitis after adjustments have been made in the orthodontic appliances. If the pressure is severe, partial or total pulpal degeneration is possible and the tooth will turn dark as haemorrhage and necrosis occur. Experiments (Graber) show that there is a reduced sensitivity to electric pulp testing methods during orthodontic treatment, and the pulp reaction returns to normal after the completion of orthodontic therapy. According to Reitan disturbance of the pulp tissue during orthodontic treatment may result from permanent tipping of the tooth, as the nutrient blood vessels may be compressed and give rise to stasis and subsequent degeneration changes. He goes on to maintain that such sequelae rarely occur after bodily tooth movement and practically never in cases where there has been intermittent
tooth movement. Graber claims that elongation is the
orthodontic movement most likely to devitalise a tooth and
stresses that the use of very light pressures and great caution
are essential when attempting this movement.

Simpson and Salzmann both agree that there are only few
records of actual pulp death occurring following orthodontic
treatment, but Simpson refers to a tendency for the highly
specialised pulpal tissues to degenerate into a tissue resembling
connective tissues. Stuteville also concluded that "relatively
few pulps are killed by orthodontic forces" and Kronfeld
emphasised the high degree of difference in individual reaction
in the pulp to similar conditions.

Effect of previous trauma.

The fact that any previous injury to the pulp is a point to
be noted in increasing the likelihood of the occurrence of
pathological pulpal conditions following orthodontic treatment is
brought out by Markhus and he showed that the threshold of
stimulation of the pulp was lowered following the application of
pressure on the tooth, indicating pulpal irritation. He went
so far as to say that the pulp testing of at least the four upper
central incisor teeth should be carried out as a pre-operative
safeguard for the patient and the operator.
Effect of pulp removal.

In conclusion, it is interesting to note that Reitan showed that removal of the pulp had no influence on the other tissue changes associated with orthodontic tooth movement.
CHANGES THROUGH THE PLACING OF ORTHODONTIC BANDS.

Orthodontic tooth movement is commonly achieved by applying a controlled force to a tooth in a definite direction and at this time a commonly accepted method of controlling the applied force entails the placing of a band of stainless steel material around the crown of the tooth to be moved. These bands are constructed ideally to be a very close fit but nevertheless a bonding medium is used to maintain them in position and this is commonly a zinc oxyphosphate dental cement.

Etching of Enamel by Cement.

The placing of the band in this manner and its many attachments creates two problems which can lead to significant tissue changes. The first problem is that the cement used most commonly is an acid material and this may cause a reaction with the basic enamel substance of the tooth. Obviously since a large proportion of orthodontic therapy is instituted for cosmetic purposes, at least in the minds of the patients, or their parents, if child patients, a subsequent marring of the labial enamel of the incisor teeth can be quite disappointing to say the least.

51 Graber has stated how "no tissue changes are observed in the enamel through tooth movement per se. Decalcification around bands as a result of debris that is not removed and an etching of the enamel rod's surface often may be seen by the naked eye.
Gross studied the etching of enamel under orthodontic bands and although admitting that the chemistry of cement was such that it could cause harm claimed that the conditions under which etching of the enamel definitely occurred were yet to be demonstrated and concluded that the mixing of the cement was of prime importance particularly in cases where re-cementation of bands were carried out.

This was promptly attacked by Bodecker who claimed that the most significant variable present is the resistance to etching of the individual teeth.

**Progress of Dental Caries Under Bands.**

A different aspect of cementing orthodontic bands on to a tooth was studied radiographically by Quinn. His clinical study dealt with the progress of dental caries beneath orthodontic bands, and he found that although caries may progress beneath orthodontic bands the rate of its progress is less rapid in banded than unbanded teeth.

This study was a radiographic one and I would like to say that such a study relies somewhat on the interpretation of the operator as well as the data he collects, and should be assessed as such.

**Gingival Disorders.**

The second problem that arises is from the band itself. The actual contact of the band with the gingival tissues can
cause trouble apart from the bulk of the band and its attachments interfering with the normal sluiceways and natural massage of the perigingival tissues. Heuttner working on Macaca Rhesus monkeys found loss of the gingival fibres attached to the papillary layer of the oral epithelium in many cases. Hyperplasia of the oral epithelium and inflammatory reactions were also observed in the interdental tissues. He found the transeptal fibres the most resistant to damage after the placing of orthodontic bands; indeed he found them very resistant in various damaging procedures. Erickson, Kaplan & Aisenberg agreed with this latter finding.

Huettner was able to correlate that placement of the band on the tooth had an important bearing on whether the depth of the gingival sulcus increased or remained fairly constant. Anterior bands cemented on the centre of the crown of the tooth lead to minimal gingival involvements, and molar bands lead to the most common and severe hyperplasia and inflammation.

Stuteville concluded that the "injuries to the gingiva can be reduced by the use of well fitting appliances".
CHANGES BY ORTHODONTIC TREATMENT TO ASSIST PERIODONTIC TREATMENT.

This leads to a consideration of the use of orthodontic treatment in an effort to assist the elimination of periodontal disease.

One aspect of orthodontic treatment is to relieve gross crowding of teeth, thus enhancing the natural self-cleaning mechanism of certain areas and also facilitate artificial cleaning. Rix cited atypical swallowing as leading to a poor centrifugal development of the dental arches, and Tully claimed that the eliminating of the tooth crowding will not alter this abnormal oro-muscular activity. Also Forsberg pointed out that the association between periodontal disease and tooth crowding was not very strong when analysed statistically, but Hellgren produced at a later date evidence of a more significant correlation.

Actually the role of malocclusion as a producer of occlusal trauma and its resultant periodontal disease has been assumed for a long time. Karolyi, in Diseases of the Soft Structures of Teeth and their Treatment, is credited with originating the theory of occlusal trauma as an etiological factor in periodontal disease in 1894.

McCall observed "What causes harm in one mouth may not have an effect in another," and also that "some of the most
serious clinical manifestations of trauma occur when the occlusal relations of the dentition appear to be within the realm of normal.\footnote{44}

Glickman observed that "any malposition or functional aberration which causes an uneven distribution of the load upon individual teeth or groups of teeth is a potential source of injury to the periodontium.\footnote{44}

Anderson emphasised the preventive nature of orthodontics by stating that "traumatic occlusion" in adults resulting from long term malocclusion indicated the need for earlier orthodontic interference. Tremendous areas of bone destruction continuing to a point of premature loss of teeth" will in the future be overcome by early preventive treatment. \footnote{43}

Ditto & Hall showed no correlation between any of the Angle classes of malocclusion and percentage distribution of periodontal classifications. They did suggest that crowding is an important factor but not for any special type. \footnote{34}

Geiger's work showed there was no correlation between crowding and either the incidence or the severity of periodontal disease. \footnote{43}

Wilson and Glickman both thought that excessive overbite and overjet may impair periodontal health. In contrast Miller in explaining a "Periodontist's View of Occlusion" related an individual norm of degree of overbite, that is, is the overbite normal for the particular individual. \footnote{101}
Ditto & Hall concluded that overbite is not a factor affecting the distribution of periodontal disease. Geiger's work suggests a trend towards an inverse relationship between an increase in the depth of bite and the severity of the periodontitis.

Geiger claimed that a cross-bite relationship had no significance to the general severity of periodontal disease but was a significant etiological factor in the localised severity of the disease, particularly with regard to pocket formation.

Geiger further showed a direct relationship between the incidence of missing teeth and the severity of periodontitis. Tooth drift related to missing teeth did not influence the general severity of the disease but was apparent as a local factor.

Another result of orthodontic treatment can be the correction of an incisor overjet that is so marked as to be stopping lip seal. This again is not as simple as it may appear, as Tulley pointed out that the teeth may not be the primary cause of separation of the lips at rest. The lips may be deficient in length or flaccid. Patients so afflicted may consciously effect a lip seal by habitual contraction but the seal fails when the patient is asleep, allowing drying of the labial gingival tissues which can lead to inflammation and hypertrophy.
Orthodontic treatment may be undertaken to correct a deep overbite. In the absence of any direct trauma, however, such deep overbites have been shown by Emslie to be much less conclusive to periodontal disease than a reduced overbite or an open bite.

However, Gross and Yuktananda showed that orthodontic treatment of an adult can be of value in the treatment of established periodontal conditions by reducing the areas of stagnation and enabling a more thorough subgingival curettage to be performed even though these cases may require permanent splinting.

Hovell in advising against the practice of serial extractions pointed out the danger of the cheek teeth drifting mesially, accompanied by tilting and disturbance of the contact point level.

This aspect of tissue changes related to orthodontic procedures is summed up neatly by Dummett. "The incidence of periodontal disease from incorrect orthodontic procedures can be greatly reduced and the number of cases of periodontal disease recognised as being amenable to orthodontic treatment can be materially increased if there is closer co-operation" between these two specialities in dentistry.
CHANGES IN THE PROFILE.

Tissue Changes remote from the site.

Now that we have covered the reactions of the tissues in the actual area where the orthodontic forces are applied, namely the tooth and its root, the periodontal membrane and the alveolar bone immediately surrounding the tooth socket, it is time to consider the more general changes in the individual. It is most interesting to see how far reaching these changes can be, or should I say how far our present knowledge allows us to ascertain how far reaching these changes may be.

In this section of this review I will once again attempt to classify the changes into sections dealing with any general dentofacial rearrangement, and then more specifically mandibular changes and maxillary changes. Here again such definition is artificial and only for convenience, as will be seen, for instance, with changes in the maxilla. I have found it necessary to refer to differences in the relative antero-posterior position of the maxillary bones as part of the general dentofacial rearrangements, but have dealt with midpalatal maxillary suture changes separately, so as not to lose the trend of the more general changes.

In considering the possibilities of rearrangement of the bones forming the dentofacial complex it will be necessary to refer to a number of studies which have used cephalometric techniques
for their investigation. As a help in more readily comprehending the significance of their findings I have included here a simple diagram with the more salient points and angles marked.

A - Point A. The deepest point on the maxillary mid-line between the anterior nasal spine and the prosthion.

B - Point B. The deepest mid-line point on the mandible between the infra-dentale and the pogonion.

BP - Bolton P. The highest point on the concavity behind the occipital condyles.

FA - Facial Angle. The inside inferior angle formed by the intersection of the Frankfort horizontal and the facial plane.

FH - Frankfort Horizontal. The horizontal plane through the right and left cephalometric porion and the left orbitale. Drawn from the superior margin of the acoustic meatus to the orbitale.

G - The Gonion.

Gn - Gnathion. A point near the chin at the intersection of the facial and mandibular planes.

N - Nasion. The suture between the frontal and the nasal bones.

OP - Occlusal plane. A line bisecting the occlusion of the first molars and the central incisors.

P - Porion. The highest point on the superior surface of the soft tissue of the external auditory meatus.

Pg - Pogonion. The most anterior point on the mid-line of the mandibular bone.

S - Centre of the Sella Turcica. Located by inspection of the profile roentgenogram.
An extensive preliminary survey by Brodie and associates of cases exhibiting the three Angle types of malocclusions and the results of orthodontic treatment for these cases led to the following general conclusions:

1. Although a number of cases exhibit mesial or distal movement of the buccal teeth, and/or correction of the overbite, Brodie did not consider his evidence as conclusive.

2. In both growing and none-growing cases, the angle BSN and the pterygomaxillary fissure are shown to be remarkably constant.

3. In all cases in which intermaxillary elastics were worn there was a disturbance in the angle formed between the occlusal plane and the Bolton plane. During Angle Class II treatment the angle increased and with treatment of Angle Class III cases it decreased. A tendency for the angle to return to its original size following treatment was noted, but this tendency decreased with age.

4. In a number of cases covering all classes some of the resultant change is provided by a definite change in the position of the mandible. Occasionally
this was represented by an antero-posterior shifting, but more commonly it was through a downward and backward rotation of the mandible.

5. Any axial inclination of the teeth disturbed by orthodontic treatment tended to correct itself following treatment.

6. Actual bone changes accompanying orthodontic treatment seemed to be restricted to the alveolar process. This structure had extreme ability to adapt itself to changes in the axial positions of the teeth.

7. Changes subsequent to treatment are limited to a shifting in the occlusal plane and to changes in the axial positions of the teeth in adult cases. In growing children normal growth changes are also in evidence.

8. There seemed to be a definite correlation between success in treatment and growth. The adult cases studied, although clinically successful as far as the maintenance of the occlusal relations were concerned, were not so markedly improved in regard to facial aesthetics.

The conclusion that orthodontic forces by themselves do not stimulate growth may be contested on a number of points. Firstly that gentle forces allow the alveolar bone time to express its "extreme adaptability", whereas greater forces, sufficient to lead to a cessation of tooth movement (as shown by Storey and discussed
on page 15 will lead to stress being placed on more distant parts of the dentofacial complex. This will be gone into in more detail when considering the spreading of the maxillary midpalatal suture.

Also even Brodie and his associates draw a distinction between the final results achieved when treatment is commenced during growth or in adults. Bjork found a better response to orthodontic therapy in sturdier children. Is the improved facial aesthetics an indication of growth stimulation along more normal lines?

Bone growth is by apposition, at sutures or in cartilages. Storey referred to great forces which are being applied to stop and conversely to stimulate the growth of long bones in sheep and it is becoming obvious that bone growth by the latter two means is extremely resistant to deformation. This leads to the question of whether the individual responds more readily to forces correcting an abnormality than to forces creating an abnormality, and so far this is unanswered.

A study on monkeys with surgically created cleft palates by "Harvold throws some light on the problem. Amongst other things his animals were alazarinated prior to undergoing maxillary expansion by orthodontic means. His histological results showed that at all the maxillary sutures bone growth had been stimulated in accordance with the application of the
orthodontic force. A considerable amount of work on rapid expansion of the maxillary dental arch and the concomitant changes in the midpalatal suture and in the vomero-maxillary articulation will be dealt with later.

Going back to the first point of view it is found that Hellman after no little work on this aspect concluded that orthodontic treatment realigned the teeth but had no influence on the growth of their supporting bones. He did show that the pogonion moved forward faster than the anterior nasal spine. Further he believed that when skeletal changes occurred after treatment they were the result of growth and not of the orthodontic treatment.

This has been contested by Silverstein who applied a detailed analysis to his results. Basically his study revealed that although orthodontic treatment does not markedly alter the skeletal growth of the individual it did change the facial profile, particularly with females. Hellman had previously found sex differences in the timing, quantity and rate from birth onwards in the growth of the various proportions of the face.

Silverstein found that in untreated cases the mandibular plane angle decreased with age. The group which had had orthodontic treatment showed that the rate of angular decrease had been inhibited slightly. With the females in his treated
Fig. I.17.—Percentage of facial growth at different ages. 1, cranial width; 2, cranial height; 3, cranial length; 4, bizygomatic width; 5, bigonial width; 6, facial height; 7, facial length. Note the large proportion of all dimensions achieved at an early age. Dimensions which the dentist has most opportunity to alter are facial height and length.
group he found that the mandibular plane angle had increased (the reverse) with age.

Further results from this study may be summarised as follows:-

The mandibular alveolar relationship, as shown by the angle SNB, was found to be more acute (that is the point B was more posterior) at the age of eight years in the orthodontically treated cases but this was not statistically significant.

Similarly the facial plane angle (SNP) at the age of eight years was four degrees more acute in the orthodontically treated cases but this was not statistically significant.

The maxillary alveolar relationship, as shown by the angle SNA, normally changed only very slightly with age. Orthodontic treatment altered the normal growth trend slightly by decreasing the angle SNA over the eight to twenty years of age period.

The behaviour of the maxillary base is indicated by the angle SNANS. Here untreated males and females were similar at eight years of age, and did not change with age. Changes after orthodontic treatment were found to be less than the differences existing before the treatment was started.

The relation between A B and the facial plane (NP) showed a very significant difference between the treated and untreated group at the age of eight years. In females the
Fig. 1.16.—Pattern of facial growth. Three skulls superimposed on the cranial base: light line, at birth; dotted line, at completion of primary dentition; heavy line, in young adulthood. Note orderly downward and forward development of the face and the large percentage of total facial growth completed by the beginning of permanent dentition. (After Broadbent.)
trend was to increase the angle and in males the trend was to decrease slightly so that at twenty years of age there was a four degree difference.

Silverstein referred also to slight changes in growth trends after treatment, using the trend analysis.

Various other studies on this problem deserve mention here although they were more restricted in their scope.

59

Hames investigated the bony profile changes resulting from cervical traction in comparison to those resulting from inter-maxillary elastics. He found that Angle Class II treatment of either type led to a distal position of point A, and with a few exceptions, also effects a distal positioning of point B to a lesser degree. Actually use of intermaxillary elastics in treatment tended to nullify this undesirable change in point B, although with few exceptions this type of orthodontic treatment did not succeed in making the chin more prominent in the profile. He found no explanation for this mandibular behaviour. With both methods of treatment the increase in dental height was similar. Cervical anchorage treatment combined with the wearing of a bite plate led to an increase in the mandibular plane angle and a distal position of the point B, whereas with intermaxillary elastics there was no significant change.

84

King reported a significant change in the point A with cervical traction and also a significant anterior change in
the pogonion in the male patients studied although no inter-
maxillary elastics were used.

85
Klein reported an increase in the angle of convexity
(NAP) of an average of 2.8 degrees following cervical traction
treatment.

77
James investigated the results of cervical anchorage on
patients who had good facial patterns and who had poor facial
patterns. He reported no significant changes and that the
relative changes appeared to be in proportion to the severity
of the pre-existing discrepancy.

58
Hall using only 17 cases came to the following conclusions:

(a) there was a forward movement of the mandibular molar
teeth in most cases;

(b) there was an extrusion of the molar and upper incisor
teeth in most cases;

(c) there was distal movement of the upper first molar
teeth in non-extraction cases;

(d) there occurred an increased length of the facial
plane in all cases;

(e) there was no change in the gonial angle;

(f) there was an uprighting and lingual movement of
the maxillary incisor teeth;
(g) there was an increase in the Y axis indicating more vertical than horizontal facial growth; and there was a downward and some forward positioning of the chin.

Taken all round most reports agree that there is some improvement in point A when related to the profile.

With reference to the mandibular changes associated with the use of Angle Class II elastics it would appear from the literature that such is not as frequent as might be expected.

Bjork gave his opinion in no uncertain terms as follows: "that the mandible resumes its original distal position in the course of treatment and that "the mandibular prominence which may arise in the course of treatment evidently lies within the range of normal growth".

Silverstein found that the forward movement of mandibular growth was inhibited rather than improved by Angle Class II treatment.

Urban stated that the effect of intermaxillary elastic traction on the lower denture and the facial profile may be unfavourable except in cases which involved a distal positioning of the teeth on the base bone.

Holdaway reported success in achieving forward positioning
of the mandible with the use of strong Angle Class II elastics and even varied the application of forces in his treatment to attain the greatest effect in the desired area.

Bayue in a preliminary report (only 30 cases) on lower arch changes subsequent to cervical force treatment said that there appeared to be a definite increase in the mandibular bimolar dimensions ranging from 1.0 to 4.0 mms. The bicanine dimension in about half of the cases was seen to have increased after correction of the molar relationship.

Other studies have been made using the Andresen appliance method of treatment for Angle Class II malocclusion cases. The one I wish to mention here was done in New Zealand by Gresham. He found a significant improvement in the occlusal positioning of the mandible, and most of these cases showed a new forward rest position. Commenting on this he quoted Ricketts: "we can no longer accept it (the mandibular rest position) as unchangeable", and referred to an observation that "the pattern of muscle function can be changed by Rogers' myofunctional therapy".

Gresham measured the angle SNPg at the end of his treatment and then ten to eighteen months later. Of the twelve patients so available three showed a tendency to distal repositioning, two showed further forward growth and seven showed no significant change. He concluded by stating that Andresen appliance therapy was suitable only when a true post-normality of the mandible
existed and that then only about 30% of cases showed acceleration of normal condylar growth.

Browne has stated that there may be greater increments in length in the mandible than would otherwise occur without the Andresen activator treatment but said that his results are unfinished.

It can be concluded that in no wise is the last word written on these profile changes, and indeed such may never be the case. Not only in the individual's reactions to various types of orthodontic therapy a factor here, but orthodontists themselves vary in their opinions of what is a desirable profile, let alone how to achieve it.
CHANGE AT THE TEMPOROMANDIBULAR JOINT.

Introduction.

Angle's opinion was that changes in tooth relationship resulted solely from periodontal tissue transformation.

Brietner was the first (1930) to prove histologically a tissue transformation in the region of the temporomandibular joint. (Obviously human material for histological study is hard to obtain but cephalometrics are a help, although not as precise as histological sections).

Haupl & Psanky in 1939 showed tissue changes in the temporomandibular joint of a baboon treated with an activator.

Grossman & Hoffer using cephalometric observations showed a transformation in the joint based on positional changes.

Haupl & Stellmack in 1960 reported on human histological material for the first time.

With assessment of lateral radiographs with these changes in view the diverse growth conditioned changes of any particular case have of course to be taken into consideration. In some cases it is extremely difficult to assess with certainty what is growth in development and what is the result of functional treatment (Teigelhamp) nevertheless the temporo-
Fig. 3.—Posterior side of the head of the condyle. A, Bone deposition in the glenoid fossa. B, Bone deposition on the condyle posteriorly. C, Cartilage.

Fig. 4.—High magnification of part of the anterior wall of the fossa. A, Giant cell (osteoclast) as evidence of bone resorption. B, Articular disc.
mandibular joint is another region where tissue changes can be induced by experimental movement of the teeth.

**Bone Changes.**

By moving the mandible forwards bone apposition can be obtained in the glenoid fossa and on the posterior part of the condylar process of young animals, with corresponding bone resorption of the anterior side.

In mesial movement of the mandible bone formation was found in the distal wall of the glenoid fossae of the skull arranged in horizontal spicules, while resorption of bone was found on the mesial wall of the fossa. New bone was also found on the distal side of the condyle and the ramus. With distal movement of the mandible the location of the bone changes were the reverse of these. Resorption had taken place on the distal side of the glenoid fossa and addition of new bone had occurred on the anterior border. All this apparently was superimposed on the backward movement of the glenoid fossae during the growth span to which attention was drawn by Ricketts.

Different human material has been reported by Haupl being the case of a newborn child suffering with Pierre Robin syndrome showing a particularly severe distal displacement of the mandible which was interfering with breathing. The child died after treatment which included a wire to the mandible giving a forward
Fig. 1.—Sagittal section through a temporomandibular joint of a Macacus rhesus monkey. A, Disc in the glenoid fossa. B, Head of the condyle. C, External pterygoid muscle. D, Mandibular canal.

Fig. 2.—Glenoid fossa. A, Deposition of new bone. B, Cartilage on the head of the condyle. C, Bone resorption (See Fig. 4).
pull, had been finished and the temporomandibular joints were examined histologically. They showed transformation in the condylar head at the articular eminence and in the depth of the glenoid fossae all leading to an anterior positioning of the mandible.

**Changes in the Rest Position.**

In the more normal course of events the ultimate result of the changes taking place in the temporomandibular joint is frequently influenced by muscle function, and is usually related to changes in the rest position of mandible as a result of treatment. According to Drake working on only two cases exhibiting Angle Class II Division I malocclusion of the teeth and post-translation of the mandible, orthodontic treatment had led to a posterior repositioning of the condylar rest position and the occlusal condylar relationship had remained the same. He concluded that these cases had an anterior displacement of the rest position rather than a posterior displacement of the mandible.

However, a far greater volume of material has been used and analysed by Ricketts. He confirmed the concept that abnormal rest positions of the entire mandible were typical of Angle Class II malocclusion cases. In all his work he mentioned the surprisingly wide variations which were observed in all aspects of the joint and the denture and Reitan has gone so far as to say
that "the changes occurring during (orthodontic) treatment can in most cases be regarded as variants of normal growth".

After reviewing Rickett's article again I feel that Reitan's is too much of a generalisation.

Variations in the Form of the Joint.

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Ricketts examined the form of the joint as it occurred in cases showing an Angle Class II and Angle Class III malocclusion of the teeth and compared it with the form in individuals showing a normal occlusion of the teeth. He found that Angle Class II conditions were associated with condyles in a downward and forward relationship in approximately two thirds of cases, that the inter-occlusal dimension was twice as great as the normal and that the path of closure was more distal than normal. There was no essential condyle position difference in the fully occluded relationship of the teeth position. Further, he found that in cases exhibiting Angle Class III conditions the condyles tended to be long and narrow, and were seated upperward and forward in relatively shallow glenoid fossae.

He went on to say that true distal displacement of the condyles resulted from tooth interference although to a much lesser extent than had been previously expected, and that mesial displacements even in Angle Class II cases were more common than it had been anticipated.
Fig. 5.—Anterior side of the head of the condyle. A, Cartilage. B, Osteoclast in Howship lacuna. C, External pterygoid muscle.

Fig. 6.—Angle of the mandible. A, Internal pterygoid muscle. B, Bone deposition. C, Bone resorption (See Fig. 7). D, Masticator muscle.

Fig. 7.—High power magnification of part of Fig. 6. A, Bone deposition (osteoblasts) toward the bone marrow. B, Giant cell (osteoclast) on the outer border of the angle.
After orthodontic treatment the distance from the head of the condyle to the roof of the glenoid fossae was almost the same as in the untreated malocclusion cases. The amount of condylar growth during orthodontic treatment varied from zero to 12 mms. with boys increasing at an average yearly rate of 3 mms. and girls 2 mms. (The average age at the beginning of observation was twelve years). The yearly average increase during treatment of the Angle Class II cases was 2.25 mms. and that of the untreated cases 2.05 mms. Typically the growth was directly down the long axis of the neck of the condyle, 63%, with 15% showing growth upwards and backwards 2.5 degrees and 22% showing growth upwards and forwards. Therefore Ricketts showed that the concept of the stability of mandibular form was supported in only two thirds of his sample.

In reference to the regional fossae, Ricketts referred to previous work which had suggested that after the age of six the glenoid fossae and the entire temporal bone behave similarly during growth. He showed that backward movement of the fossae (directly related to the cranial base) cancels out some of the forward growth of the mandible, while direct vertical growth carries the mandible directly downwards. He showed that local modification of the fossae and the temporal bone occurred in some cases, and that although in a minority these changes affected the overall growth result in the face when they did occur.

Furthermore Ricketts showed that the position of the condyle
in the fossae during treatment could change in some cases. A downwards and forwards position was assumed by the condyle in 13% of his cases and as more distal and more seated into the fossae position was achieved in 27% of his cases, some showing as much as a 3 mm. change.

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Tiegelkamp in reviewing tracings of one hundred and forty patients before, during and after suitable orthodontic treatment, found that to a high degree the position and the shaping of the mandible are subject to functional influences. In the cases which are presented the functional stimuli transmitted to the tissues by an orthodontic appliance were the cause of the transformations in the shape of the mandible. He concluded that "we are fully aware that we are unable to change the inherited growth potential, but changes in shape can be the result in functional treatment and thereby influence the maxillo-mandibular relationship". This sums up the Continental school of thought on this aspect of orthodontic therapy.

Post Treatment Changes.

Post treatment changes in the condyle were accepted by Ricketts to be due to positional changes in the mandible since his control group showed no change of condylar relation during growth, and the permanency of this repositioning is insured by the adaptive modification of the growing structures in the temporomandibular joint (Gresham).
CHANGES IN RELATED MUSCULATURE.

Muscles in Malocclusion Cases.

Reviewing tissue changes associated with orthodontic treatment must include a short consideration of changes in muscular function. I underline the word short, as current thought in this country on the importance of muscular function has tended to minimise it from its former important position. 6, 46, 107

As Ricketts pointed out, the mandible maintains a position in a chain of musculature extending from the tongue to the hyoid bone to the pharynx and the larynx and grows together with the pull of the musculature, not directly against the fixed base of the glenoid fossae. He believes that changes in the rest position of the mandible are due primarily to alterations in the neuro-muscular system. In individuals exhibiting Angle Class II malocclusions the necessities of function, such as protrusion for the purpose of incision, lead to muscular compensation in the form of hypertonicity of the muscles involved in protrusion and opening. Speech also demands muscular compensation in these cases, the sounds, S, P, B, and M in particular call for extra muscular effort.

Ricketts further points out that psychological states may be induced by individuals who, on becoming socially conscious of their facial appearance as related to their malocclusion, adopt a special jaw closure to mask the deformity,
He terms this the patients' "Sunday bite". This forward positioning of the mandible for aesthetic purposes created an abnormal stabilising action of the protruding components of the associated musculature and consequently in cases exhibiting Angle Class II malocclusions this brings attention to the physiological state of the external pterygoid muscles. Unfortunately, these muscles are difficult of access for study purposes in the living and so little is known of their condition under prolonged excessive function.

Cephalometric findings showing changes in the maxillo-mandibular relationship have been confirmed in many cases by electromyography, particularly so since Greensfield & Wyke (1956) have been able to establish characteristic electromyographic patterns for certain basic movements.

An interesting electromyographical study on the temporal and masseter muscles has been reported by Karua. It showed that during deglutition and during masticatory function, on the ipsilateral side persons who had not undergone orthodontic therapy showed more temporal muscle activity than masseter muscle activity, and that this predominance was reversed in the persons of the group who had had orthodontic therapy, that is that the masseter muscle was the more active muscle. In both groups one temporal muscle consistently registered greater activity regardless of whether on the ipsilateral or contralateral
side. His study verified that the temporal muscle is the better suited for positioning and movement of the mandible and that the masseter muscle is the one best suited for applying power to the act of mandibular closure in functional movements. He further claimed that his results indicate that harmony of the occlusal relationships of the teeth rather than the sagittal relationship of the mandible to the maxilla is the primary determining factor of the excellence of muscular function.

Moyers showed that orthodontic therapy can alter the character of the spike potentials in certain muscles of the temporomandibular joint articulation, and that aberrations in muscle function can result from malocclusion of the teeth.

**Muscle Exercises.**

Some reference must be made to an extended advocacy of a myofunctional orthodontic therapy by Rogers. He recommended for cases exhibiting a post normal occlusion with reduced function of the protractor muscles an exercise of the lateral pterygoid muscle. This involved the patient, with head bent back and the arms turned outwards and backwards, repeatedly protruding the mandible.

Muscle exercises have in general proved of only a limited value in orthodontic therapy, and many leading practitioners tend to ignore their possible value. It cannot be denied that only by a close co-operation between all parties, and a
persevering enthusiasm over long periods will expectations be fulfilled.

Further to Rogers' ideas Washburn has illustrated the relationship between muscle function and mandibular growth and development, especially in respect to the gonion angle, the alveolar process and the chin.

**Muscles and Retention.**

In conclusion a proper cognizance should be made of the part played by the oral musculature in maintaining the dental structures in a state of balance. This becomes most important when the question of retention is considered as the musculature forms a basic element in the closed functional system described by Salzmann and discussed on page 93. When teeth are moved outside the area of tolerance relapse follows but the individual's limit of area of tolerance is so far not exactly defined. Until electromyographical analysis is perfected and more widely applied this factor may well remain obscure.
CHANGES WITH MAXILLARY ARCH EXPANSION.

Conflict of opinion.

Expansion of the maxillary dental arch and its effect on the base maxillary bone and related tissue reactions would seem a simple enough sequence which could be presented as a cut and dried case. Such, however, is not the story at all, and I quote Debbane: "two schools of thought seem to prevail".

On the one hand there is the idea that any expansion of the maxillary dental arch is confined to the teeth themselves and the immediately surrounding alveolar bone. Such authorities as Brodie Downs, Goldstein & Moyer and Bjork lend themselves to the support of this idea. On the other hand the concept that expansion forces can lead to opening and widening of the midpalatal suture of the maxillary facial complex is supported in the European school of thought. Such expansion is, further, believed to lead to concomitant widening of the intranasal space by a similar amount.

This is indeed a fundamental difference in orthodontic thinking, and, as Debbane pointed out, can have a bearing on orthodontic therapy.
Historical background based on observations.

It would seem that spreading of the maxillary midpalatal suture has quite a history when considered in relation to the growth of orthodontia. As long ago as 1860, Angell described separation of the maxillae by a type of screw appliance. He took development of a space between the two upper central incisor teeth as his criterion that separation of the maxillae had occurred.

45 Goddard in 1894 talked about the deposition of osseous material within the open suture being able to maintain the new width and correlated this bone deposition with the healing of fractures.

115 Ottolengui in 1905 expounded evidence to show that midpalatal suture opening had occurred and drew attention to the position the vomer bone occupies.

168 172 Willis and Wright suggested that the spreading of the midpalatal suture would result in a straightening of a deviated nasal septum if originally present in a constricted upper arch and they concluded that maxillary arch expansion would result in a widening of the nasal cavity floor, thus improving nasal deficiency. 172 Wright also drew attention to the idea that the suture is a growth centre united by connective tissue fibres which prevent it from closing at least until later in life.
The concept that the nasal cavity was influenced by the spreading of the midpalatal suture was tested by Brown in 1909 working on a fresh cadaver. This was followed up by Dean who verified the occurrence of an increase in space in the nares, and showed that maxillary bone displacement was not always symmetrical. However, a report by Ketcham showed no concomitant increase in the width of the nasal cavity with the increase in maxillary arch width. He further warned against accepting the spate of reports based on radiographic studies which were then appearing by Landsberger, Pullen, Dewey and later Chateau as he drew attention to some of the difficulties of interpreting radiographs in the presence of a thick nasal spine or vomer.

Pullen in 1912 demonstrated that the fibromembranous connective tissue of the midpalatal suture allowed for mobility of the facial bones united by the suture, and he contended that the anterior third of the maxillary region responded more readily to any readjustments after opening of the maxillary suture.

Izard, by studying the suture on a collection of dried skulls, reported ossification starting about sixteen years of age and being completed at about twenty-five years of age. He stressed an early start for any expansion treatment.

Experimental work.

Following all these investigations and observations, and in view of the conflicting opinions that these had led to the way
was wide open for controlled experimental studies.  

33 The first study was by Dewey who worked on dogs, and he concluded that expansion forces applied to the teeth resulted in a development of bone through the entire maxilla and nasal space which accounted for the individual's improvement. He did not find opening of the midpalatal suture.  

39 Neither did Federspeil who observed the midpalatal sutures of six patients undergoing orthodontic expansion directly by surgically reflecting the overlying tissues.  

On the other side of the debate, so to speak, Bober found from his work that expansion of the maxillary arch resulted in an opening of the midpalatal suture and that this is followed by a straightening of the nasal septum. He also observed invigorating effects on the pituitary gland.  

Also a study of frontal roentgenograms of patients before and after orthodontic maxillary arch expansion by Derichsweiler led to his concluding that separation of the maxillary bones had followed the orthodontic expansion and he theorised that the opening of the suture is comparable to a "greenstick" fracture, later to fill with new bone, resulting in an enlargement of the nasal cavity and a widening of the external nares.
Against these opinions are the findings of Subtelny and Brodie who used a cephalometric laminographic technique to study the changes at different depths within the maxillary area of patients subsequent to orthodontic expansion. This was primarily a comparison between cleft-palate and non-cleft palate cases, and we are here interested in their findings on the non-cleft-palate cases, which were their control group. In this group changes in the maxilla arising from the application of expansion forces to the teeth were confined to the teeth and the alveolar bone surrounding them. Following the taking of specific measurements, they stated that: "The distances between unerupted teeth, the lateral walls of the nasal cavity and the lateral margins of the maxillary bones remained constant".

Much of this work has referred to "expansion forces" and "teeth undergoing maxillary expansion" or "expansion of the maxillary arch" but the method of expansion has not been considered closely enough. Previously in our consideration of tissue changes in the alveolar bone and periodontal membrane it was described how the different methods of application of the orthodontic forces varied the changes thereby induced particularly with reference to magnitude and duration. So here it will be obvious now that a light gentle force applied over a long period will allow teeth to move through the alveolar bone without placing any undue stress on the surrounding sutural system,
whereas a heavy force which crushes the tooth root against the alveolar bone leads, as was previously discussed in reference to Storeys' work (page 15 in this review), to a cessation of tooth movement until undermining resorption takes place. If the force is still acting, and if this is acting in a lateral direction in relation to the maxillary bones, then the lateral stress will be borne by the sutural system. In my opinion much of the above mentioned work should be qualified by the consideration of how much force was applied and over what duration of time.

23 Chateau & Chateau reported in 1950 on extremes in gradients of force and distinguished between expansion of the maxillary arch performed over a period of months and traumatic opening of the midpalatal suture ("osteotomy") as performed over a few days. Although no difference in the final result was reported the opening of the midpalatal suture was found to restore normal breathing and improve the general health of the patient.

22 Cauhepe reported that it was possible to produce a sutural fracture of the two maxillary bones by lateral application of strong forces, but this he termed as surgical in nature, rather than orthodontic, once again bringing out the difference in the reaction of the midpalatal suture to different degrees of force.

30 Debbane in 1958 concluded that the question of the influence of expansion upon the maxillary midpalatal suture was
apparently still unresolved, and he attempted to present the results of his work on cats as a combination of cephalometric and histologic data as well as clinical observations. Unfortunately his numbers of animals were small, two to a group and three in his control group, although his initial selection was strict. In any case his obvious application to detail gives his findings some standing.

His results showed evidence that orthodontic expansion forces applied in the maxillary region are capable of opening the midpalatal suture. The degree of opening was greater anteriorly but anatomic variations in the sutural system of the cat's upper jaws were quoted as a possible explanation of this. The forces used were obviously of such a magnitude as to be considered traumatic when used on cats. Debbane commented that probably only strong forces are capable of opening the midpalatal suture. One interesting finding was that there was a distinct difference in the tissue reactions when the type of force was varied. There was a greater opening of the midpalatal suture when intermittent expansion forces were applied, yet the amount of tooth movement was considerably smaller, suggesting to Debbane that the dento-alveolar area may be better able to resist sudden applications of force than the suture area.

Even more recent work by Thorne in 1960 using serial roentgenograms and defining the orthodontic force used (a fixed
screw plate device) showed widening of the distances between the apical bases with a corresponding but not quite as great an opening in the nasal cavity. Following suitable retention a large percentage (23 out of 28) showed either no loss of the increased width or even a further gain, whereas five cases which had little or no retention did show a decrease in the increased width.

Obviously much more experimental work has to be done to finally assess the results of widening the maxillary arch on the midpalatal maxillary suture, and this should ideally be performed on human subjects. In the interim it must be realised that widening the midpalatal maxillary suture is a traumatic operation and the amount of force and its application must be carefully judged for each individual case so that any concomitant traumatic pathology created is minimised.

Retention following Expansion.

To better understand the problems involved in the retention of maxillary arch expanded cases, I am concluding this section with a few words on the closed stomatognathic functional system as expounded by Salzmann.

In the normal course of events "the teeth must arrange themselves in consonance with the lines of stress of the closed functional system established by the jaws and the muscles of
mastication in order to avoid shearing influences and to maintain a state of functional equilibrium."

Seipel has advanced the hypothesis that "orthodontic changes are facilitated where tooth movements are going parallel to trajectorial structures within the alveolar bone, without breaking the continuity of the trajectorial pathways or stretching them". Moreover Salzmann emphasises that orthodontic tooth movement which brings teeth into conflict with the closed functional system as indicated by the trajectories (the intrinsic lines of stress) of the jaws results in the returning of the teeth from their newly achieved but imbalanced positions to their former positions in the jaws, which were not in a shearing relationship to the trajectories of the jaws.

The final stage of orthodontic treatment, the retention period, is to allow the bone changes time "to undergo fixation through permanent trajectorial changes". (Seipel.)
CONCLUSION.

Basically appliances are used to exert a force on teeth and this force is expected to produce certain changes.

If we understand the changes involved when teeth are moved orthodontically it becomes possible to adjust our appliances in a manner which will produce the required changes with the minimum amount of injury to the tissues involved. Furthermore when we know what these changes are it will become possible for us to better assess our limitations in treatment. Consequently it is obvious that a knowledge of the tissue changes incidental to orthodontic tooth movement is essential for the proper practice of orthodontia.

In the past hundred years orthodontia has graduated a long way from the description of orthodontic tooth movement ascribed to John Townes in 1865, whereby teeth requiring rotation were twisted in their sockets "with a pair of forceps for the purpose of correcting irregularity of position". The advances made were only through an appreciation of the actual biological processes involved in tooth movement, and it is a hope for the future that in an even shorter historical period of time the mechanical appliances now used with such digital skill and ingenuity will be considered equally as crude a technique as
that mentioned above by future generations of orthodontists.

Once again I stress the thought that only by further enlightened basic research can such a hope assume reality.
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ABBREVIATIONS:

Amer. J. Ortho &  American Journal of Orthodontics,  
Dent. Pract. &  Dental Practitioner & Dental Record.
Dent. Rec.  Dental Record.
Int. J. Ortho  International Journal of Orthodontia,  
J. Amer. D.A.  Journal of the American Dental  
Association.
J. A. M. A.  Journal of the American Medical  
Association.
Soc.  Orthodontic Society.


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