The Apical Base: Zone Of Interaction Between The Intestinal And Skeletal Systems*

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FOREWORD

The concept proposed in this article is not appearing here for the first time. Most of the supportive, scientific evidence, e.g., that derived from the fields of anatomy, histology, experimental embryology, human growth and development was set forth in a motion picture-lecture prepared for the Orthodontic Alumni Society, University of Illinois, in 1963. A shorter, revised version, augmented by results of subsequent studies, was presented as the eighteenth Northcroft Memorial Lecture delivered before the British Society for the Study of Orthodontics in London on November 9, 1964, and published in the *Dental Practitioner*, Volume 15, No. 9, May 1965.

Since time immemorial the teeth have been equated with the bone of the jaws that held them. This seemed perfectly obvious. For a similar period of time the alveolar process has presented an enigma. It has been shown to be true bone by all structural and vital criteria but has also been known to exhibit characteristics that were peculiar to itself. It has no distinguishable boundaries, it fails to form in the absence of teeth and disappears when they are lost. It came as a surprise to find that it was derived from the teeth themselves although this surprise was not shared by the experimental embryologist who found it quite in conformity with embryological events in other parts of the body.

We have found it helpful to divide the dentition at three horizontal levels and to examine each in detail for the factors operating on the teeth at that level. These three levels are the occlusal, the apical base of the maxilla and the apical base of the mandible. The factors working at the occlusal level, i.e., upon the crowns of the upper and lower teeth, are of greatest interest to the orthodontist as well as the most generally recognized. We shall consider them first.

The forces working at this level are principally those of the tongue on the inside and the lips and cheeks on the outside; these are integral parts of the digestive system. In the newborn these two muscle masses are in contact at the periphery of the tongue but this contact is gradually broken by the eruption of the teeth. It is easy to imagine then how the arrangement of the teeth and the disposition of the very labile alveolar bone would be controlled by the interaction of opposing muscle forces.

In this review we shall concern ourselves mainly with the buccinator muscle on the outside of the arches since it lies in most intimate contact with the teeth (Fig. 1). At the level we are considering it here, namely, the occlusal, its fibers run in a predominantly horizontal direction. In back of the dental arches it crosses from the buccal to the lingual and takes attachment to the pterygomandibular raphe. Thus it is fastened behind to structures that are subject to little growth change after the third year of life.

Since the dental arches must accommodate the succedaneous teeth and the three molars of the permanent dentition, it seems obvious that the buccina-

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tor must grow in length from one raphe to the other, i.e., circumferentially. However, there is no functional need for growth at the level of the tooth crowns after the dentition is complete.

Turning now to the level of the maxillary apical base we find factors operating under the dictates of the skeletal system. Even a casual examination of infant and adult skulls is sufficient to convince anyone that the bodies of the maxilla and mandible increase in depth and width, and vital stains have proved that this growth is brought about in part by the addition of new bone to their outer surfaces. Such growth has been impossible to measure longitudinally in the living human.

Such surface additions do not result in an ever-increasing thickness of bone

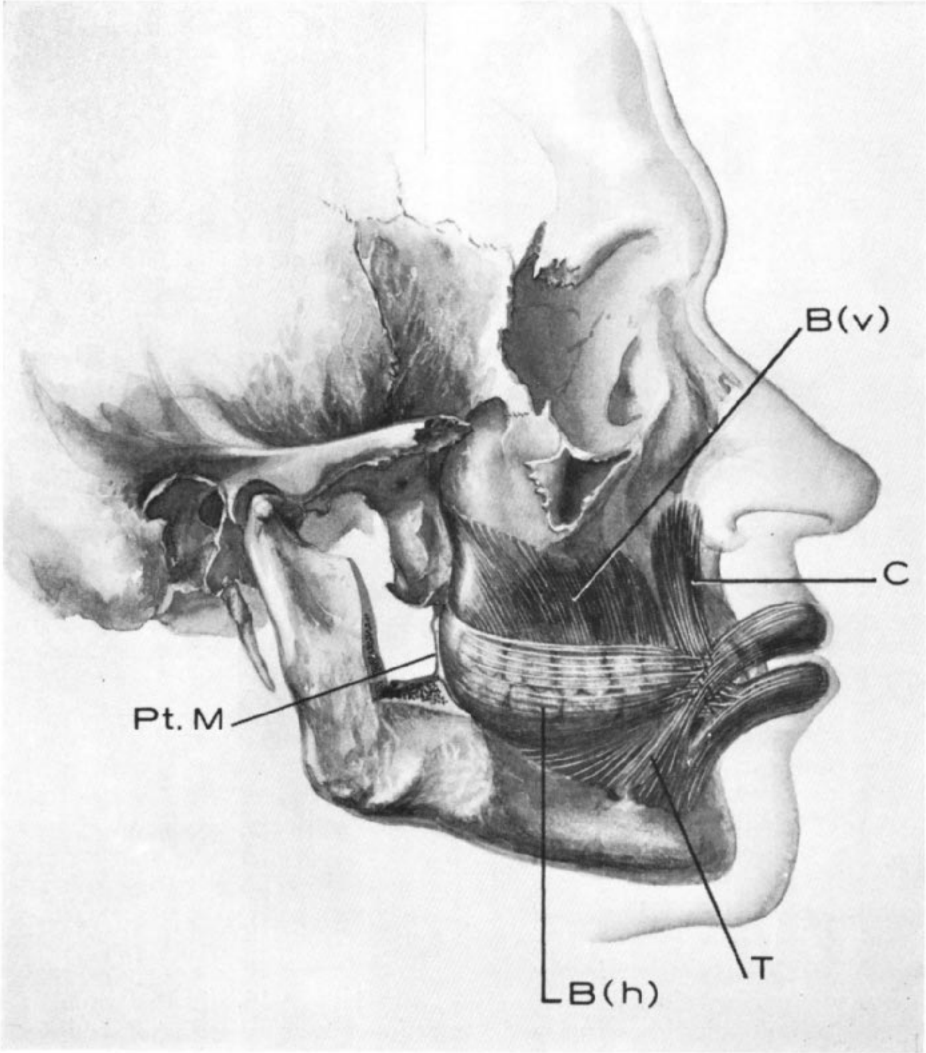


Fig. 1 Buccinator muscle as revealed by dissection of 200 cadavers (Ransford). Bv—vertical fibers of buccinator; Bh—horizontal fibers of buccinator; Pt. M—pterygomandibular raphe; C—caninus; T—triangularis.

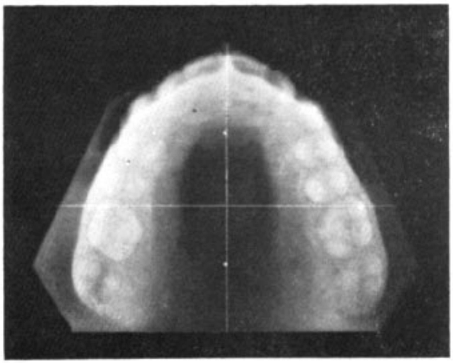


Fig. 2 X-ray of plaster model as suggested by Downs.

over the roots of the teeth. By a balanced process of deposition and resorption of surfaces within the bone, inclusions such as trabeculae and tooth roots are caused to maintain a close and constant relation to the outer surface. Thus, as the outer surface of the bone increases in periphery, the apices of the tooth roots follow it into a larger arc, although the crown arch does not follow it after a certain age. This would seem to be the most logical explanation for the gradual uprighting of the teeth as the adult stage is approached.

When viewed in this light, the alveolar process is seen to be an admirably adapted structure bridging the gap and maintaining function between two systems whose origins and development are widely different.

Ever since the advent of cephalometric roentgenology regret has been expressed that it was not possible to study the third plane of space, the horizontal, with this technique. Thus quantitative studies of widths and areas in the horizontal plane have been wellnigh impossible on the living. However, a method has now been devised which renders possible the determination of linear and area dimensions of the maxillary dental and apical base regions in the horizontal plane.

Our lead to this approach was derived from the demonstration by Downs, in 1944, that it was possible to delineate both the dental arch and what was assumed to be the maxillary apical base by x-raying the plaster model from directly above with the teeth resting on an x-ray film (Fig. 2). It eventually occurred to us that a similar view could be obtained from an occlusal view of the living by positioning the x-ray tube above and in front of the head with the axis ray directed at right angles to a film between the teeth (Fig. 3). To check the accuracy of the technique Richardson,[1] a graduate student, conducted a pilot study on twenty-five individuals from 3 to 27 years of age and showed that these x-rays were comparable to x-rays of the models of the same individuals. The method was next tested on a series of models taken on children at 8 years and again at 16 years. This revealed that with a slight change in technique it was possible to obtain an accurate outline of the apical base from the plaster model without recourse to the occlusal x-ray. Given a series of models, the way was now open

Fig. 3 Method of obtaining x-ray delineation of maxillary dental arch and apical base in the living human.

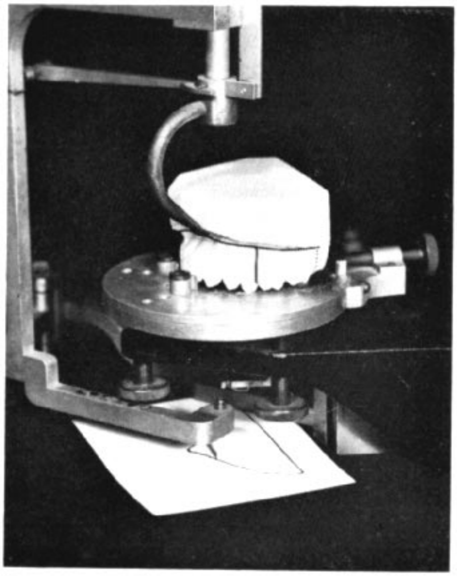


Fig. 4 Method of drawing apical base from plaster model.

for longitudinal studies of linear and area dimensions.

Briefly, the technique is as follows (Fig. 4): The model is placed, teeth down, on a platform equipped with a Stanton pantograph modified to allow a pencil marker to follow the course of an anthropometric needle on a sheet of paper lying below the platform. Because the apical bases have been defined as the zones of the maxilla and mandible that house the root apices, the point of the needle is set at the level of the apex of the root of the central incisor. This distance is derived by a correctional scale from the lateral cephalometric x-ray by dropping a perpendicular from the root apex of the central incisor to a line representing the occlusal plane. This distance is maintained constant for all models of the same individual. This precaution is essential because the maxilla tapers outwardly from above downward and hence its periphery becomes smaller as it ascends. Unless the distance above the occlusal level is maintained constant for the individual, the marked vertical growth of the maxilla makes it impossible to determine the changes taking place at the precise level in which we are interested. The periphery of the model is drawn at this distance above the occlusal plane, ending posteriorly at points directly above the mesial contacts of the first permanent molars. The area is closed by connecting the molar points with a straight transverse line.

Longitudinal series of apical base outlines (Fig. 5) have revealed a behavior pattern typical of other parts of the head skeleton, i.e., it is characterized by a steady increase on diminishing gradients. Furthermore, this increase is accompanied by changes in form. It becomes shorter and the anterior portion becomes wider.

Up to the present stage of these studies only that portion of the apical base which supports the deciduous dentition and later the succedaneous teeth has been measured. To quantitate the areas of the apical base at different age stages, each has been measured by polar planimeter and expressed in square millimeters. The purpose of

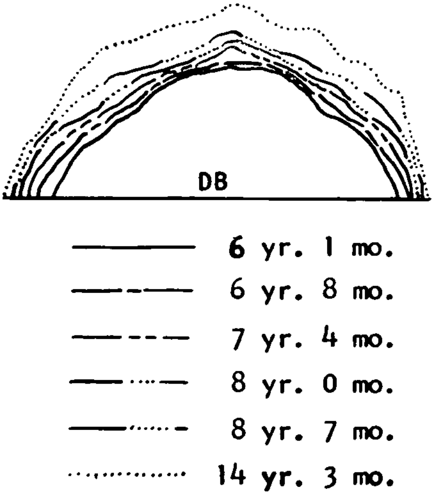


Fig. 5 Apical base drawings of an individual from 6-14 years.

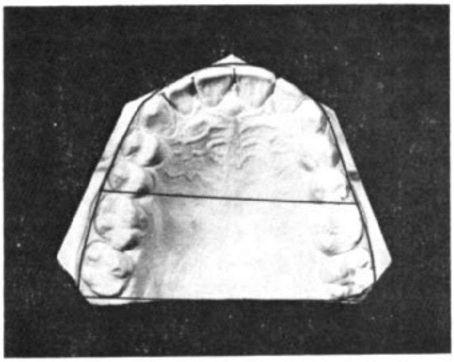


Fig. 6 Method of drawing perimeter of dental arch area. In practice this is done from x-ray of model.

limiting our first studies to the area anterior to the first permanent molar was to permit an evaluation of John Hunter's postulate of 1771 when he stated:

> "The jaw still increases in all points till twelve months after birth, when the bodies of all the six teeth are pretty well formed; but it never after increases in length between the symphasis and the sixth tooth; and from this time too, the alveolar process, which makes the anterior part of the arches of both jaws, never becomes a section of a larger circle, whence the lower part of a child's face is flatter, or not so projecting forwards as in the adult."

The greatest area of the tooth arch was similarly measured by planimeter, but from the occlusal x-rays of the models (Fig. 6). Beginning at the same base line, the periphery was drawn by connecting a series of straight lines between the most prominent points on the buccal or labial of the teeth. This simulates the course that is followed by the labiobuccal musculature at the level at which it is thought to exercise its most effective influence on the dental arch. In this manner we are able to study the changes that take place at the two levels where it is thought different factors operate.

The graph shown in Figure 7 and those that follow require a word of explanation. On the left, arranged vertically, are figures representing square millimeters in hundreds. At the bottom, arranged horizontally, are figures representing the ages in years at which determinations were made. These run from 6 to 17 years. The sample consisted of eighty-eight subjects with essentially normal occlusion. This will be referred to as the control. It was almost equally divided as to sex and the determination of the mean at each age stage was derived from no less than fifteen individuals and from many more at some stages. The resulting curves were not smoothed. The apical base is represented by solid lines, the tooth arch by broken lines. But it should be remembered that both are measurements of *areas.*

This graph reveals the mean measurements of the area of the apical base

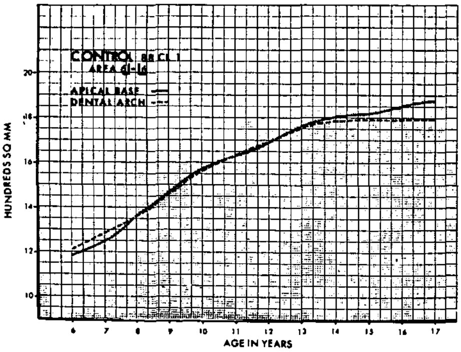


Fig. 7

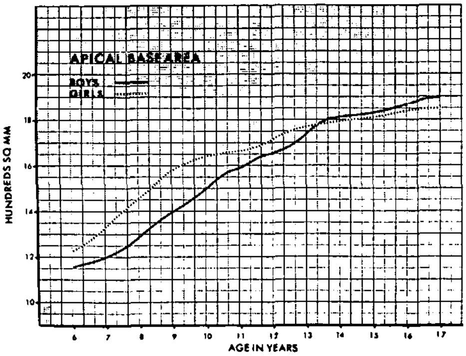


Fig. 8

and of the tooth arch in the total sample of eighty-eight boys and girls from 6 to 17 years of life. It will be noted that the two curves start at almost the same size although the dental arch is about 20 sq. mm larger in this sample at the 6 year level. From 8½ to 13 years the curves remain almost identical but then they break apart, the apical base continuing to increase at only a slightly diminishing rate while the curve of the tooth arch area flattens until there is 80 sq. mm separating them at 17 years. However, it should be noted that the area of the dental arch continues to increase, albeit at a very slow rate. We shall return to this point later.

Figure 8 shows the sex differences in the increase in apical base area. It will be noted that it is larger in girls than in boys at 6 years but that the boys pass the girls between 13 and 14 and continue to gain on them to at least the 17th year.

Figure 9 indicates the sex difference in the area of the dental arch. Girls exhibit a marked acceleration beginning at 8 years which slows between 9 and 10, while boys exhibit their most rapid gain beginning between 9 and 10 and continuing until between 13 and 14. There is little difference between them at 17, that of the boys being only 20 mm larger.

By the time we had reached this stage of our studies certain seeming contradictions were obtruding themselves. The chief of these was the slow but continuous increase in the dental arch area after all of the succedaneous teeth had taken their places. This did not fit with the well-known fact that the size of tooth crowns does not increase. The combined mesiodistal diameters of the teeth had been measured by many workers with the invariable finding that if any change was evident it would be a shortening. We finally realized that we had been trying to equate linear dimensions with areas. To determine the differences this might introduce we measured the lengths of the perimeters. Employing a map measure, an instrument that permits the determination of the length of irregular lines, we plotted the lengths of the peripheries against the square millimeter of areas contained within them.

The graph shown in Figure 10 requires a further word of explanation because of the different scales on the two sides. The figures on the left side give the area in hundreds of square millimeters contained within the perimeter, the length of which is expressed in millimeters shown on the scale to the right (perimeter solid line, area dashed line). The two curves are shown together here to convey some idea of how an alteration in the shape of a perimeter can alter the size of the area it

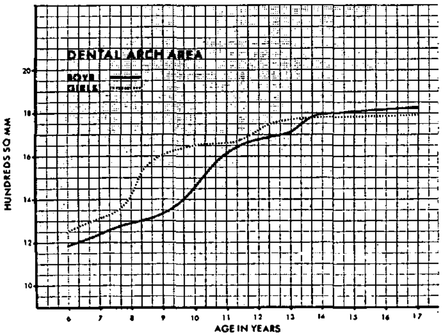


Fig. 9

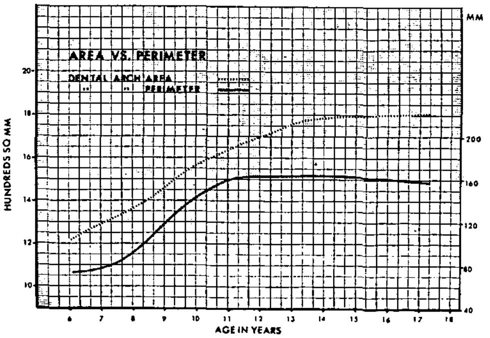
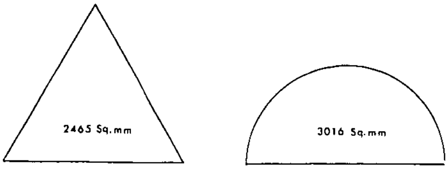


Fig. 10



BOTH PERIMETERS 145 mm.

Fig. 11

encloses.

From these curves it becomes apparent why it has never been possible to find correlations between dental arch widths and facial skeletal widths, although the effort has been made repeatedly. Figure 11 reveals the error of equating a perimeter with the area it encloses. The perimeters of the triangle and of the semicircle are identical, yet the semicircle encompasses 20 percent more area.

All of the graphs thus far have represented the mean values of a sample of eighty-eight children with acceptable occlusions. But a mean value of a group is of scant comfort to the clinician faced with a single child. He wants to know where this child would fit in relation to the scatter of the group. Thus far our data have not been statistically analyzed but we have determined their maximum and minimum limits. These are set forth in the following graphs.

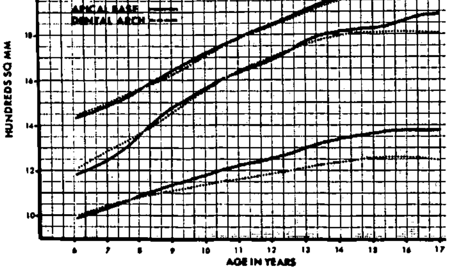


Fig. 12

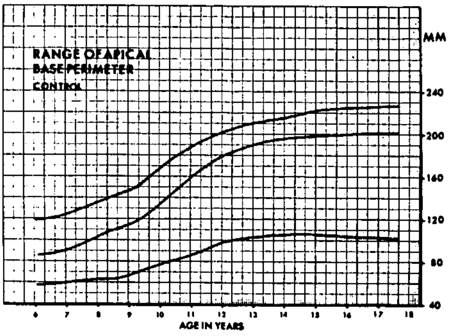


Fig. 13

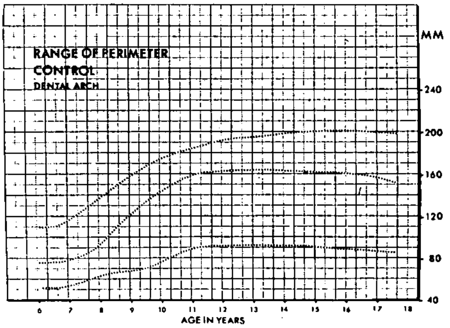


Fig. 14

Figure 12 portrays, from the bottom curve to the top, the minimum, mean and maximum increases in the areas of the apical base and those of the dental arch in the control sample. It seems significant that the means of the sample lie closer to the maximum values than to the minimum.

Figure 13 sets forth the minimum, mean and maximum values of the *perimeters* of the areas of the apical base represented in the previous graph. Again, it should be noted that the mean value of the perimeter of the apical base lies much closer to the maximum value than to the minimum.

Figure 14 exhibits the behavior of the minimum, mean and maximum lengths of the *perimeters* of the dental arch area in the control sample. Each of these shows a rather abrupt break or levelling off around the 11th year, although the maximum shows a slow rise from this point to the 14th year.

With these findings as a background, attention was turned to malocclusions. The same techniques were applied to a group of Class II, Division I cases with the following results.

The dotted line in Figure 15 represents the apical base area growth in a sample of forty-eight Class II, Division 1 treated malocclusions in contrast with that of the control. All cases had been equipped with bands on the upper first molars to which facebows and cervical straps were applied until a full Class I molar relation was established.

The curves of the apical bases of the two groups at 6 years reveal a difference in their areas of only 80 sq. mm but thereafter they behave in distinctly different manners. The curve representing the control indicates the behavior of typical, facial-skeletal growth. That of the Class II, Division 1 malocclusions exhibits increasing separation from or lag behind those of the control.

Beginning with the institution of treatment between 10 and 11 years on the average, the curve of the Class II, Division 1 sample rises steeply until it almost reaches the level of the control group; by the 17th year they are identical to all intents and purposes. The potentials of the two groups seem to have been the same.

The marked changes in the areas of the apical base and of the dental arch during treatment shown by the graph in Figure 16 accompanied the change in molar relations and seem to have resulted from it since no mechanical forces were allowed to operate on any teeth save the upper first permanent molars.

The range of area of the apical base and that of the dental arch of the treated sample is set forth in Figure 17. The similarity in the *form* of the minimum, mean and maximum curves is

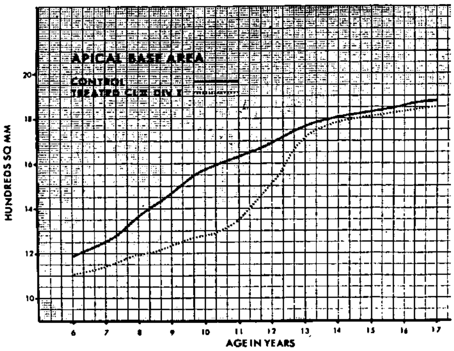


Fig. 15

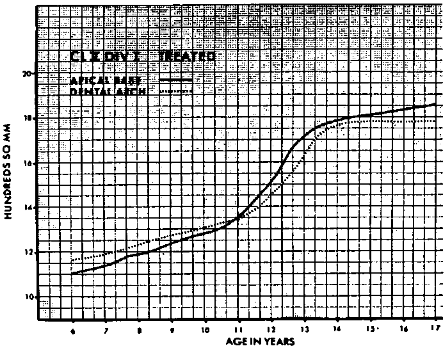


Fig. 16

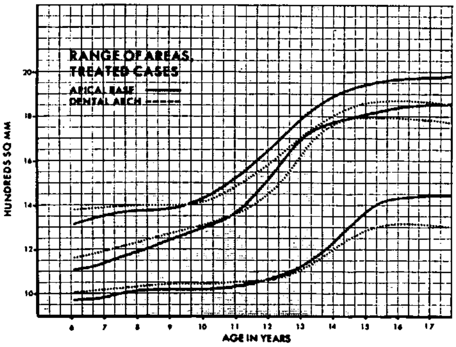


Fig. 17

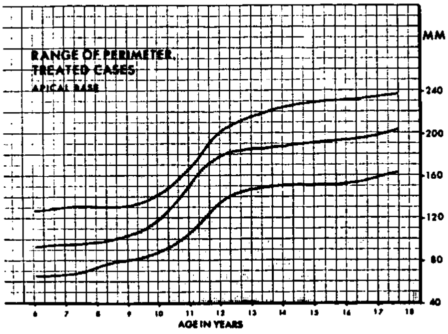


Fig. 18

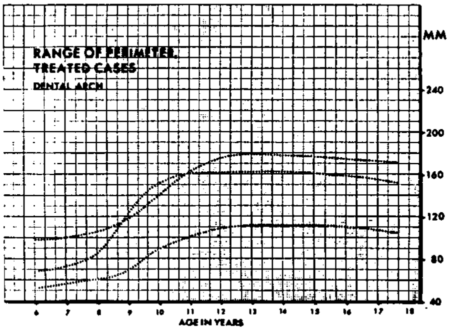


Fig. 19

apparent. Equally apparent is the fact that the mean curves are closer to the minimum at 6 years but rise rapidly toward the maximum value following the institution of treatment.

Figure 18 sets forth the minimum, mean and maximum changes which occurred in the *perimeters* of the apical bases of the treated cases. Note that all of the curves are still rising, even at 17 years.

The minimum, mean and maximum values of the *perimeters* of the dental arch areas, as shown in Figure 19, are in sharp contrast. In all of these a sharp break occurs between the 10th and 12th years and no further increase occurs; indeed, there is a gradual shortening from the 14th year onward. The behavior of the mean curve in this slide is attributable to the fact that the females outnumbered the males in the treated sample.

Figure 20 may serve to make the graphs more readily understandable. They represent the actual outlines of

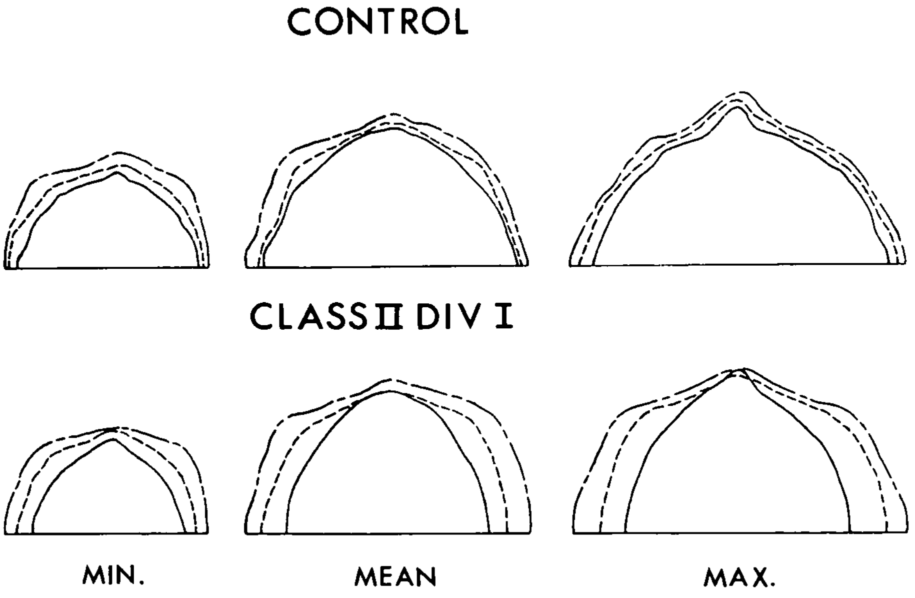


Fig. 20 Minimum, mean and maximum apical base outlines, control sample (above) and Class II, Division 1 sample (below).

the apical bases anterior to the maxillary first permanent molar at 6, 12 and 18 years. The top row represents the minimum, mean and maximum of the control sample and the bottom row the same for the Class II treated sample. Rather marked differences can be seen between them. The apical bases of the Class II, Division 1 malocclusions are more sharply tapering at the 6 year level but attain about the same form by 12 years.

In contrast with this is the growth behavior of the dental arch (Figure 21). The solid lines on this drawing represent the age changes in the apical base and the dotted lines the changes in the dental arch over the same period, i.e., from the 6th year to the 18th year. In the case shown, which was the largest in the treated sample, neither the periphery nor the area of the dental arch changed beyond the 12th year.

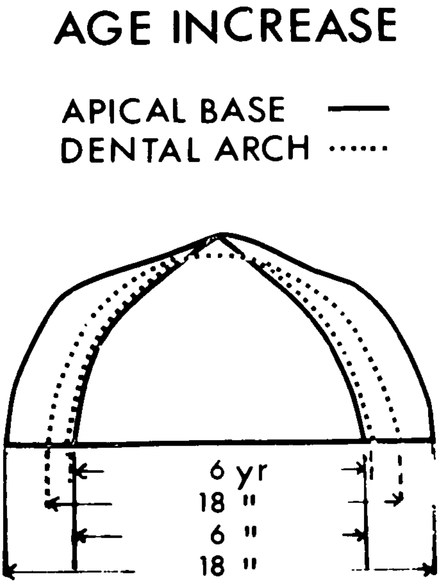


Fig. 21 Age increase in areas of apical base (solid line) and of dental arch (dotted line) from 6-18 years in largest case in control sample.

Discussion

As a result of the findings that have been presented here as well as evidence derived from the fields of human and comparative anatomy, histology and embryology, it seems clear that certain changes in concept are indicated in orthodontics. For too long we have been viewing through dark glasses dental arches that were crowded and/or shortened on the false assumption that such arches reflected the degree of development of the jaws that held them. As has been shown, they are not thus related. This pessimism has been heightened by the all-too-prevalent custom of basing treatment on the initial observation of a child, regardless of age or degree of development.

The striking differences exhibited by the length of the perimeter of the dental arch on the one hand and that of the apical base on the other strongly suggest that the crowns of the teeth are controlled by different factors than are the apices, and that we are faced with different influences at the occlusal level and at the levels of the maxillary and mandibular apical bases. The evidence that this is likely the case is readily available.

The complete formation of the tooth crowns occurs within the confines of the jaws and, so long as they are thus sheltered, they are carried passively by their bony environment. Upon eruption, however, their crowns are immediately subjected to new environmental forces, viz., the tongue, lips and cheeks. Their apices are not similarly influenced; they remain close to the site of their initiation, viz., the apical base.

As the jaws increase peripherally, the arch formed by the apices of the tooth roots does likewise so that its form at this level may come to differ widely from that at the level of the crown arch. Figure 22, taken from Lundstrom's 1923 article, shows how he illus-

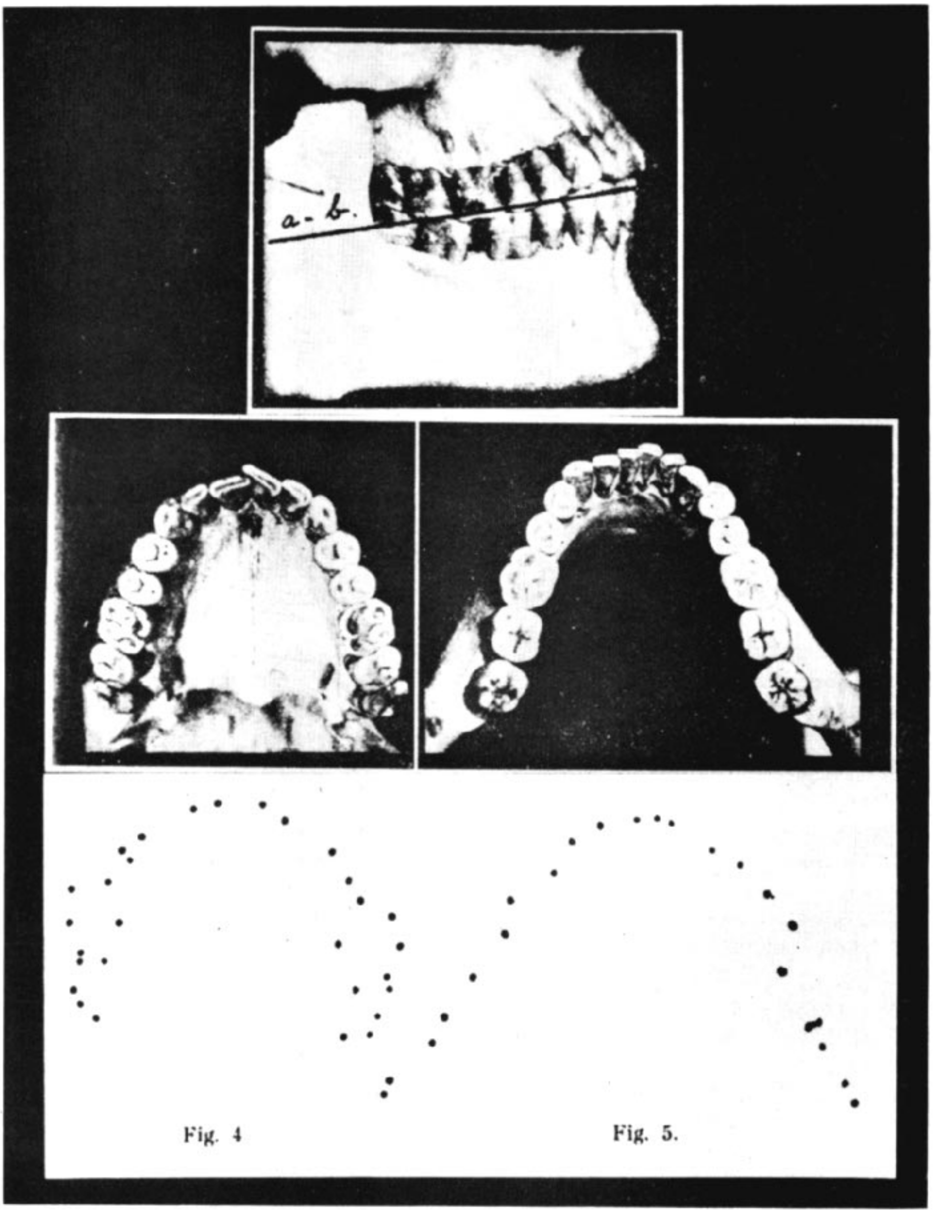


Fig. 22 Reproduction of illustrations from A. Lundstrom, "Etiology of Malocclusion Considered as a Problem in Connection with the Apical Base," 1923.

trated it. More recently it has been demonstrated by Dempster, Adams and Duddles[2] at the University of Michigan.

The following of the peripheral growth of the maxilla and mandible by the root ends of the teeth is characteristic of the growth behavior of bones. Most bones are not solid. They contain within their outer compact shells what might be thought of as inclusions, e.g., trabecular lattice work of spicules, marrow spaces or, in the present case, tooth roots. The spatial relations between these inclusions and the outer bone surfaces is established at a very early age and remains as a pattern, constant and proportional as it grows.

There is no interstitial growth of bone. All growth or other changes take place at surfaces whether they be external or internal. Thus as the maxilla grows peripherally, new bone is laid down on its outer surface and on all trabecular surfaces that face in the same direction. Concomitantly, resorption takes place on all surfaces facing in the opposite direction. The walls of the alveoli of the teeth represent similar surfaces and behave in an identical manner. Thus the teeth are kept in the same relation to the jaws that hold them throughout growth, at least their apices are. As we have seen, their crowns are under the influence of forces acting in an opposite direction.

The spontaneous change in the form of the upper dental arch which accompanies correction of the Class II molar relationship by cervical traction alone had been noted a number of years ago. It was assumed that this change was limited to the dental arch and was credited to changes in the muscular drape of the lips and cheeks. It came as a surprise that the apical base was similarly affected.

A possible explanation for this behavior of the apical base was offered by the study conducted by Howland.[3] He demonstrated with strain gauges that each of the three major classes of malocclusion presented its own rather characteristic pattern of labiobuccal pressures in the maxillary dento-alveolar and apical base areas in the canine-first premolar region. The peaked dental arch and apical base of the Class II, Division 1 case is associated with pressures that are significantly higher than in the other two classes.

Our interpretation of the findings on the apical base of the treated Class II, Division 1 malocclusion is approximately as follows.

The gradual change of a Class II to a Class I relation is accompanied by changes other than those of the teeth alone but the nature of these changes is poorly understood. That the alveolar process is remodelled seems certain and that the degree of such remodelling would decrease from the gingival to the apical end of the root would be a logical expectation. These changes alone would lead to decreased labiobuccal pressures.

An additional and probably more important factor is the marked and continuing growth of the apical base which has been demonstrated by these studies. Since the labiobuccal musculature has its major origin at this level, it can be realized that an increase in the periphery of the apical base would serve to increase the periphery of the muscular wall surrounding the alveolar processes and the dental arches, and hence further enhance the proper arrangement of the teeth.

Among the most important results flowing from the more widespread use of cephalometric x-rays is the realization of the importance of growth to the successful treatment of malocclusion. Until now, however, this information has been derived from lateral films only and has yielded data on heights and depths only. Even with these limita-

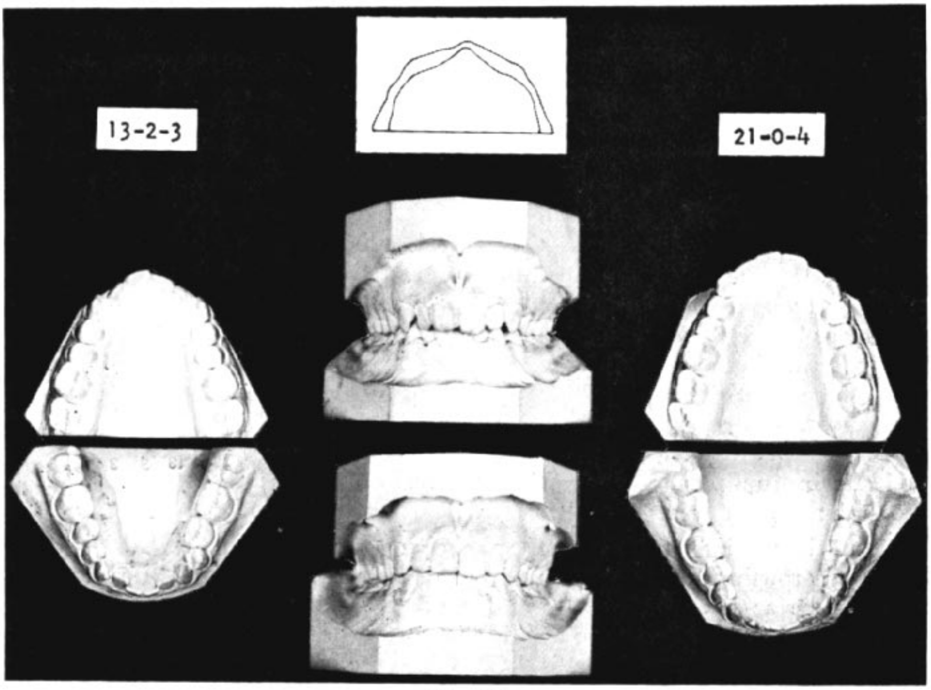


Fig. 23

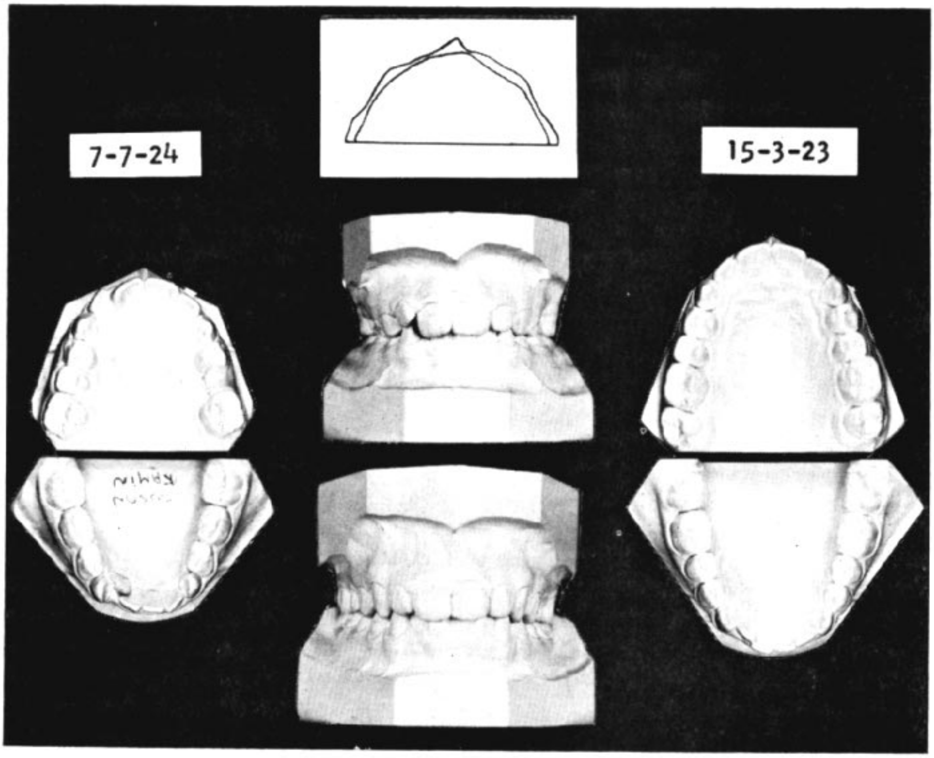


Fig. 24

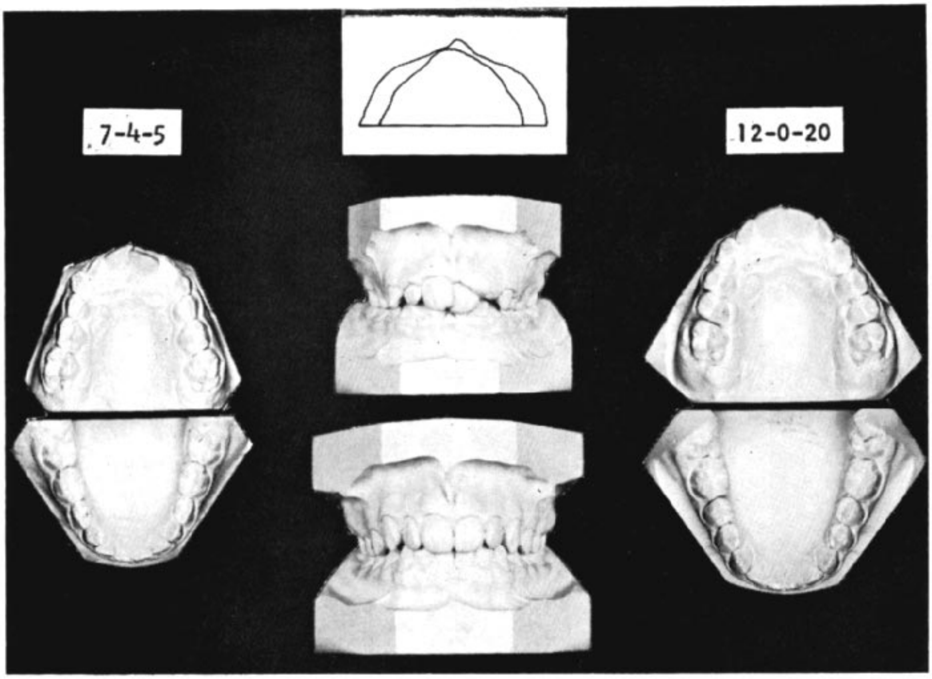


Fig. 25

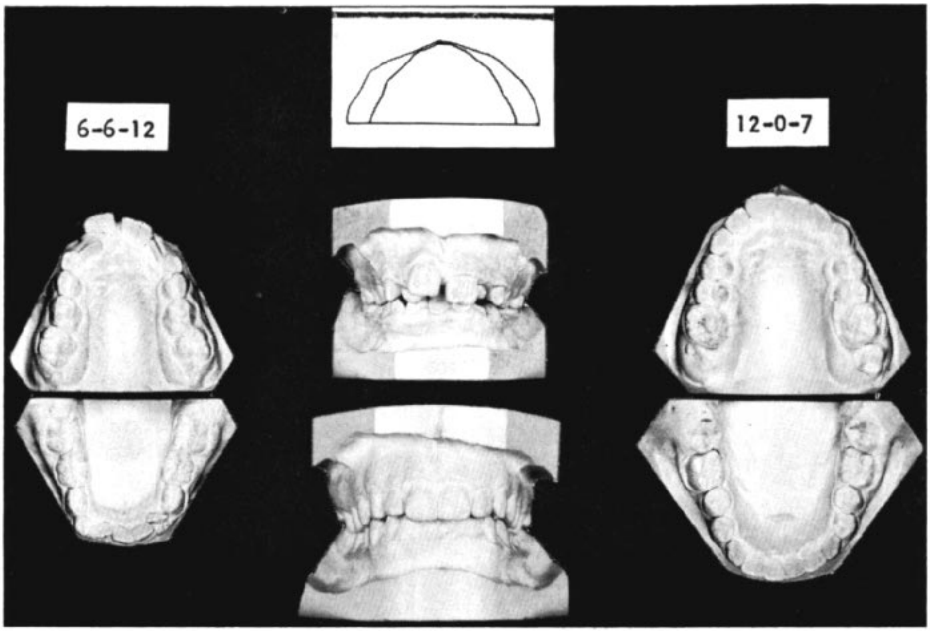


Fig. 26

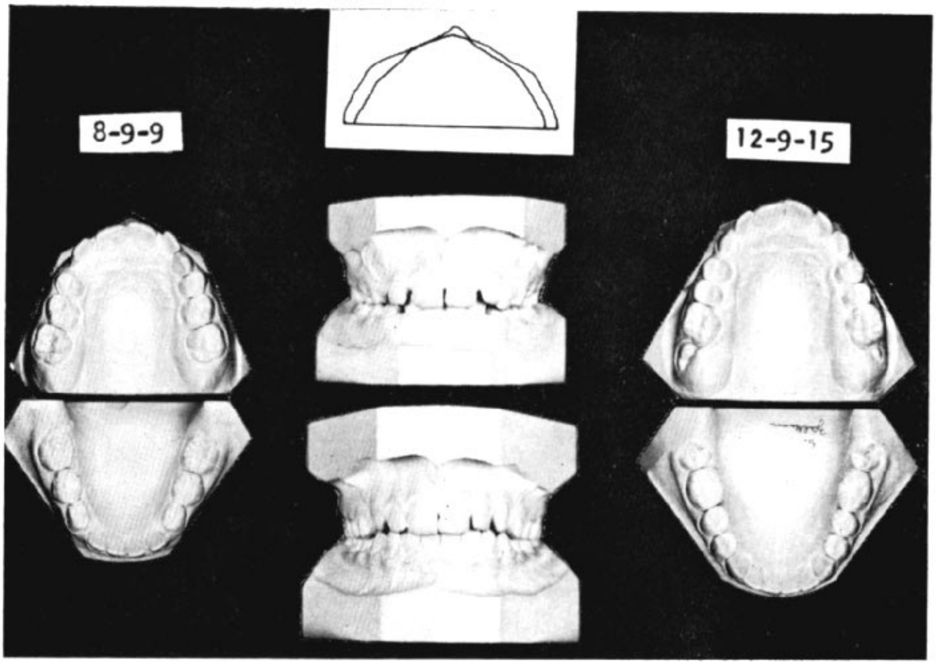


Fig. 27

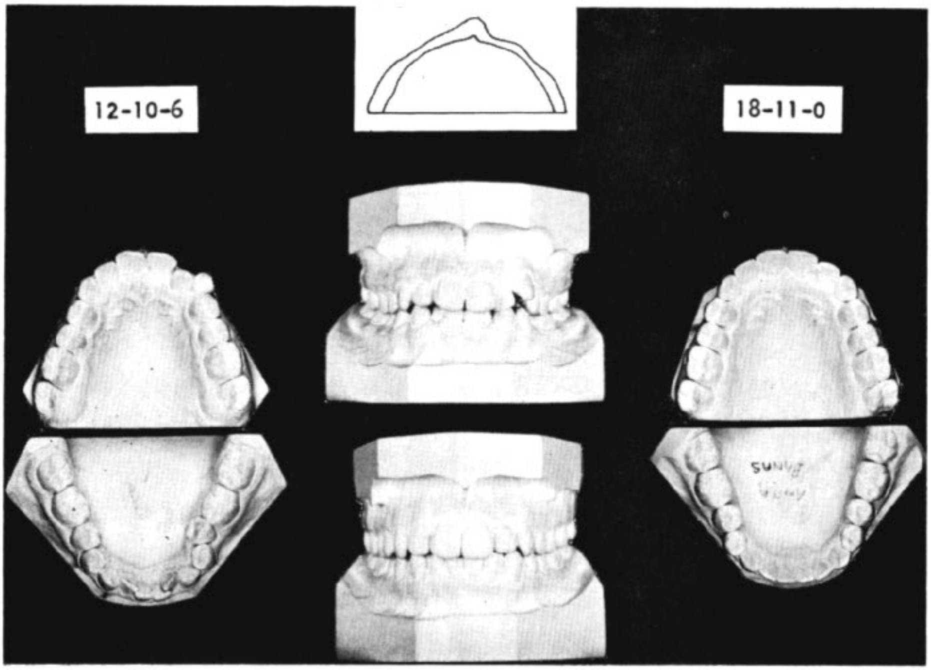


Fig. 28

tions it has been shown that anterior teeth tend to assume more upright positions during growth and that the denture appears to assume a more posterior relation to its skeletal support. With the technique that has been proposed here it is now possible to add findings in the third plane of space, not only of linear, but also of area dimensions. And as we have seen, a change in the form of the peripheries results in totally unexpected change in the areas that they enclose.

In order to reduce the findings of this study to a clinical level the following cases are illustrated. In each of these the data are arranged similarly. On the left and right are the occlusal views of the models at the ages shown above them. In the center are the front views of the two sets of articulated models. Above these, in the center, are the outlines of the apical bases at corresponding ages.

Figure 23 represents a female of 13 years, 2 months with Class I malocclusion, who was treated with a complete edgewise appliance, mainly by expansion methods for a period of 19 months. The outlines of the apical base reveal the amount of growth which resulted in a successful and stable result as shown eight years later.

Figure 24 was a female of 7 years 7 months with a Class II, Division 2 malocclusion with moderate crowding of the lower anterior teeth. The case was treated with cervical traction only, to the result shown on the right. No treatment was given the lower arch and no retention was placed. Models on the right show the case five and one-half years later.

Figure 25 was a female of 7 years 4 months presenting a Class II, Division 2 malocclusion. She was treated by cervical traction alone over a period of thirty-eight months. Note the growth of the apical base that made the result possible.

Figure 26 was a male, aged 6 years 6 months, with a severe Class II, Division 1 malocclusion complicated by insufficient arch length in both jaws. The case was treated by cervical traction until a Class I relation was attained. By this time the upper arch was as it is shown on the right and the lower needed only finger springs from a lingual arch to position the laterals. Note the growth of the apical base.

Figure 27 was a female of 7 years when first seen. Her sole difficulty was a lack of space for three of her four permanent canines. A plain acrylic bite plane was placed at 8 years 9 months to relieve the pressure on the lower incisors resulting from the deep overbite. Nothing else was done.

Figure 28 was a female of 12 years 10 months with a Class II malocclusion and crowding of both arches. Extraction of four premolars was advised without success. She was treated with complete edgewise appliances by arch extension. The result at 18 years 11 months portrays the case three years out of retention.

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