The Control of Vertical Overbite in Clinical Orthodontics

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The orthodontic profession has assumed much of the responsibility for improvement of function of the teeth and jaws. Since function is closely associated with overbite, the correction of vertical overbite and open bite comprises the major part of clinical orthodontics. It is basic to our discipline and constitutes our primary function. We have been slow to realize that vertical overbite and/or open bite depend largely upon the amount of vertical growth of molar teeth, but more especially upon the relationship between this growth and the growth of the mandibular condyles. The relationship of vertical growth to horizontal growth together with relative vertical growth of the posterior and anterior alveolar processes controls the amount of overbite.

To control overbite and/or open bite one must first control growth increments which determine overbite and open bite. Can this be done? The purpose of this paper is to show that growth increments *can* be controlled in most instances, and also to show *how* this may be accomplished. Some growth sites can be brought under the control of the orthodontist while others cannot. We will try to show just which sites can be influenced by orthodontic therapy and the extent to which this is biologically possible. Also, we will identify those sites which can be influenced little or none by orthodontic treatment.

We will endeavor to discuss this subject as comprehensively as possible; the entire discussion will be objective and factual. Most of these facts have already been published.[14,15,16,17] The information reported here was derived from a study of a random collection of sixty-two growing individuals eleven to fourteen years of age.

Growth Increments Which Affect Overbite

The growth increments relevant to the subject of overbite are found at the following anatomical areas: (1) the mandibular condyles, (2) the body of the maxilla, which has the effect of lowering the palatal plane, (3) posterior alveolar process of the maxilla, (4) posterior alveolar process of the mandible, (5) vertical growth of the anterior alveolar process of the maxilla, and (6) vertical growth of the mandibular incisors (Fig. 1).

The growth of the mandibular condyles has far-reaching implications in the treatment of malocclusion. This growth varies greatly in amount, direction, and chronological timing. It may grow in proportion or disproportion to the rest of the mandible. Marked disproportion in amount or direction may change the general conformation of the bone. Ricketts[22,23,24] has called attention to these changes and has pointed out their clinical implications. The relationship of condylar growth to the other five increments is an important study; knowledge of this is of tremendous importance to the clinical orthodontist. When this increment is grossly out of proportion to the others, overbite will be affected either favorably or unfavorably, depending upon whether there is too much or too little.

Mandibles with acute gonion angles

Based on lectures at School of Dentistry, University of Kentucky, March, 1967.

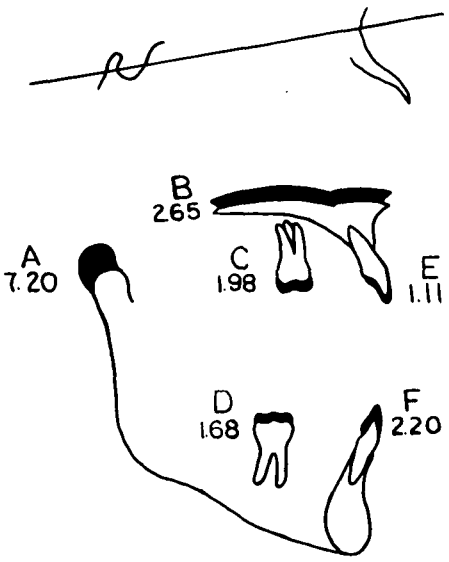

Fig. 1 Showing average growth in millimeters during a three year period from 11 to 14 years. A. condyle, B. maxilla, C. 6, D. $\bar{6}$, E. 1, and F. $\bar{1}$.

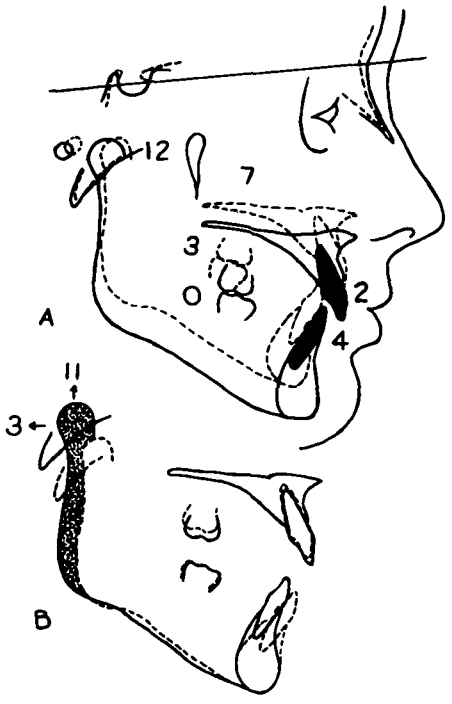

Fig. 2 A four year growth study of a female from age 8 to 12, showing that the condyles grew 12 mm, the maxilla 7 mm, 6 3 mm, $\bar{6}$ 0 mm, 1 2 mm, and $\bar{1}$ 4 mm. This was very favorable growth. Of special interest is the fact that $\bar{1}$ migrated lingually 4 mm, 6 moved mesially only 1 mm and did not grow vertically.

appear to grow more than those with obtuse angles since they thrust the chin forward more with a given number of millimeters of growth. Creekmore[3] has shown that this is not true and that the reason it appears to be true is because much of the growth is expressed vertically in the case of obtuse angles. Natoli[11] has shown why a given number of millimeters of growth at the condyles produces greater over-all mandibular length when the gonial angle is obtuse. He states that since the mandible is straighter the actual direction of the growth is more nearly in a straight line and therefore more effective in adding over-all length. Maj and Luzi[6] have called attention to the fact that obtuse mandibles increase more in over-all length.

The vertical growth of the body of the maxilla has much relevant importance to the amount of vertical overbite, since this growth, through occlusal contact, has the effect of pushing the mandible downward and backward. It is closely associated with over-all facial proportions and together with the growth of the maxillary posterior alveolar process is the primary cause of increase in anterior facial height (Fig. 2). Contrary to some expressed opinions, the maxilla is more responsible than the mandible for chin position vertically and to a considerable extent, anteroposteriorly (Figs. 3 and 4). The downward growth of the maxilla is antagonistic to condylar growth in determining chin position.

The vertical growth of the maxillary molar teeth has a significant effect on lower face height and interjaw space; this growth greatly affects vertical over-

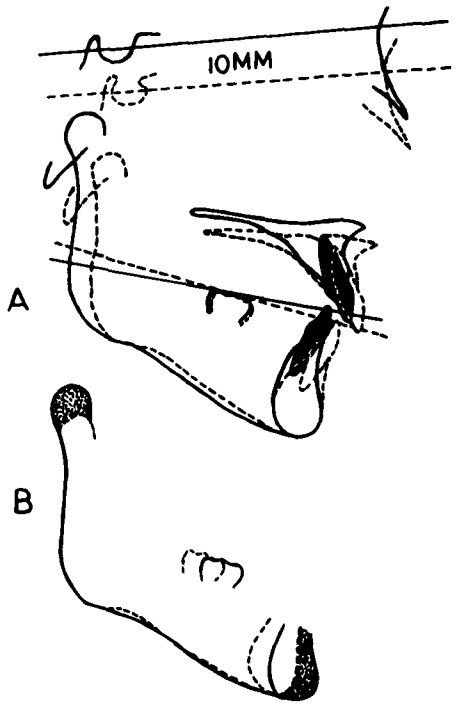

Fig. 3 This is the same individual shown in Figure 2. The tracings are superimposed on the mandibular plane and registered on the lingual border of the symphysis. A. Note that the occlusal plane tipped down on the posterior end both with relation to SN and mandibular plane. This was due to a differential in growth between posterior and anterior teeth. Also the growth of the maxilla was responsible for 10 mm of increase in facial height while the mandible was responsible for none. B. Shows relative growth of ramus and corpus.

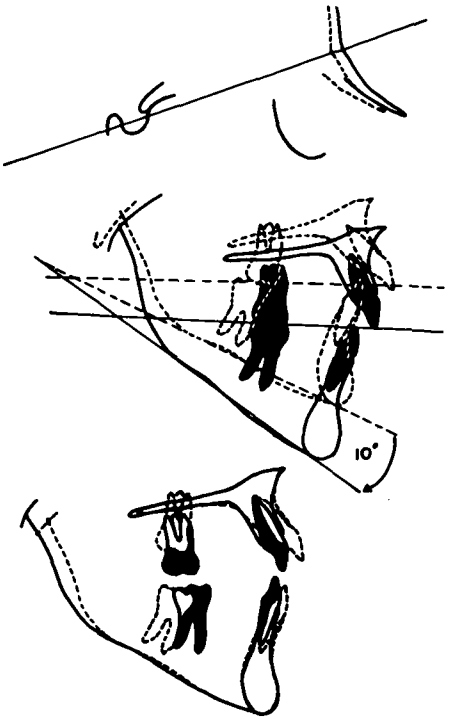

Fig. 4 Before and after treatment tracings of a female covering three years time from age 12 to 15 years. Here again the downward growth of $\underline{6}$ was responsible for 19 mm of anterior facial height while $\overline{6}$ was responsible for none. The orthodontist who treated this case was aware that Class II elastics were undesirable here but he was not aware that a cervical face bow to the maxillary molars is just as bad or worse. Treatment helped to create a vertical dysplasia of great magnitude.

bite. The author is well aware that the apparent growth of $\underline{6}$ may not be the actual growth of the alveolar process because of resorption and apposition at the palatal plane, as shown by the work of Björk.[2] The downward growth of $\underline{6}$ exceeds the downward growth of $\underline{1}$ by about a two to one ratio. Then it can be said that the downward movement of the maxillary molar teeth within the facial complex is the most important growth factor in reducing the amount of overbite, particularly that growth which occurs below the palatal plane. It is the most important factor in establishing *facial height*. Merow[8] found a correlation coefficient of .80 with this growth and increase in facial height. Creekmore[3] found this reading to be .62 which was significant at the .1% level. About seventy per cent of the total vertical growth of the face is accounted for by the downward growth of the maxillary molar teeth leaving about thirty per cent to the growth of $\overline{6}$.

Vertical growth of the mandibular molar teeth plays a minor role among

RELATIVE GROWTH OF MAXILLARY MOLARS AND INCISORS (mm)

PATIENT	$\underline{6}$	$\underline{1}$
F.E.	3.5	0.0
C.K.	5.5	1.0
J.H.	4.5	0.5
J.D.	3.5	3.0
J.B.	4.5	4.5
D.C.	3.0	2.0

Fig. 5 These six subjects represent *extremes* of differential vertical growth of $\underline{6}$ and $\underline{1}$. It is very unusual for $\underline{1}$ to grow more than $\underline{6}$. One can readily picture that the occlusal plane markedly tipped downward on the posterior end in the first three subjects.

RELATIVE GROWTH OF MANDIBULAR MOLARS AND INCISORS (mm)

PATIENT	$\overline{6}$	$\overline{1}$
C.H.	0.0	4.0
E.F.	2.0	4.0
D.C.	3.0	4.0
S.D.	4.5	3.0
F.S.	4.0	2.5
J.F.	3.5	2.5

Fig. 6 Six subjects showing differential vertical growth of $\overline{6}$ and $\overline{1}$. Such variations in growth cause changes in the cant of the occlusal plane. It is important to see that such variations do occur and to know that unlimited combinations can be found.

overbite factors. This growth has an effect, certainly, and has importance, but is subordinate to maxillary growth. However, it plays a most important role during treatment, that is, correct treatment. In growing individuals, it accounts for about thirty per cent of total vertical growth at the anteroposterior level of the first molar teeth.

The maxillary incisor teeth move downward and away from the anterior nasal spine by the growth of the alveolar process. Of all six increments this is the smallest. It is about one third of that of the mandibular incisors. Frequently the maxillary incisors do not move away from ANS at all from age eleven to fourteen, while during this period the maxillary molars usually grow from 2 to 5 mm. This phenomenon accounts for the fact that the occlusal plane descends more on the posterior end. The small amount of growth of $\underline{1}$ helps to prevent excessive overbite in many instances. Contrary to what we would expect to find, $\underline{1}$ usually grows much more in open-bite than in closed-bite cases. Excessive growth of the condyles causes a rotation of the mandible and tends to push $\underline{1}$ forward preventing downward growth.

Mandibular incisal growth is the last increment to be considered. This growth is perhaps the greatest and most variable of all the increments considered here. It seems to be Nature's best compensating factor in bringing about morphological and functional harmony. The mandibular incisor is the great "compensator" in preventing open bites. In treatment it can be intruded readily and has a very strong tendency to extrude in the posttreatment period. For this reason it should never be intruded under any circumstances if it can be avoided. Of course, if molars cannot be moved occlusally, then intrusion of $\overline{1}$ is inevitable if overbite correction is effected.

There is much variability in the amounts of these increments, and there is an infinite number of combinations which may be found (Figs. 5 and 6). To analyze cause and effect and "give and take" among these growth entities requires a depth of understanding difficult to obtain. The muscles of mastication have a very important effect upon these six growth increments. Alveolar bone growth seems to be less vigorous and less dependable than condylar growth. Hence, it is less likely to reach its inherited potential and can usually

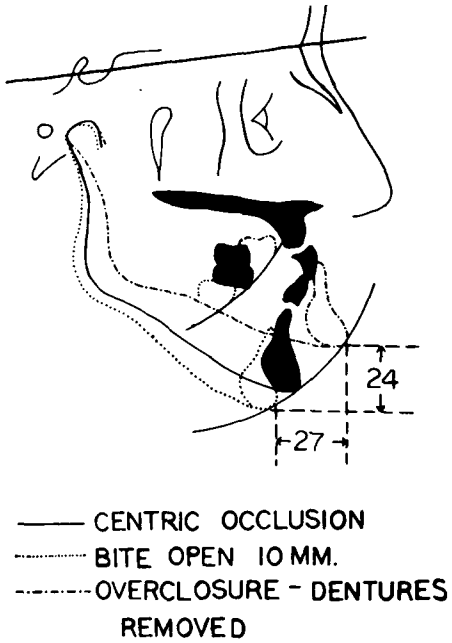

Fig. 7 An edentulous individual showing relative amounts of vertical and horizontal change which occur when molar height is changed. The relative amounts of vertical and horizontal change of the chin will depend upon facial type.

be relied upon to respond to therapeutic stimuli.

The Mechanism of Growth

Here we must briefly repeat what has already been published. In Figure 7 is shown an edentulous individual. Three cephalograms were taken, one in centric occlusion with the dentures in place, one in a position of overclosure with dentures removed and one with a block of wax between the dentures.

You will note that, as the molar height increases, the chin swings downward and backward, the mandibular plane becomes steeper, the gonion angle moves posteriorly and the facial angle decreases. Thus, by varying the molar height we were able to change the facial angle 14 degrees and the inclination of the ramus 11 degrees. It will readily be seen that molar height not only controls the vertical position of the chin, but also to a considerable extent the anteroposterior position. The chin moved vertically 24 mm and anteroposteriorly 27 mm. These principles have a definite application to the treatment of Class II malocclusions. Obviously too much vertical growth of the molar teeth would prevent the forward positioning of the chin rendering Class II correction very difficult. The first four increments mentioned above control the behavior of the mandible. They determine whether pogonion shall move downward and forward or downward and backward. They determine whether a Class II condition will be easy or difficult to correct.

Horizontal growth, that at the condyles, is pitted against combined vertical growth. They are opposite forces. Each is competing for the control of the chin. Condylar growth is trying to carry the chin forward while combined vertical growth in the molar area is trying to carry the chin downward. Increasing vertical growth of molars has the same effect on the direction of the chin as decreasing condylar growth. Decreasing molar height has the same effect on the chin as causing the condyles to grow.

Obviously there is a clear clinical application. If vertical growth is deficient we try to stimulate it; if it is excessive we try to inhibit it.

Bite Opening Potential

It is not the actual amount of vertical overbite which causes acute problems in correction but rather, the lack of *potential* for permanent change.

It is not too unusual to treat a case with 7 to 8 mm of overbite to 1 or 0 mm and have this correction remain permanently (Fig. 8). On the other hand, it is not too uncommon to have difficulty maintaining a 3 or 4 mm of bite correction. This difference is due to the fact that in the first instance we were able to induce ample vertical growth of the posterior teeth.

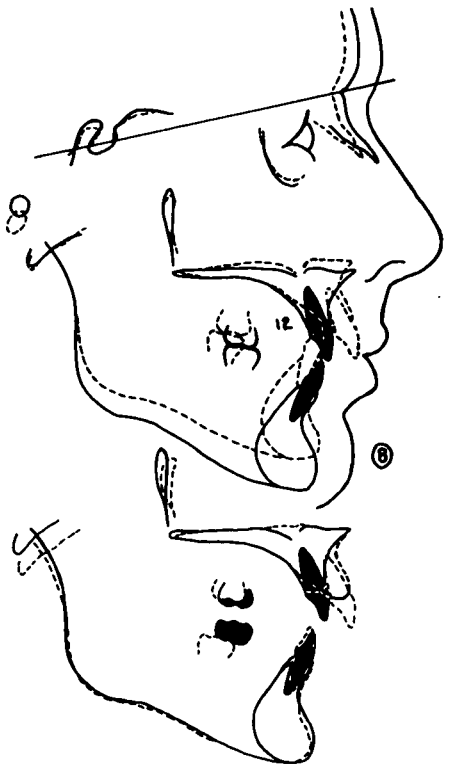

Fig. 8 Pretreatment and posttreatment records superimposed at sella. The vertical overbite was 12 mm in the beginning and was reduced to 0 mm. This has remained the same during two years of posttreatment observation. Of special interest is the marked bodily retraction of the maxillary incisors, the marked vertical development of the mandibular molars, and 8 mm of increase in anterior dental height (encircled "8").

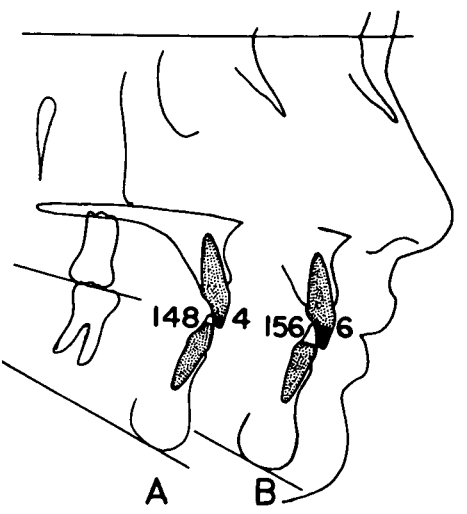

Fig. 9 This is a three year growth study of a female from 9 to 12 years of age. (A and B respectively) The vertical overbite increased from 4 mm to 6 mm, and the interincisal angle increased from 148° to 156°. The large interincisal angle was thought to be the principal causal factor in the increase of overbite.

The amount of overbite per se offers little basis for identifying causative factors. These factors may be local, such as a large interincisal angle (Fig. 9. or overdevelopment of the premaxilla. There may be inharmonies of the deeper structures, such as lack of molar height, excess ramus length, or unfavorable glenoid fossa position. The degree of overbite offers little indication of how a case will react to treatment. So, we need to point out physical characteristics which vary as does the potential for permanent bite correction. The important thing is to estimate this potential which does not necessarily vary according to the amount of overbite. What does vary with this potential?

This brings us to the subject of facial types. Certain types have greater potential for permanent correction than others. Hyperdivergent facial types usually exhibit a favorable reaction to overbite correction even though there may be a deep overbite in the beginning. Hypodivergent facial types with a deficiency in anterior facial height usually present problems in maintaining permanent overbite correction. Since overbite is not well correlated with most measurements in the human head, it does not seem logical that it can be used as a basis for type. Using the word "overbite" to explain overbite is like trying to pull ourselves up "by the boot straps." The very best and most dependable characteristic for assessing this bite opening potential is the amount of vertical facial growth which has oc-

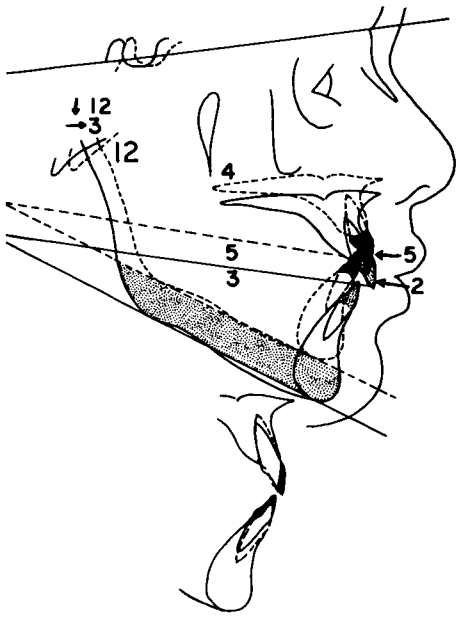

Fig. 10 In this case the vertical growth actually reduced the overbite, and also overbite correction was made easier. The condyles grew 12 mm, the maxilla grew 4 mm, $\underline{6}$ grew 5 mm, and $\overline{6}$ 3 mm. The vertical overbite was reduced from 5 to 2 mm.

curred prior to treatment (Fig. 10). This growth must be considered in relation to condylar growth. What criteria do we look for? The SN-MP, FM, and OM angles are good indicators. When these angles are large there is usually good potential for permanent overbite correction. In other words, molars will usually move occlusally. A large OM angle (21° or above) will, in nearly all instances, indicate good potential for overbite correction. Conversely, a small OM angle (7° or below) will usually indicate much difficulty in maintaining permanent overbite correction.

Cause and Effect

There is much evidence to support the belief that growth at the posterior aspect of the face (first four increments mentioned above) represents the *cause* of whatever happens in the anterior portion of the face. In this sense the growth of the incisor teeth, particularly $\overline{1}$, is largely an *effect* of posterior facial growth.

The interincisal angle is an important cause of overbite (Fig. 9). When a deep overbite develops, accompanied by a large interincisal angle, it tends to force the crowns of the mandibular incisors lingually and the apices of the maxillary incisors labially. This in turn increases the interincisal angle which causes still more overbite. Thus, a symbiotic relationship develops between the size of the interincisal angle and the depth of the overbite.

Sassouni[13] found that in normal occlusion and Class I malocclusion there usually exists a harmonious and consistent relationship between the axial inclinations of anterior teeth and the anteroposterior relation of the maxillary and mandibular bases. For instance, he states that, when there is an average or nearly ideal anteroposterior relationship between the denture bases and good occlusion, the angle formed by the palatal plane and the long axis of $\overline{1}$ is equal to the angle formed by the long axis of $\underline{1}$ and the occlusal plane. Sassouni states further that under conditions of Class II and Class III malocclusions, "The upper and lower incisors seem to behave independently and fall under the influence of lip, tongue, finger, and other habits which emphasize the original discrepancy even more."

Thus, it seems that Nature can make necessary compensations and adjustments in axial inclinations of incisors *only* when good occlusal relations of teeth are present. This is why it is of transcendent importance to correct overbites until incisors are end to end, obtain the correct interincisal angle (about 135°), and secure the integrity of the mandibular arch with a cemented retainer from cuspid to cuspid. When this has been done a harmonious axial relationship, though not necessarily a

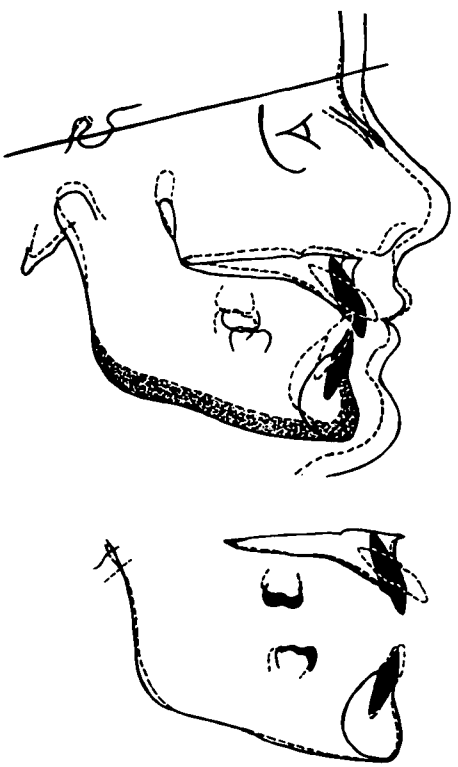

Fig. 11 Before and after treatment tracings of a female from age 11 to 13. Prior to treatment growth had been predominantly in a horizontal direction but during treatment it was downward and forward. Based on many observations, it seems reasonable to attribute most of the vertical development to treatment.

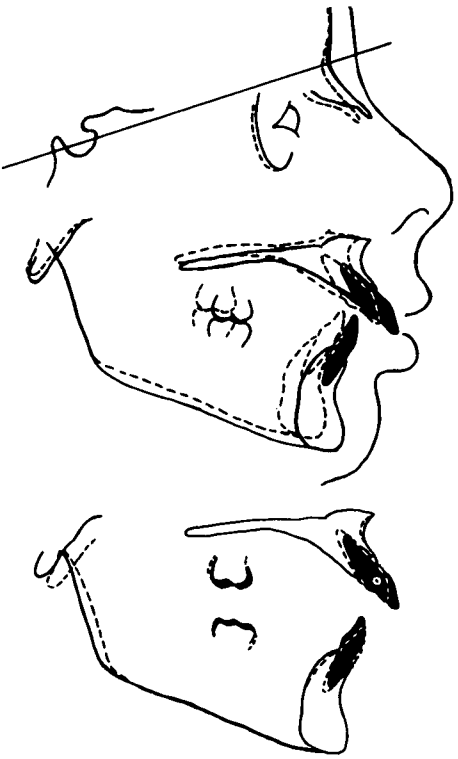

Fig. 12 A three year growth study of a male age 8 to 11. Please note that the forward growth of the mandible carried the maxillary arch along with it. The ANB angle remained the same and the overjet was somewhat increased.

constant one, can continue to exist throughout the remainder of the growing period.

Figure 11 shows a hypodivergent individual whose treatment it is believed was responsible for considerable vertical development of the alveolar processes. If this is true, then in the absence of treatment alveolar development would have been less, but condylar growth would have been the same. This would have positioned the chin farther forward pushing all of the maxillary teeth with it (Fig. 12). By correcting axial inclinations, reducing overbite, eliminating overjet, and placing a fixed retainer we gave Nature a chance to produce normal growth in the posttreatment period (Fig. 13).

Does alveolar bone have a "growing sense"? Or, is it completely subservient to the growth of basal bone? Many years will be required to amass enough information to answer these questions and establish a sound tenet. While alveolar bone growth usually responds to vertical therapeutic forces, we find many exceptions to this general rule. While it is possible to inhibit alveolar bone growth in many instances, we find many cases which grow in spite of our efforts at inhibition. A considerable amount of undocumented information has been observed which points to the possibility that alveolar bone may have a growth

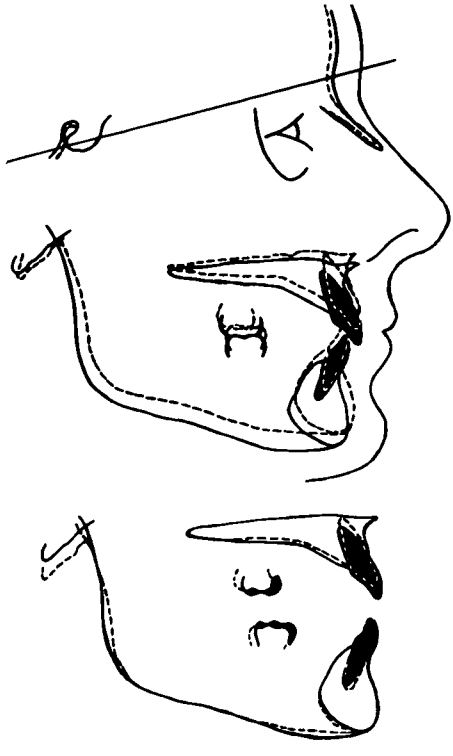

Fig. 13 This is the same individual shown in Figure 11. The tracings are post-treatment and three years later, 13 to 16. The axial inclinations remained essentially as they were arranged in treatment. Vertical development continued even after treatment and it was felt that normal function established by treatment was largely responsible for making this possible.

potential which frequently asserts itself independently of growth elsewhere.

Just why the maxillary posterior alveolar process grows vertically in one case and that of the mandible grows vertically in another case is not known. Any attempt to explain this phenomenon would be merely conjecture; however, it seems logical to believe that this growth is associated with the functional level of the posterior portion of the tongue.

The level of the posterior end of the occlusal plane should be rather important to the function of the tongue and other involved musculature. As an example consider a case in which the mandibular molars grew vertically 5 mm while the maxillary molars grew only 1 mm during the same period. Now suppose that in this same individual growth had been reversed and the maxillary molars had grown 6 mm and the mandibular molars had grown 0 mm. Such growth would have had exactly the same effect on facial morphology, but would place the posterior end of the occlusal plane 5 mm lower in the oral cavity. To change the level of the masticating table 5 mm would certainly have an effect on the function of the tongue and perioral musculature. Thus, it would seem that differential vertical growth of maxillary and mandibular molars is associated to some extent with functional level of the tongue.

Changes of the *Y* axis are indicators of the *effects* of growth in the posterior region of the face; changes of the SN-MP angle are indicators of the *cause* of the axis changes. A change in the *Y* axis merely tells us that there has been a change in the direction of progression of the chin. The SN-MP angle tells us what caused this change. If we measure vertical and horizontal growth increments we can tell *how* it occurred. Some *Y* axis opening changes are favorable and some are not, but this angle itself does not help distinguish between the two situations. Given the vertical growth increments in the molar region and those of the condyles, one can calculate the behavior of the *Y* axis quite accurately. If we are given only the positional changes of the chin as shown by the Y axis, we have no idea of how the posterior portion of the face has grown.[16]

When we find an open bite accompanied by an average SN-MP angle, it is an indication that molar teeth have grown vertically out of proportion to the growth of the incisor teeth (Fig. 14). It

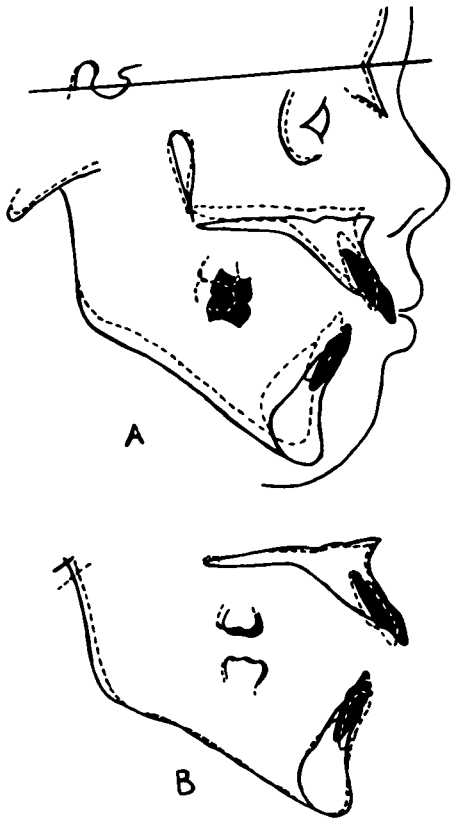

Fig. 14 This shows a two year growth study of a male age 8 to 10. A Class I case in which it was thought that four premolars should be removed to aid in limiting the ANS to menton distance and relieve mentalis muscle strain.

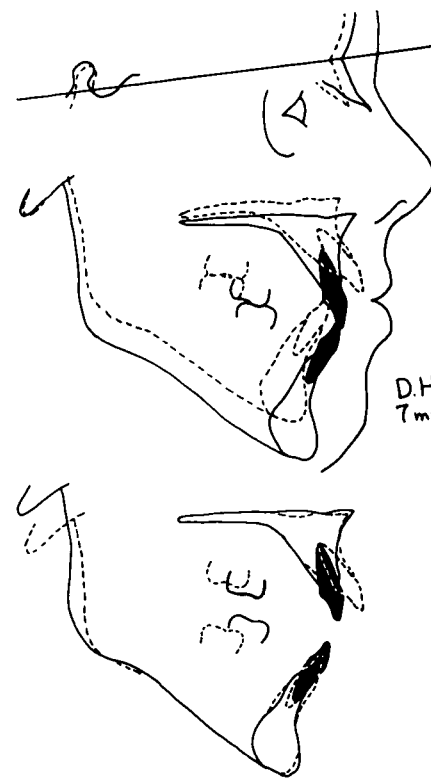

Fig. 15 The same subject as shown in Figure 14. These are pretreatment and posttreatment records superimposed at sella. The patient faithfully wore a high-pull face bow to the maxillary molars for two years trying to limit vertical development. Also, four premolars were removed, not to relieve crowding, but primarily to reduce dental height. Treatment was not responsible for the mandibular molar development since no intermaxillary elastics were worn. Obviously, there is still too much dental height and there is still mentalis muscle strain. Anterior dental height increased 7 mm in spite of our efforts to prevent it. Since the *correct* treatment principles were used, and still the treatment objectives were not reached, one shudders to think what would have happened had the *wrong* procedures been used.

means that while condylar growth and molar growth have kept normal proportions to one another, there has been *too* much molar growth to harmonize with incisor growth. The case shown in Figures 14 and 15 could have been treated without removing teeth. Ample arch length could have been provided for all teeth, but this would have produced still more anterior dental height. There was already too much height between chin and nose and the mentalis muscle was under great strain.

Since the glenoid fossa has a rather constant relation to porion, a large FM angle will *always* mean a short ramus in relation to molar height. It only registers the vertical dysplasia which exists below the glenoid fossa. The SN-MP angle registers the vertical dysplasia which exists both below the glenoid fossa and betwen this fossa and sella. A high SN-MP angle reflects a short

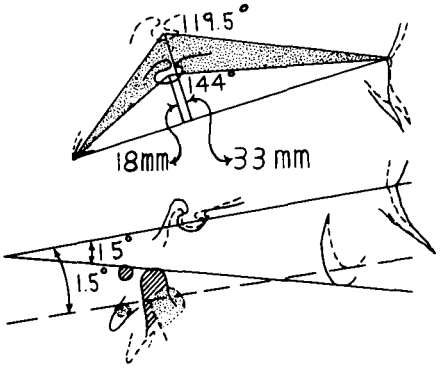

Fig. 16 Showing variations in the position of the glenoid fossa with relation to sella, and variations in the N-S-Ba angle. The saddle angle can vary as much as 25° and the angle between the SN and Frankfort planes as much as 14°.

ramus and/or a glenoid fossa positioned abnormally high. The FM angle is an indicator of relationships roughly in the denture area, while the SN-MP angle is an indicator of these same relations plus relationships *beyond* the denture area.

Thus, a high SN-MP angle may be the result of a normal ramus to molar height relationship with a porion-glenoid fossa complex positioned too high in the head (Fig. 16). Or, it may also be the result of a short ramus plus a fossa positioned too high. When the two angles are about the same (SN and FM planes about parallel) both register the same dysplasia, but must be given a different interpretation. When these planes are parallel, only one (FM) means very much; the SN-MP is somewhat misleading. Even though this is true it is usually not necessary to measure the FM angle because the OM angle will usually register the same dysplasia. The SN to MP angle under these circumstances does not reflect the inharmony *within* the denture area, because the posterior ends of both maxillary and mandibular bases are situated low producing a low SN to MP reading.

If we take a marked dysplasia in the denture area and compound it by tilting the denture complex down in front by placing porion too high in the head, we have a more severe dysplasia. If we take this same denture area dysplasia and place the glenoid fossa low in the head, we thereby reduce the severity of the total dysplasia.

Treatment should be geared to the indicators which can be detected. In some cases we can point out some valuable, well-defined indicators. In others, the indices are not well defined and their reliability cannot be counted upon.

Overbite Correlations

It may be noted in Figure 17 that only a few of the commonly used cephalometric measurements have a significant correlation with vertical overbite. This means that overbite varies quite independently of most relationships in the head. These correlations were derived from a random sample of fifty children aged eleven to fourteen selected from a group of four hundred.

These correlations may be saying many things to us if we could comprehend their meaning. They may be saying that the correct relationship of $\overline{1}$ to NB is more important than that of $\overline{1}$ to the occlusal plane ($r = -.44$ and .30, respectively). Since the correlation coefficient of overbite with $\underline{1}$ to the occlusal plane is almost as great as overbite with interincisal angle ($-.43$ and $-.45$, respectively), we may make the following deduction. In producing functional harmony we may first place the maxillary incisor in correct axial inclination from the standpoint of aesthetics and then adjust the mandibular incisor to produce the correct interincisal angle. This seems to work well in actual practice. Fortunately when the maxillary incisor is correctly angulated and the interincisal angle is correct, usually the mandibular incisor is also acceptably related to the occlusal plane and to NB.

OVERBITE CORRELATIONS

Nº	MEASUREMENT	COR. COEF.
1.	SNA	-.13
2.	SNB	-.28
3.	$\underline{1}$ TO NA (Angle)	-.38
4.	$\overline{1}$ TO NB (Angle)	-.44
5.	$\overline{1}$ TO APo (mm)	-.46
6.	OCC. TO FACIAL	.18
7.	RAMUS HEIGHT	.12
8.	ANT. FACIAL HEIGHT	.07
9.	% RAMUS TO ANT. FACIAL HEIGHT	.10
10.	ANT. DENTAL HEIGHT	-.19
11.	% RAMUS TO ANT. DENTAL HEIGHT	+.26
12.	FACIAL DEPTH	.09
13.	% DEPTH TO HEIGHT	.00
14.	POS. FACIAL HEIGHT SELLA TO MAN. PL.	.35
15.	FACIAL ANGLE	-.14
16.	INTERINCISAL ANGLE	.45
17.	$\underline{1}$ TO OCC. PLANE	.43
18.	$\overline{1}$ TO OCC. PLANE	.30
19.	$\underline{1}$ TO SN	-.42
20.	$\overline{1}$ TO MAN. PLANE	-.04
21.	ANB	.21
22.	F.M. ANGLE	-.35
23.	OM ANGLE	-.36
24.	SN-MP ANGLE	-.27
25.	$\underline{1}$ TO NA (mm)	-.20
26.	PO TO NB (mm)	.10
27.	$\overline{1}$ TO NB (mm)	-.29

SIGNIFICANCE AT 1% LEVEL = .35

Fig. 17 This table contains the results of correlating overbite with 27 cephalometric measurements. Some of these are discussed in the text.

In other words, we can usually "have our cake and eat it too."

It is the author's feeling that we may compromise the inclination of the mandibular incisor with impunity, but cannot afford to compromise its *position*. This concept is strikingly borne out in the APo correlation ($R = -.46$). This is, of course, a measure of the anteroposterior position of the incisors on the mandible as related to overbite. It means that when the mandibular incisors are positioned back on the mandible, overbite tends to be greater. It is not the inclination but the position of $\overline{1}$ which is important.

It may be noted that the correlation coefficient for the angle formed by $\overline{1}$ and the mandibular plane with overbite is —.04. This can be interpreted to mean that this relationship is not of great importance to stability and to the function of the teeth and jaws. Again, this is exactly what we observe clinically in our patients.

This table of correlations may be broadly divided into two categories: those structures immediately adjacent to the incisors and those structures remotely situated with relation to these teeth. The first category is represented by correlations number 3, 4, 5, 16, 17, 18, and 20. These have already been discussed. The second category includes 22, 23, and 24 (FM, OM and SN-MP angles).

It is encouraging and comforting to find a consistency in structures situated so far from what is being measured, in this case overbite. It is hardly likely that this would be true unless the growth of these "distant" structures is a *causative* factor in the production and/or prevention of overbite. The correlation of SN-MP with overbite was found to be insignificant (.27). The reason this reading is low was explained in a recently published article.[17] The FM angle is significant at the one % level (.35), and can be used as a useful criterion in judging bite-opening potential. It is noteworthy that the OM angle has the highest correlation (—.365) of any of the relationships which involve structures at the posterior aspect of the face. Since this is true and since clinical experience verifies it, it must be regarded as the most reliable of all factors in judging bite opening potential.

Thus, it has been shown that we can use correlation coefficients to verify the soundness of clinical concepts. In the ten thousand correlation coefficients studied, we have not found them inconsistent with clinical observations.

Conservation of Growth

The word *conservation* here is used in the sense of sparing the use of something so it will "go farther." In this case we are sparing the use of condylar growth so it will thrust the chin farther forward. This is done by reducing or limiting opposing growth increments. These opposing growth increments are those which cause maxillary and mandibular molar teeth to move occlusally. Obviously such treatment procedures are not needed in hypodivergent cases with closed bites, and with small ANB angles. They apply particularly to hyperdivergent cases with large ANB angles, high SN to MP angles, and open-bite tendencies.

It is not the amount of annual growth of the condyles which determines the forward progress of the chin but the way in which this growth is utilized. A moderate amount of condylar growth can, if properly used, solve the problem at hand. On the other hand, a generous amount of condylar growth, if "wasted," will fail to solve the problem for us. It is the job of the orthodontist to "stretch" condylar growth and "make do" with what we have. Thus, in a real sense the orthodontic problem involves a growth conservation program.

Treatment Principles

A discussion of detailed treatment procedures is not within the scope of this paper. However, it must be said that for best results in closed-bite cases it is desirable to direct treatment toward stimulating mandibular molars occlusally and inhibiting the growth of the mandibular incisors. The same is true in the maxillary arch but to a lesser degree. We must again say, parenthetically, that it is undesirable to intrude mandibular incisors because, when these teeth have been intruded, they usually try to extrude and thereby invite overbite return. This has been shown by Creekmore,[3] Merritt,[9] and Zingeser.[26] It is desirable to inhibit downward growth of the maxillary molars in open-bite cases. This can be done with a high-pull headgear. If inhibition is not possible, then we can at least refrain from inducing growth by using the wrong therapeutic forces. Why is this true and why are these principles biologically sound? Because in natural growth the maxillary molar is the primary *bite opener* and the mandibular incisor is the primary *bite closer.*

According to our investigations the mandibular molar teeth are easier to move occlusally than the maxillary molar teeth, and the growth of the mandibular incisor teeth is easier to inhibit than that of the maxillary incisor teeth. Thus, the mandibular teeth have the greater potential for aiding bite correction *provided* the correct treatment procedures are used. What are these correct treatment procedures?

In a study of twenty cases treated with a removable activator-type appliance, alveolar bone response was in sharp contrast to that routinely elicited by treatment with the edgewise appliance. In these twenty cases the vertical growth of the alveolar process was definitely no more than that seen in natural growth. The very act of banding all molars and premolars and uprighting them seems to call forth a response which does not occur unless they are banded and so positioned. This fact was brought into sharp focus in a recently published article which discussed treatment with a "continental" removable appliance.[7] By studying the tables in this article it was quite apparent that there was no comparison between the vertical response to the removable appliance and to banded appliances. The author of the article in question was extolling the virtues of the removable appliance since it allegedly allowed more forward position-

ing of the chin. Of course, the reason the chin was allowed to grow forward more with this removable appliance was because mandibular molars were not induced to grow occlusally. The profession must get away from the obsession that the greatest forward progression of the chin represents the greatest achievement. For example, two millimeters difference in the anteroposterior position of the chin is of little importance to facial aesthetics, but the same difference vertically can be of much greater importance to the function of the teeth and jaws.

Midline Corrections

The principles of treatment to be described here have been used very successfully for the past twenty years; it had been assumed that most orthodontists also used them. In recent years it has been observed that they are not well understood and that there is a definite need for their discussion.

It is well known why teeth shift laterally within the respective jaws in which they are situated. Why do mandibles shift laterally? I think that it can be said that mandibles shift laterally because of at least five reasons: (1) the maxillary arch is too wide either bilaterally or unilaterally, (2) the mandibular arch is too narrow either bilaterally or unilaterally, (3) the maxillary arch is too narrow, (4) the mandibular arch is too wide, and (5) a combination of these situations. We could have a constriction, for example, on the left side of the maxilla and constriction of the right side of the mandible. The mandible shifts to the right or the left for the sake of convenience and comfort. It shifts laterally to bring enough teeth into occlusion to masticate efficiently.

Frequently during treatment we will note that the midline deviation becomes greater as we go along. In the beginning, the midline may be slightly off, but near the end of treatment it may become worse. Why does this happen? It seems logical to assume that since teeth become loose as treatment proceeds, they are subject to the pressures of mastication. If the patient does all of the mastication on one side, greater asymmetry may be produced. The maxillary posterior segment on the side of mastication tends to shift buccally. Also, if our treatment procedures are faulty and we expand an arch through poor arch construction, say on the maxillary left side, then the mandible will shift in that direction to keep pace with the expanded arch so that mastication can be performed. Also, if due to poor arch manipulation and poor treatment procedures, we allow the mandibular arch to become more narrow on one side, then the mandible must shift toward that side in order to masticate efficiently. If both sides have been constricted equally, the individual must choose whether to use the left or the right side.

We will not discuss the correction of lateral shifts of teeth within the arches. We all know how to move teeth laterally, with coil springs, vertical loops, rubber bands, elastic threads, etc. We will deal only with correcting a mandible that is displaced laterally. The first thing to do, of course, is to note it on the model and note the extent of the deviation and the possible cause. The cause may or may not be apparent from examination of the models. Then, we go to the patient and have him move the mandible to where the midline of the maxillary teeth is directly over the midline of the mandibular teeth. This usually entails moving the mandible forward and, of course, to the right or to the left. We must be careful to have the patient move the teeth into an end-to-end position, or almost such a position, as we make this examination. When the mandible is in the right position, we study the tooth movements that will

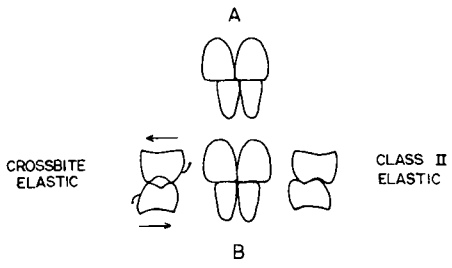

Fig. 18 This illustrates the use of intermaxillary elastics in the correction of a midline asymmetry. A. The midline of the mandibular arch is to the patient's left of the center of the maxillary arch, when the teeth are in natural occlusion. There is also an anteroposterior discrepancy, especially on the left side, which does not show in this diagram. B. The relationship of the molars when the patient places the mandible forward and to the right until the midlines are directly over each other. A Class II elastic on the left side and a crossbite elastic on the right will be required to correct the asymmetry. Torque force may also be indicated in one or both arches.

be necessary to place the posterior segments of teeth into apposition. In nearly all cases, if not all, it will be apparent that one side of the maxilla must be moved laterally, buccally or lingually. We may note also that a posterior segment of the mandibular teeth must be moved laterally, either on one side or both sides.

As we see the lateral discrepancy of the posterior segments of both maxilla and mandible, we should at the same time note the amount of vertical movement of the posterior teeth that is going to be necessary to bring them into occlusion when the anterior teeth are also in occlusion.

If we have a condition in which the mandible is shifted toward the left side, the teeth in the mandible are in the proper positions on the bone but the entire jaw is shifted toward the left side due to a combination of some of the aforementioned causes (Fig. 18). When the patient moves the mandible, which is to the left, to where the midlines are correct, we note that the maxillary arch is too narrow on the right side. We see a cross-bite condition on the right side, meaning that the maxillary arch is either too narrow on the right side or that the mandibular arch is too wide on the same side, or a combination of both. At any rate, the correction requires a Class II elastic on the left, and a cross-bite elastic on the right, running from the lingual of the maxillary right molars to the buccal of the lower right molars. The Class II elastic together with the cross-bite elastic will have the effect of rotating the mandible toward the right side and shifting the left condyle forward. The cross-bite elastic will also constrict the right mandibular posterior segment and expand the maxillary right posterior segment. This will usually correct most midlines; however, there are many varieties of midline deviations which require different procedures (Figs. 19 and 20). The time to apply these elastics is certainly not at the beginning of treatment. It will usually be after the leveling procedures, very frequently after all space closures if there have been extractions, after the bite has been opened and after good arch form has been attained. In other words, we must so arrange the teeth in the individual arches to occlude correctly when the midline is correct.

In order to accomplish the correction of asymmetry of arches, in most instances it is necessary to think in terms of the correction of segments of teeth. When it is necessary to extract four premolars, we must consider the mesiodistal shifting of the buccal segments before our spaces are closed. This greatly facilitates the correction of the midline. If we extract teeth and close the spaces, leaving the midline discrepancy as it was in the beginning, then we have a major job to accomplish.

Occasionally a malocclusion may be found in which there is a lateral shift of the anterior teeth within one or both

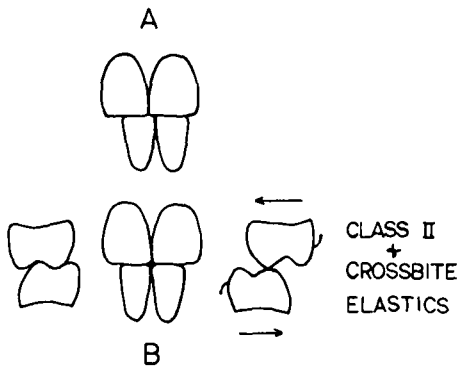

Fig. 19 A. Shows the existing asymmetry of the midlines, when the teeth are in natural occlusion. B. The relationship of the molars when the patient places the midlines in harmony; a Class II and a crossbite elastic on the left side will be required to correct the midline asymmetry. Torque may also be needed to aid the elastics.

of the arches in addition to a lateral shift of the mandible. In such cases it may not be necessary to place the intercentral embrasures directly over one another at the oral examination, but instead allow for the tooth shift by having the patient move the mandible only part of the way.

Now let us consider a case in which the midline of the mandible is deviated toward the left side approximately one half the width of a lower incisor (Fig. 19). The first thing to do is to have the patient move the mandible toward the right until the two midlines are together.

We note that, when the mandible is in this position, the buccal segments on the right side are directly over one another, while on the left side the mandible is constricted, or the maxilla is too wide, or both. For correction place a Class II elastic on the left side and a cross-bite elastic on the same side running from the lingual of the mandible to the buccal of the maxilla. This will have the effect of moving the mandible forward, rotating it toward the right side, and at the same time moving the teeth in both arches occlusally. We are also moving the maxillary left posterior teeth lingually, and the mandibular left posterior teeth buccally. This should bring about the correction of the midline of the two arches. While the operation of the two elastics prescribed will in most cases correct the asymmetry, yet it is possible that in addition to these it will be necessary to use a Class III elastic on the right side for a short time. That will have the effect of rotating the mandible from left to right while bringing the posterior segments into apposition laterally.

Let us use as an example a Class II, Division 1 extraction case in the last three to four months of treatment. Rotations and leveling have been accomplished, all spaces are closed and the Class II is corrected, but the mandibular midline is one mm to the right. The first molars and second premolars are in good occlusion on both sides. The first bicuspids have been extracted; we note that the cuspids are occluding reasonably well, especially on the left side. When we place the mandible so that the midline of the maxillary arch is directly over the midline of the mandibular arch, we see that the laterals are occluding quite differently on the two sides. On the left, the mandibular and maxillary laterals are in contact; on the right side the laterals are one mm apart. They occlude on the left side when the midlines are correct, and on the right they do not. This immediately tells us that the mandibular left lateral incisor is forward on the mandible and that the mandibular right lateral incisor is too far distally on the mandible; or, the maxillary left lateral incisor is too far posteriorly, as the right lateral incisor is anteriorly. The four halves of the arches are not anteroposteriorly harmonized, and we must check treatment arches for symmetry. It is obvious we must place a Class III elastic on the left side and a Class II

elastic on the right. This will have the effect of rotating the mandible while moving the maxillary left posterior segment anteriorly and the maxillary right posterior segment posteriorly. We may need a cross-bite elastic from the lingual of the mandibular right to the buccal of the maxillary right. The bite must have been opened to an end-to-end relationship before we can expect to correct this asymmetry. These elastics should be worn in this manner until there is an overcorrection, that is, until the midline of the mandible is toward the left side.

What is the rationale for this method of correction of midline asymmetries? Elastics must be strong to overpower muscle pull and overcome a deeply ingrained neuromuscular functional pattern. Elastics do not affect mandibular position per se. They only affect tooth position, which in turn influences mandibular position. In other words, a mandible will only adjust to an altered tooth position, and not be directly affected by elastic pull, however strong this may be. In many instances the vertical dimension plays an important part in the etiology of asymmetries of the teeth. A differential in the vertical growth of the alveolar process can be quite important in producing a horizontal asymmetry. The correction of this by the vertical pull of the elastics is an integral part of the over-all correction. Thus, both the vertical and horizontal disharmony must be corrected.

In Figure 20 it can be seen that both cross-bite elastics are pulling the mandible toward the patient's left and we want it to move to the right. Quite a paradox! The mandible will move to the right only after the teeth have moved on their bases, after the maxillary teeth have moved in the direction we want the mandible to move and/or the mandibular teeth have moved in the opposite direction.

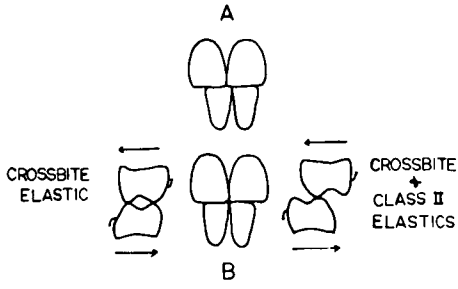

Fig. 20 A. The existing midline asymmetry when the teeth are in natural occlusion. B. The relationship of the molars when the patient moves the mandible to bring about harmony of the midlines. The arrangement of elastics necessary to correct the problem is indicated. Note that both crossbite elastics are pulling the mandible to the left but we expect it to move toward the right.

Elastics must be very strong (up to 16 oz.). It is best to use weaker elastics for about three days leading up to the stronger ones. The patient and parents must be informed carefully about the purpose of the elastics. They must be told that in order to break a habit of many years standing we must use strong forces to shock, disturb and confound the existing neuromuscular balance. They must also be told, with emphasis, that the elastics are not to be removed from the mouth under any circumstances—not even to brush the teeth. But, they can be promised that only three to six weeks will be required to correct the asymmetry. The reader must be reminded that such a system of elastics must not be applied unless both arches are completely leveled.

Many men have expressed concern about the possible reaction of the temporomandibular joint to such drastic and forceful changes in the position of the mandible. They have wondered if such therapeutic measures would lead to malfunction and discomfort at the time of the treatment or in the future. The author can truthfully say that in twenty years of application exactly as described here he has never noted any

discomfort at the time or later. Quite to the contrary, on numerous occasions discomfort and clicking have been eliminated by these procedures.

About the only exceptions to rapid correction that have been observed are deepseated anatomical asymmetries. These are usually in the form of gross differential in growth of the two rami; however, the abnormality may be located in the temporal bone or the maxilla. In such instances the recommended principles still apply; however, the effect is different. In these cases the mandible will not change its position appreciably and only the teeth will move. Since anteroposterior movement of teeth on their bases is usually necessary, considerable time will be required. In order to bring the two midlines in harmony it will be necessary to continue elastics until both maxillary and mandibular teeth are moved off the center of their respective bases. The maxillary incisors will be off center in one direction and the mandibular incisors will be off in the opposite. This, of course, is not desirable but is the only alternative other than surgery to equalize ramus length.

Discussion

Most serious students of orthodontics are now beginning to agree that facial divergence (steepness of the mandible) is a meaningful anatomical reality. Agreement is beginning to emerge on the concept that this is the soundest and most basic entity on which to base facial type. Of course, facial typing as used here means categorizing faces using as a basis factors relevant to treatment.

It is utterly appalling that the literature continues to contain expressions of concepts which are wholly untrue and diametrically opposite to the facts. Beginning as early as 1937 and continuing down through 1967, the literature continues to state that muscle pressure will intrude molars which have been moved occlusally during orthodontic treatment and continues to recommend depression of mandibular incisors.[1,4,10,21,25] This concept is just as untrue in 1967 as it was in 1937, and creates much confusion in the minds of uninformed readers. We have a moral obligation to our colleagues to place in print only correct precepts.

Subjective observation, however astute, will not tell us how much mandibular incisors have moved lingually during treatment. Before the use of cephalometric radiograms in our office, we were acutely aware of the danger of moving mandibular incisors too far lingually and tried to avoid it. After superimposing the mandibles of pretreatment and posttreatment tracings we were astonished at the amount of lingual movement which could not be observed on the models or seen by direct clinical observation. Since Holdaway[5] called attention to the importance of the effective symphysis, more and more orthodontists are aware of the danger of moving mandibular incisors lingually in certain types of cases. The work of Steiner[19,20] has brought order, definition, and direction to this aspect of treatment, and has enabled the profession to become more objective and articulate. Accurate methods of superimposition must be known and used in order to evaluate our results. Tracings are of little value unless they are correctly superimposed. We must know what we did right and what we did wrong on the last patient; otherwise, we have no basis for improvement on the next one and may go on making the same mistakes year after year. Few men are fully aware of the relative amount of anchorage present in mandibular molars as compared with mandibular incisors and cuspids. It is often almost physically impossible to move mandibular molars forward. Frequently we find from two to three times as much resistance to forward movement in mandibular molars as in maxillary molars.

These things cannot be learned comprehensively without diligently studying treatment results cephalometrically.

It makes a lot of difference what we believe. If we are unaware that intrusion of mandibular incisors is undesirable, we will have no qualms about producing it. We will go along year after year effecting this undesirable tooth movement and continue thinking that there is no need of correcting overbite for "it won't work anyway."

What effect does treatment have upon the six increments under discussion? There seems to be agreement among well-informed investigators that orthodontic treatment has little or no effect on condylar growth. Creekmore[3] studied these six growth increments on sixty-two growing individuals and compared them with fifty treated cases. While the two groups were not identical in age yet the average condylar growth was almost identical, and therefore should be favorably comparable. The results are found in Figure 21. It can be seen that the growth of $\underline{1}$ is subject to therapeutic forces and can be readily inhibited. Also it will be noted that mandibular molar growth was stimulated quite appreciably. Treatment procedures might have been responsible for the fact that $\overline{6}$ growth increased more than $\underline{6}$ growth. Had there been greater use of the cervical face bow to $\underline{6}$ there might have been a different story. There was no discernible effect on the vertical growth of the maxilla above the palatal plane. In other studies of treatment we have seen considerable evidence that the downward growth of the palatal plane can be inhibited.

The results of these investigations show that there are exciting possibilities of altering growth patterns of the face to the advantage of the patient. Vertical overbite can be successfully managed by the differential stimulation and inhibition of vertical growth of alveolar processes.

A COMPARISON OF GROWTH INCREMENTS IN TREATED AND UNTREATED CASES

INCREMENT	GROWTH	TREATED
CONDYLE	7.20	6.73
MAXILLA	2.65	2.37
$\underline{6}$	1.98	2.44
$\overline{6}$	1.68	2.77
$\underline{1}$	1.11	1.10
$\overline{1}$	2.20	0.64

Fig. 21 This table shows the effects of treatment on the six growth increments relevant to overbite. It may be noted that condylar growth was not affected by treatment. The growth of the maxilla was not affected unless it was slightly inhibited. The growth of maxillary and mandibular molars was very significantly increased. The maxillary incisor was not affected by treatment. The mandibular incisor growth was very significantly inhibited by treatment. The growth of $\underline{6}$ was increased 20%, the growth of $\overline{6}$ increased 60% and $\overline{1}$ reduced 70%.

Summary

1. The degree of vertical overbite is determined by the relationship between vertical and horizontal growth, and the relationship between the vertical growth of molars and incisors. Six specific growth increments are responsible for overbite and/or open bite. These are discussed in relation to their effects on overbite correction.
2. Predominantly vertical growth of the chin tends to reduce vertical overbite. If overbite is not reduced, then the potential for its permanent correction definitely will be increased.
3. Predominantly horizontal growth of the chin tends to increase vertical overbite. If overbite is not actually increased its correction usually becomes more difficult.
4. Anterior dental height holds the key to overbite correction. If, during treatment, the distance from ANS to menton increases the amount of the overbite, the success of the overbite correction is assured.

5. When anterior dental height is not appreciably increased we may expect the return of overbite.
6. In cases of deep overbite the primary treatment objective is to move all molar teeth occlusally and to avoid intruding mandibular incisors.
7. In open-bite cases the primary objective is to prevent increase in anterior dental height. Consequently, molars must not be moved occlusally.
8. The interincisal angle is an important cause of excessive overbite and must be adjusted adequately (to about 135°) in treatment.
9. Retention is an important part of overbite management and the cemented retainer on mandibular cuspid teeth is essential. This prevents the mandibular incisors from being driven lingually by terminal condylar growth.

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ACKNOWLEDGMENT

The author would like to express appreciation to Dr. Thomas Creekmore, his former associate, and to Dr. J. Robert Natoli, Jr., his present associate, for the preparation of the data and illustrations. Without their help these investigations would not have been possible.

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