Some Effects of Mandibular Growth on the Dental Occlusion and Profile

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The objective of orthodontic study of facial growth is to understand how growth can affect the dental occlusion and facial profile. When jaws grow they move and carry the dentition with them. If both jaws move the same amount in the same direction, the dental occlusion is possibly unchanged. When growth is dissimilar the jaws develop a new relationship to each other. Usually this change in jaw relations is partially or totally masked at the dental occlusion by compensatory tooth movements in one or both jaws. When jaw growth is not totally compensated by tooth movement, a change in the dental occlusion occurs.

Differential growth can occur anteroposteriorly, vertically or transversely. Variations in growth have traditionally been analyzed using cephalometric radiographs. Customary methods have involved superimposing the tracing of one radiograph upon the tracing of a second radiograph. The superimpositions were usually oriented on some presumably stable structures to assess the growth changes that have occurred. Measurements between points were made in the before and after jaw tracings. The amount and direction of growth were described using the movement of these points. This resulted in a linear concept of quantitative growth. The final result produced a conclusion that the face grows downward and forward in a straight translatory manner.

A different technique to study growth has been widely reported in recent years by Björk and coworkers.[1-4] The fundamental difference in their technique is that fixed metallic markers have been placed in the growing jaws permitting superimposition on the jaws themselves. This permits excellent descriptions of tooth movement *per se* on the jaw. It also reveals the error of the use of the palatal and mandibular planes as superimpositioning points to reveal tooth movement.[6]

Björk's technique has disclosed that growth of the jaws is not linear as previously supposed. His precise tool clearly indicated that the usual pattern of jaw growth is dissimilar and unequal in amount and direction. The effect of this lack of uniformity is that facial growth is revealed as a primarily rotary phenomenon. In almost all of the cases thus far reported the maxillae and the mandibles have grown dissimilar amounts in the anterior and posterior areas producing rotations in the sagittal plane. These rotations would produce major changes in the dental occlusion if they were not compensated by dissimilar dentoalveolar growth. Fortunately this compensation usually occurs and the changes manifested in the dental occlusion are minimal. This is totally consistent with the usual clinical observations of minimal changes in Class II or Class III with growth alone.[5] Björk[4] showed that the external surfaces of the jaws were remodeled during growth masking the rotations. Indeed, these remodeled external surfaces contain the very landmarks orthodontics has used

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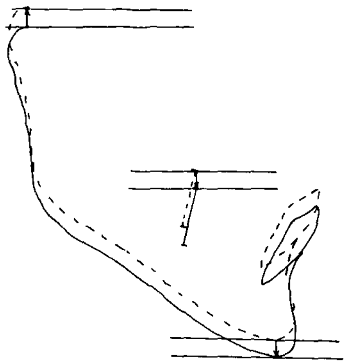

Fig. 1 Two tracings of the same mandible illustrating translatory movement resulting from equal increments of growth. The center of rotation is at infinity.

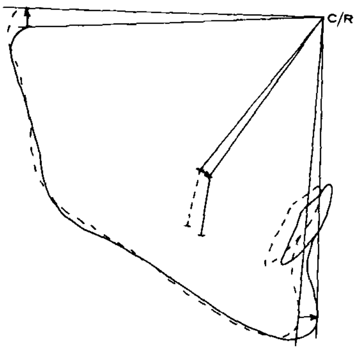

Fig. 2 Forward rotating growth resulting from vertical condylar growth exceeding vertical sutural-alveolar growth. The center of rotation, C/R, is shown.

to study growth. This, of course, leads to the conflicting results and controversial conclusions present in the literature.

The purpose of this report is 1) to demonstrate and explain jaw rotations that occur, 2) identify how variations in these rotations differentially affect the dental occlusion and profile, 3) show how vertical growth of the ramus is capable of producing anteroposterior dental and profile changes, and 4) demonstrate a method of analyzing jaw growth and its effect on dental occlusions for patients.

Mandibular Rotations

When the increments of vertical growth at the condylar fossa area exactly equal the increments of vertical growth at the maxillary sutural-alveolar process area, no rotations occur. This proportional, balanced vertical growth results in translation of the mandible as shown in Figure 1. The direction of the translation is controlled by the direction of the vector of growth.

When the vertical growth at the condylar-fossa area exceeds the vertical growth at the sutural-alveolar process area, forward rotation occurs. Figure 2 shows vertical growth at the condyle and no vertical growth at the incisor. This disproportionality results in a center of rotation anteroposteriorly located over the incisor. The vertical location of the center of rotation is determined by the direction of the vector of condylar growth. Notice in Figure 2 that this particular center of rotation possesses almost total vertical change at the condyle, partial vertical and partial anteroposterior change at the molar, and almost total anteroposterior change at the incisor and pogonion. The center of rotation is not a cause. It is a result and it describes the proportionality of vertical growth coupled with the direction of the vector of condylar growth.

Figure 3 has the same direction and the same amount of condylar growth as Figure 2 but, in addition, has an increment of vertical growth at the alveolar processes. This moves the center of rotation anteriorly in the direction of infinity. The result of this compared with Figure 2 is that, while the condyle moves the same amount in the same vertical direction in both cases, in Figure 3 the molar is carried in a more vertical and less anteroposterior direction as are the incisor and pogonion.

As the amount of vertical growth at the alveolar processes more nearly equals the vertical growth at the condyle, the mandible approaches parallel

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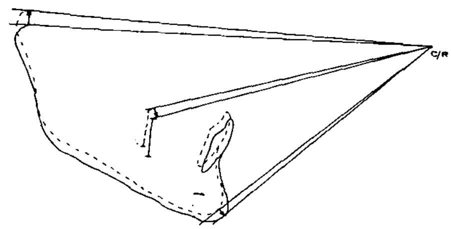

Fig. 3 Growth resulting from the same vertical condylar growth as in Fig. 2 but a greater increment of vertical growth at the sutural-alveolar area. The center of rotation, C/R, has moved away from the dentition toward infinity.

movement. When vertical growth of these two areas is equal in amount, the growth is proportional and translation occurs as shown in Figure 1 with the center of rotation at infinity.

When the vertical growth at the alveolar processes exceeds the vertical growth at the condyle, backward mandibular rotation occurs. In this instance the center of rotation must be posteriorly located. Figure 4 shows a small amount of condylar vertical growth and a larger amount of vertical alveolar growth. The center of rotation is posteriorly located and the teeth and pogonion are carried downward and backward.

Figure 5 depicts the same vertical amount and direction of condylar growth as seen in Figure 4; however, an increased amount of vertical alveolar growth is apparent. This results in a relatively increased proportion of vertical sutural-alveolar growth as compared with condylar-fossa growth. Increasing disproportions of vertical growth move the center of rotation toward the mandible. This increases the amount of backward direction that the teeth and pogonion manifest as growth occurs. This is ideal for Class III mechanics but undesirable for Class II treatment.

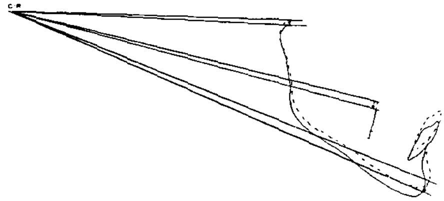

Fig. 4 Backward rotating growth resulting from vertical sutural-alveolar growth exceeding vertical condylar growth. The center of rotation, C/R, is posterior to the head.

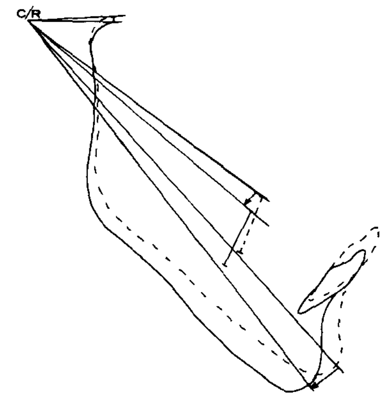

Fig. 5 Growth resulting from the same vertical condylar growth as Fig. 4 but with a greater increment of vertical sutural-alveolar growth. The center of rotation, C/R, has moved toward the body.

Again, it is apparent that it is not just a matter of how much growth occurs. It is far more critical as to the proportionality of vertical growth that occurs between the condylar area on the one hand and the sutural-alveolar processes on the other. Identical increments of vertical condylar growth both in amount and direction can result in different centers of rotation depending on the amounts of vertical alveolar growth simultaneously occurring. These varying proportions result in different centers of rotation. Different centers of rotation result in teeth being carried different directions and different amounts with identical amounts of condylar growth.

Conversely, identical amounts of vertical sutural-alveolar growth paired with different amounts of vertical con-

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dylar growth can show different centers of rotation. This will result in the mandible being carried in different amounts in different directions.

It is apparent that the anteroposterior location of the center of rotation is a function of proportionality of vertical growth. As vertical condylar growth more nearly equals vertical alveolar growth, the center of rotation moves toward infinity.

The location of the center of rotation in a vertical direction is a function of the direction of the vector of condylar growth. Figure 6 shows a condyle growing upward and forward resulting in a downward and backward mandibular displacement. More vertical growth is present at the condylar-fossa area than at the sutural-alveolar processes area. This locates the center of rotation in a position that results in the molars and pogonion all being carried downward and backward also. Under these circumstances new growth is a liability for most Class II treatments.

Figure 7 demonstrates a vector of condylar growth upwards and backwards. The proportionality of vertical growth shows no alveolar growth at the incisors to match the vertical condylar growth. The result is a center of rotation that gives downward and forward condylar displacement, greater forward

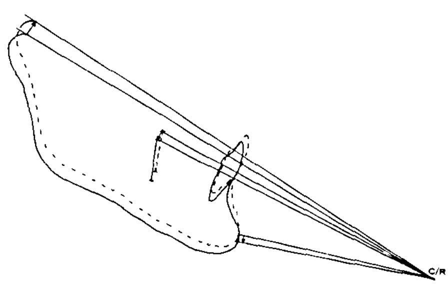

Fig. 6 Forward rotating growth pattern with a condylar vector directed upward and forward. The center of rotation, C/R, is anterior, but not vertically high or low enough to decisively influence anteroposterior tooth position.

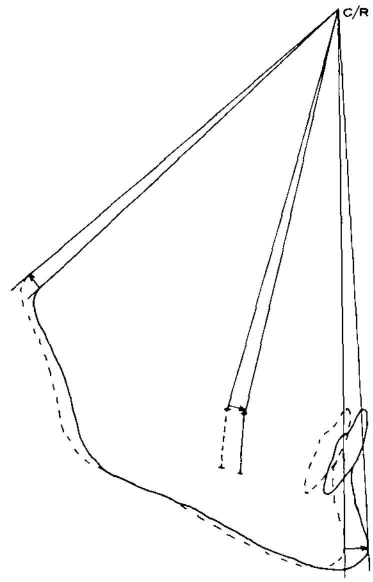

Fig. 7 Forward rotating growth pattern with vertical growth proportions similar to Fig. 2. The vector of condylar growth is up and back locating the C/R farther away from the dentition, thereby increasing anteroposterior dental changes.

molar displacement, and almost total forward pogonion and incisor displacement. This growth pattern is ideal for Class II corrections.

Figure 8 shows essentially the same amount of condylar growth both in vertical amount and direction as shown in Figure 7; however, the vertical alveolar growth exceeds the vertical condylar growth. This results in a backward mandibular rotation. The center of rotation created shows less mesial molar movement and vertical pogonion movement when compared with Figure 7. Again, identical amounts and direction of condylar growth have decidedly different effects on the occlusion and facial profile. The relative proportionality of vertical alveolar growth to vertical condylar growth is critical.

Figures 9 and 10 show identical vectors of condylar growth upward and forward. Less vertical alveolar growth

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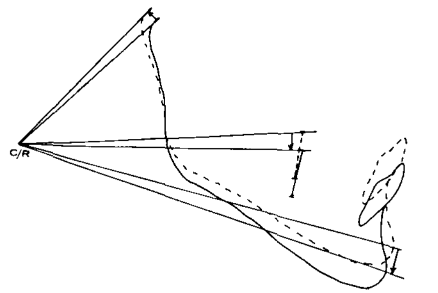

Fig. 8 Backward rotating growth pattern with the same vector of condylar growth as shown in Fig. 7; the proportions of vertical growth move the C/R posterior to the head.

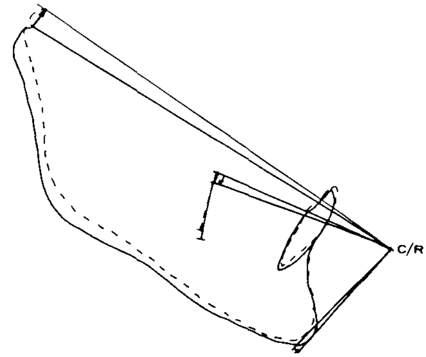

Fig. 9 Forward rotating growth pattern with the same vector of condylar growth as Fig. 6. The proportions of vertical growth show less sutural-alveolar growth thereby maximizing the anteroposterior effects.

occurs in 9 than 10. The result is a more anteriorly located center of rotation in Figure 9 with the molar carried slightly downward and backward and pogonion downward and forward. In Figure 10 both the molar and pogonion are carried a greater distance downward and backward. In both cases the condyle grows in identical amounts in identical directions but the effects on the profile and the dentition are markedly different. Figure 10 will tend toward an open bite far more than Figure 9 in spite of the fact that both mandibles experienced identical directions and amounts of condylar growth.

The center of rotation is a result, not a cause, of jaw growth; it is located in an anteroposterior direction based on the proportionality of vertical growth at the condylar-fossa area versus vertical growth at the sutural-alveolar process areas. When these are equal the center of rotation is at infinity and mandibular growth is translatory. The greater the disproportionality in vertical growth between these areas, the closer the center is to the head. A center of rotation located near the head has maximal anteroposterior dental and facial effects resulting from vertical condylar growth (Figs. 2, 7). This is true for both forward and backward rotating growth patterns. In forward rotating patterns vertical condylar growth is converted to anterior movement of the dentition when the center of rotation is above the occlusal plane (Figs. 2, 7). Anterior movement of the dentition occurs with a backward rotating growth pattern when the center of rotation is below the occlusal plane.

The dentition is carried distally with a forward rotating growth pattern when the center of rotation is below the occlusal plane (Fig. 6). Distal

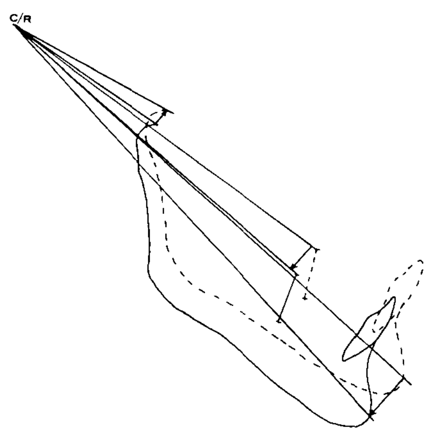

Fig. 10 Backward rotating growth pattern with the same vector of condylar growth as Figs. 6 and 9. The increased amount of vertical sutural-alveolar growth in this illustration increases the distal movement of the dentition with growth in these proportions.

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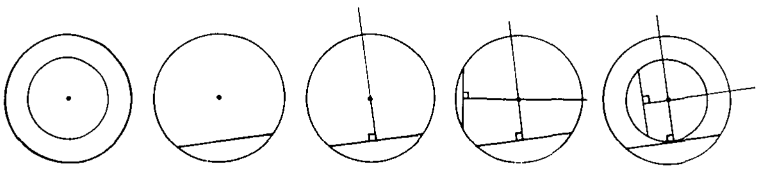

Fig. 11 From left to right. Concentric circles have the same center or center of rotation. A chord is a line intersecting two points of a circle. The perpendicular bisector of a chord passes through the center. Perpendicular bisectors of different chords intersect at the center. Perpendicular bisectors of chords of concentric circles intersect at the center.

movement of the dentition occurs with a backward rotating growth pattern when the center of rotation is above the occlusal plane (Figs. 4, 5).

Determining Centers of Rotation

It is apparent that growth is not simply a matter of downward and forward growth with the only variation being direction and amount. The critical factors are proportionality of vertical growth and the direction of the vector of condylar growth.

To understand how normal growth affects the occlusion and profile of a patient, it is valuable to determine the center of rotation. This can be done using the basic principles shown in Figure 11. These figures illustrate that a perpendicular bisector of any cord of a circle passes through the center of the circle. The perpendicular bisectors of two cords will locate the center of the circle where they intersect. This is the center of rotation.

For application of this principle to a mandible, it is necessary to determine two cords of the rotation resulting from mandibular growth. To do this, it is necessary that preobservation and postobservation tracings of the mandible are capable of superimposition on themselves. In the absence of implants this can be done using Björk's[3] method of superimposing mandibles on the contents of the mandibular canal, internal cortical border of the symphysis, and lower border of third molar tooth buds prior to root formation.

To geometrically locate a center of rotation, the steps necessary are:

1. On the preobservation tracing a mandibular reference point is selected in the region of the mandibular symphysis. A second point is selected in the region of the mandibular foramen (Fig. 12).

2. The tracing of the postobservation radiograph is superimposed on the tracing of the preobservation radiograph with the mandibular canal, lower border of the third molar follicle, and internal border of the symphysis coinciding. The two reference points are then transferred to the tracing of the postobservation radiograph (Fig. 13). The areas where the tracings fail to coincide represent external remodeling and tooth movement occurring on the jaw base.

3. A reference line is arbitrarily defined on the preobservation tracing in the region of the anterior cranial fossa (Fig. 14).

4. The tracing of the postobservation radiograph is superimposed on the tracing of the preobservation radiograph using anterior cranial structures. The cranial base reference line is transferred to the postobservation radiograph. With the cranial base reference lines coinciding, a line is drawn connecting the preobservation reference point in the area of the mandibular symphysis to the postobservation reference point. Similarly, the preobservation and postobservation references in

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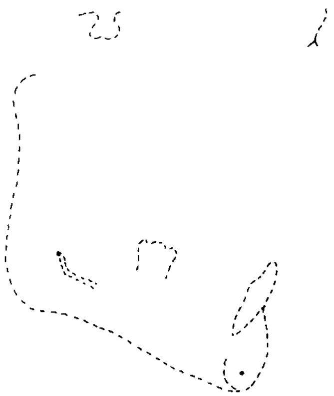

Fig. 12 Reference points selected on tracing of preobservation tracing.

the area of the mandibular foramen are connected with a line (Fig. 15).

5. Perpendicular bisectors of these lines connecting the reference points are constructed. The intersection of the perpendicular bisectors is defined as the center of rotation of the mandible (Fig. 16).

If the perpendicular bisectors have been accurately constructed, the center of rotation so located will represent all movement that occurs by disproportional growth. The method may be tested by placing a pin through the center of rotation with the preobservation and postobservation radiographs coinciding on the cranial base reference line. The postobservation radiograph then is rotated around the pin and the arbitrarily placed mandibular reference points should come to coincide with each other. The determination of the center of rotation will enable a more accurate estimation of the dental changes and profile changes that have resulted from the growth that has occurred during the observation period for that particular patient.

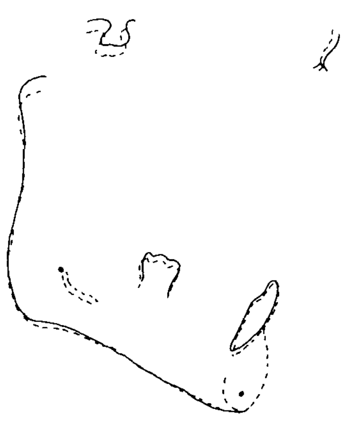

Fig. 13 Reference points are transferred to postobservation tracing with stable mandibular structures superimposed.

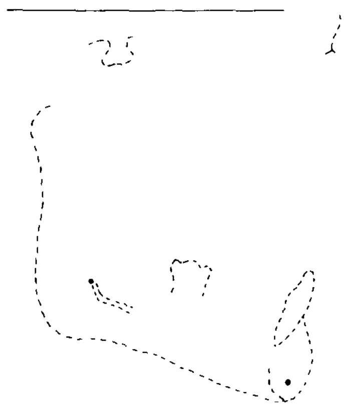

Fig. 14 Anterior cranial base line defined on preobservation tracing.

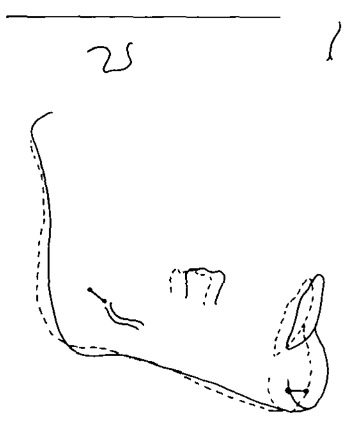

Fig. 15 Cranial base of postobservation superimposed, cranial reference lines transferred and mandibular reference points connected.

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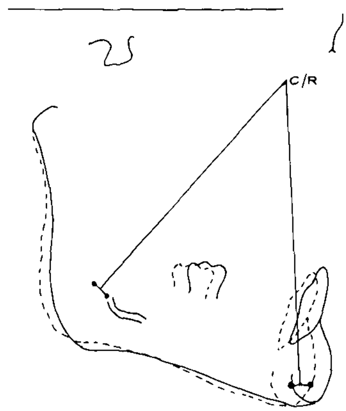

Fig. 16 Perpendicular besectors constructed. The intersection of the bisectors is defined as the center of rotation, C/R.

Discussion

Mandibular rotations result from dissimilar increments of vertical growth between the mandibular condyle and fossa on one hand, and the maxillary sutures-alveolar processes on the other. The center of rotation is located anteroposteriorly based on the degree of disproportionality in vertical growth occurring between these two areas. The greatest disproportionality locates the center of rotation closest to the head. The more nearly alike the increments of vertical growth are between these two areas, the more nearly the center of rotation approaches infinity. At exactly equal increments of vertical growth, translation occurs and the center of rotation is at infinity.

When vertical increments of condylar growth are greater than the vertical increments of alveolar growth, forward mandibular rotations occur. The center of rotation in this instance is always located anterior to the most posterior dental contact (unless dental intrusion has occurred).

When the vertical growth of the sutural-alveolar area is greater than the condylar area, backward mandibular rotation occurs. The center of rotation in this instance is always located at or posterior to the condyle (unless condylar resorption occurred).

The vector of condylar growth determines the vertical location of the center of rotation. The center of rotation is always located on an axis formed by the perpendicular bisector of the vector of condylar growth. If the vector of condylar growth is perpendicular to the occlusal plane, the center of rotation will be located on an axis perpendicular to this vector or parallel to the occlusal plane.

If the vector of condylar growth has a posterior component relative to the occlusal plane, the center of rotation will always be located on an axis perpendicularly bisecting this vector. Therefore, the center of rotation will be located in front and above or behind and below the condylar growth vector (Figs. 7 and 8). The exact anteroposterior location of the center of rotation along this axis is determined by the proportionality of vertical growth between the condylar area and the sutural-alveolar areas.

When the vector of condylar growth has an anterior component relative to the occlusal plane, the center of rotation will always be located on an axis perpendicularly bisecting this vector. Therefore, the center will be located in front and below or behind and above the condylar growth vector (Figs. 9 and 10). The exact anteroposterior location of the center of rotation along this axis is determined by the proportionality of vertical growth between the condylar area and the sutural-alveolar areas. If the vertical growth of the condylar area exceeds the sutural-alveolar areas, forward rotation will occur. The more disproportional these increments are, the closer the center of rotation will be to the head. If vertical growth of the sutural-alveolar area exceeds the condylar area, backward ro-

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tation will occur. The more disproportional these amounts are, the closer the center will be to the head.

The center of rotation is located as described for the purpose of determining the effect that growth produces on the occlusal relations and profile. As the center is located near the head, representing very disproportional vertical growth, the possibility is greatly increased for vertical growth at the condyle to result in anteroposterior changes in the dental occlusion and profile. The center of rotation is located nearest the head when the disproportionality between vertical condylar and sutural-alveolar growth is greatest. If the condylar vertical growth is much greater, a forward rotation occurs. If the sutural-alveolar areas are greater, a backward rotation occurs. Either type of rotation, coupled with a center of rotation more vertically removed from the occlusal plane, results in a center more effective in converting vertical growth to anteroposterior changes in occlusion and profile.

As the direction of the condylar vector becomes less perpendicular to the occlusal plane, it becomes more effective at converting vertical growth to anteroposterior changes in the dentition. For example, the vertical proportionality of growth is the same in Figures 2 and 7. The more anteroposterior direction of the condylar growth seen in Figure 7, however, results in substantially more anteroposterior change at the teeth and profile. This is basically a function of the radii of a circle and the change in an arc of the circle.

The clinical implications of these data are clear. If a change in dental relations is desired, the proportionalities of vertical growth are critical. For example, if a headgear is used for Class II correction, it will be most effective if the mandible is able to forward rotate with the center of rotation as in Figure 2 or better yet, Figure 7. If vertical growth of the molar is permitted, and the amount and direction of condylar growth is constant, a center of rotation as in Figure 1 can occur. This will greatly reduce or even reverse any beneficial effective growth. The headgear correction of a Class II with a growth pattern as shown in Figure 1 can only be obtained by a large amount of distal tooth movement. The headgear correction of a Class II with a growth pattern as shown in Figure 7 can be obtained by blocking the forward compensatory movement of the upper molar and the lower jaw carrying the molars into a Class I molar relation with growth. Thus it is clear that intrusive mechanics on molars may be a valuable asset during the distal pull of a headgear force if growth is to serve any useful role in the Class II correction.

The study of untreated cases thus far suggests that the centers of rotation are most frequently located in the upper outer quadrant as in Figures 2 and 3. Centers of rotation are far less common in all of the other quadrants, but they have been observed.

The study of the effects of treatment with full banded appliances suggests that the centers of rotation usually move toward infinity during orthodontic treatment. This means that treatment usually produces an increased vertical alveolar growth. If this finding is accurate and substantiated, it suggests orthodontic Class II corrections are achieved predominantly by orthodontic tooth movement. In fact, it is possible that, if orthodontic treatment changes mandibular rotations to vertical translations, treatment will reduce the prominence of chins. This will result in more convex facial profiles, on the average, resulting from orthodontic treatments. This hypothesis is based on the fact that centers of rotation are most usu-

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ally located in the anterior upper quadrant. This would tend to advance pogonion. If these centers of rotation were moved toward infinity, pogonion would move more vertically (Fig. 1).

It is also significant to note that the centers of rotation are not located at a single arbitrary point for a population group. In fact, the center of rotation for a given individual can readily move when comparing one period of growth to another. This is especially true when one period includes orthodontic treatment.

It remains to be established by data whether or not orthodontic care can change these proportions of vertical growth and the direction of the vector of condylar growth in a significant amount and on a permanent basis. This will govern the extent to which orthodontics is able to influence dental occlusions and facial profiles by controlling growth. The part of orthodontics that does not influence these parameters can, of course, move teeth to establish improved dental occlusions. The difference is whether the correction can permanently influence growth and its effect on occlusions and profiles or whether the correction is of the occlusion only by tooth movement alone.

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