Quantitation of rotational movements associated with surgical mandibular advancement

By Loretta K. Rubenstein, DDS; Robert A. Strauss, DDS; Robert J. Isaacson, DDS, PhD; and Steven J. Lindauer, DMD, MDSc

Surgical mandibular advancement is used to correct Angle Class II anteroposterior malocclusions and associated facial disproportionalities. The term Angle Class II, however, describes only an anteroposterior relationship; it is obvious that Class II relationships occur concomitantly with a wide spectrum of vertical variations.

The procedure of choice for surgical mandibular advancement is often the bilateral sagittal split osteotomy (BSSO). When the distal segment of the BSSO undergoes significant closing or counterclockwise rotation at surgery, the result is often unstable.[1-3] A clockwise or opening rotation of the distal segment, however, is usually clinically stable.[1,4-6] Opening rotations necessarily elongate the lower face height by varying amounts, depending on the nature of the rotation.[7] Surgical mandibular advancement is sometimes performed without conscious planning to control the degree of distal segment rotation. While the dental malocclusion may be corrected, a compromised facial profile change may also result. Thus far the nature of this rotation has only been qualitatively described in the literature.

The degree of distal segment opening rotation is determined by the vertical curve present in the existing dentition. When a curve of Spee and deep overbite are present, full advancement of the distal segment is not possible, because the mandibular incisors are mechanically blocked from advancement by the maxillary incisors.[2,8] There cannot be a full forward translation of the distal segment; instead, an opening rotation is incorporated into the advancement. This rota-

Abstract

Surgical mandibular advancement can be used to correct an anteroposterior and/or vertical malocclusion. The procedure of choice is often the bilateral sagittal split osteotomy (BSSO). By varying the amount of presurgical overbite correction, the rotational movement of the distal segment of the osteotomy can be controlled. Consequently, the malocclusion and the resultant vertical and anteroposterior facial form changes are predictably planned to produce both the desired occlusion as well as the optimal esthetic facial result. Opening rotation of the distal segment elongates the lower face height by varying amounts depending on the nature of the rotation. The amount and type of rotation can be determined and quantified by the technique presented in this paper, which is based on a geometric theorem used to determine the kinematic center of rotation of an object. This technique can shorten treatment time and produce more predictable results. The specific applications are: 1) treatment planning for individual patients, 2) uniform analyses of treatments and grouping of treatment types, and 3) development of more accurate computerized treatment planning programs.

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Key Words

Mandibular advancement • Bilateral sagittal split osteotomy • Opening rotation • Curve of Spee • Stability

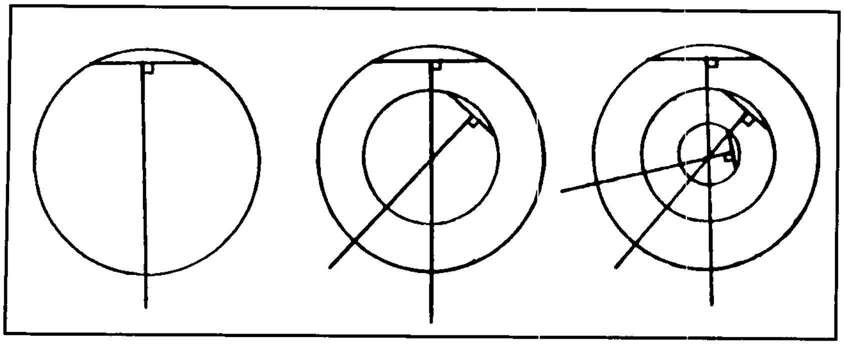

Figure 1
The perpendicular bisector of any chord of a circle passes through the center of the circle. The intersect of two or more perpendicular bisectors of any concentric circles determines the specific center of the circle. This point of intersection is the center of rotation (C/R) of all concentric circles.

tion reduces the dental overbite while simultaneously advancing the molar teeth for the Class II correction and moving pogonion more vertically.

This paper outlines a relatively simple method for describing quantitatively the amount and type of rotation undergone by the distal segment of a BSSO. The specific applications for this technique are: 1) treatment planning for individual patients, 2) uniform analyses of treatments and grouping of treatment types, and 3) increased accuracy of computerized treatment planning programs.

Materials and methods

This method is based on the geometric theorem that the perpendicular bisectors of all chords of concentric circles pass through, and intersect, at the common center of the concentric circles. The intersect of two or more of these perpendicular bisectors determines the location of the center of rotation (C/R) (Figure 1).[9]

Analysis of surgical moves:

1. The presurgical cephalogram is traced (Film 1). All key points of interest are marked on the proposed distal segment; the lower incisor (IP), pogonion (Pg) and the furcation of the first molar (FP) are selected in Figure 2A.
2. An occlusal plane (X axis) is drawn and a perpendicular to the X axis through the furcation point (Y axis) is added. These are used as X,Y coordinate references (Figure 2A).
3. The postsurgical cephalogram (Film 2) is traced on another tracing sheet, but the points of interest (IP, Pg, FP) marked on Film 1 are not yet indicated.
4. The tracing of Film 2 is superimposed on Film 1 on the distal segment of the BSSO. All points of interest and the X/Y axes are transferred forward from Film 1 to Film 2.
5. Film 2 is then superimposed on Film 1 at the cranial base (i.e. sella-nasion). The movement of all of the marked points of interest represents the surgical moves accomplished. Each pair of points is connected with a line, e.g. incisal tip to incisal tip, pogonion to pogonion (Figure 2B). These lines represent the chords of concentric circles shown in Figure 1.
6. Perpendicular bisectors are drawn through all the connecting lines constructed. With complete accuracy in technique, all of the perpendicular bisectors will intersect at one point. This point is the kinematic center of rotation, C/R (Figure 2C). If the molar is to translate anteriorly while maintaining its vertical occlusion the anteroposterior position of the C/R must lie near the Y axis. Its vertical location on the Y axis reflects the magnitude and type of rotation the distal segment undergoes at surgery. The closer the C/R is to the X axis, the more pogonion moves vertically (Figure 3A). The further it moves from the X axis, the more pogonion advances horizontally (Figure 5).
7. Exact X,Y coordinates can be ascertained using a millimeter grid overlay template. The X,Y coordinates for Figure 2C are (4, -95). With this information (X,Y coordinates of the C/R) and the number of degrees of rotation occurring around the C/R (Figure 2D) the precise vertical and horizontal movement of the distal segment can be described.

Surgical prediction: When using the technique for surgical predictions, the amount of rotation necessary to achieve the facial appearance treatment objectives is established first. The "postsurgical film" in this case is a template of the distal segment of the mandible with the marked points of interest on both tracings (Figure 2A). The template is advanced at the molar to the Class I correction, but rotated at the incisors to the desired facial height and chin advancement. The template is then superimposed on the presurgical film at the cranial base and the marked points of interest are connected (Figure 2B). Their perpendicular bisectors intersect at the C/R (Figure 2C). To surgically correct the Class II patient with a short lower face height the C/R will be vertically positioned near the X axis (-4, -41) as seen in Figure 4. This results in an opening rotation which lengthens the face. The patient with a long face will have a C/R vertically positioned further from the X axis (-11, -72) as seen in Figure 5 or at infinity as seen in Figure 6A. This results in maximal advancement and minimal vertical change at pogonion.

The difference between the pretreatment incisor vertical position and the optimal incisor vertical position at the desired facial profile correction represents the amount of orthodontic presurgical overbite correction needed to achieve the results predicted. This overbite correction can be obtained in either jaw as dictated by esthetic concerns for the maxillary lip-to-tooth and smile-line factors. The surgical prediction in Figure 7A is done by moving the template to the desired vertical and horizontal facial profile correction, but without making any orthodontic overbite correction in the initial occlusion. Since no overbite correction has been achieved, the maxillary incisors would normally prevent this type of advancement or it would require an opening rotation with an undesirable lower facial height increase. The difference between the initial overbite of 7 mm (as seen in Figure 7A) and the determined optimal overbite of 2 mm (as seen in Figure 7B) is 5 mm. In this patient, the decision was made to achieve this overbite correction with 2 mm of maxillary and 3 mm of mandibular incisor intrusion in order to achieve the desired lip to tooth length.

Discussion

Rotational movements have traditionally been kinematically described in terms of the number of degrees of rotation around a designated C/R. These are objective quantities easily produced and understood by clinicians and programmers.

The supposition that the molars are in occlusion vertically and in a Class II relationship anteroposteriorly is fundamental to the analysis described here. Within these constraints, rotation of the distal segment will carry the lower molar in an anterior direction along the occlusal plane. This molar movement will actually be the chord of an arc of a circle whose center is the C/R of the distal segment. Therefore, during a Class II correction, the anteroposterior location of the C/R must be located near the Y axis, so that the molar translates anteriorly while maintaining vertical occlusion.

The vertical location of the C/R along the Y axis can show more variation during Class II corrections. It is located above the X axis in a closing (counterclockwise) rotation and below the X axis in an opening (clockwise) rotation. When the perpendicular bisectors are parallel and the C/R is at infinity, no rotation occurs and all points on the distal segment move the same amount in the same direction as in Figures 3D and 6A-C. This type of advancement would occur if minimal presurgical overbite remained and the vertical occlusal plane had been leveled presurgically. The resultant surgical change would show correction of the Class II dental malocclusion, maximal chin advancement and minimal facial height increase. When this type of profile change is desired, the orthodontic goal is flat and parallel occlusal planes prior to surgery.

Various combinations of anterior (X) and in-

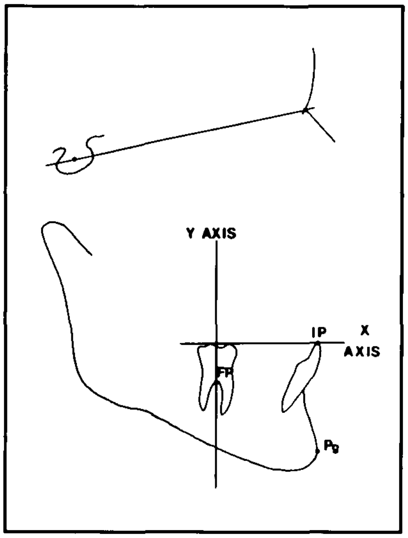

Figure 2A

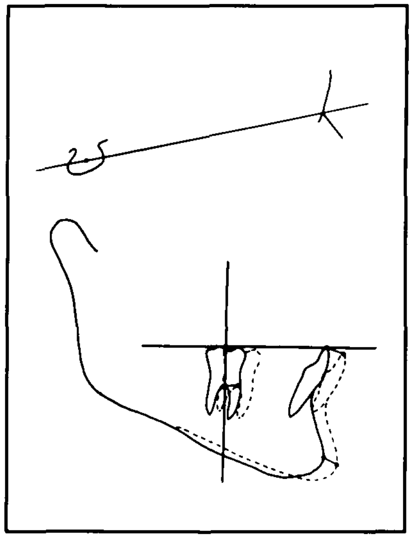

Figure 2B

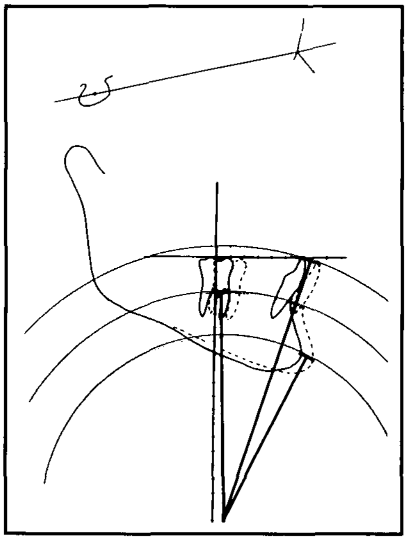

Figure 2C

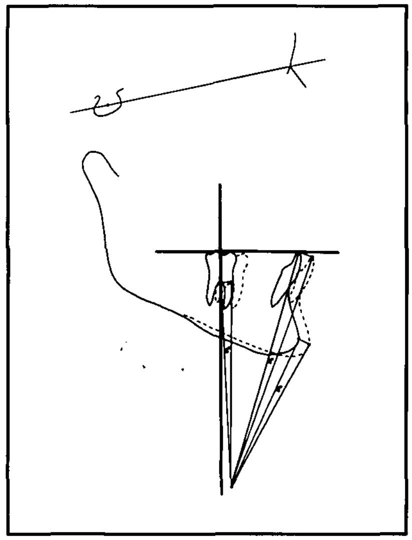

Figure 2D

Figures 2A-D

A.) The presurgical cephalogram is traced (Film 1). Points of interest, such as the mandibular incisor (IP), pogonion (Pg) and the furcation of the first molar (FP), are marked. The occlusal plane (X axis) is drawn, then a perpendicular to the X axis through FP is added (Y axis). Film 2, the postsurgical film, is similarly traced, but the above landmarks of interest are transferred from Film 1, while superimposed on the distal mandibular segment.

B.) The pre- and postsurgical films are superimposed at the cranial base (S-N). The movement of all points of interest are indicated by connecting the pairs of points, e.g. IP to IP, FP to FP, and Pg to Pg.

C.) Perpendicular bisectors are drawn through all the connecting lines. The perpendicular bisectors will intersect at the kinematic center of rotation, C/R. The X,Y coordinates of the C/R can easily be determined by using an overlay template or simple millimeter markers. In this case the coordinates are (4, -95).

D.) The X,Y coordinates are (4, -95) and the degree of rotation is 4°. With this information, the precise vertical and horizontal movement of the distal segment can be described.

ferior (Y) movements at pogonion are possible when some occlusal curve and some overbite are present in the dental arches as shown in Figures 4 and 5. This clearly demonstrates how presurgical orthodontic management can help determine the facial form changes that are produced at the time of surgery. When the C/R moves further from the X axis (i.e. the Y value of the C/R is more negative) in an opening rotation the amount of rotation progressively decreases, as shown by the difference between Figures 4 (-4, -41) and 5 (-11, -72). In this instance, some points move almost straight along the X axis and others move varying amounts on the X and Y axes. The amount of X and Y change is a function of the position of that point relative to the C/R. When the C/R is close to the X axis, rotation is greatest and the pogonion moves vertically at the same time the molars move anteriorly, as in Figures 3A-C.

Maximum rotation of the distal segment results in pogonion moving only inferiorly and at right angles to the anterior movement of the molar (Figure 3A). Since this type of distal segment movement results from the presence of a presurgical occlusal curve, the overbite is controlled by deferring most of the correction until the postsurgical period. When this occurs, a lateral openbite is created in the premolar area at the time of surgery with the occlusion tripoded on the molars and anterior teeth. This openbite is closed with vertical elastics either during or following maxillomandibular fixation.[2,3,8,10-12] It has been hypothesized that the closure of the lateral openbite resulting from occlusal curves present at surgery is rapidly corrected postsurgically due to the absence of occlusal forces on these teeth and because of associated surgical healing processes.[13] Leveling of this curve prior to surgery often is difficult and time consuming due to these same heavy occlusal forces.[10,11,13]

Treatment planning for individual patients: Treatment for the Class II patient who presents with a short lower facial height, normal chin position in profile and deep labiomental fold should be planned differently than treatment for the Class II patient with a normal facial height and severely retrognathic chin. Pogonion positioning should be consciously planned and its anterior and inferior location titrated by control of the distal segment rotation. Control of the distal segment rotation is a function of the amount of presurgical overbite correction. For those patients who are not able to tolerate an increase in lower facial height, presurgical overbite correction should be accomplished by orthodontic intrusion of incisors. When the treatment plan requires an increase in facial height,

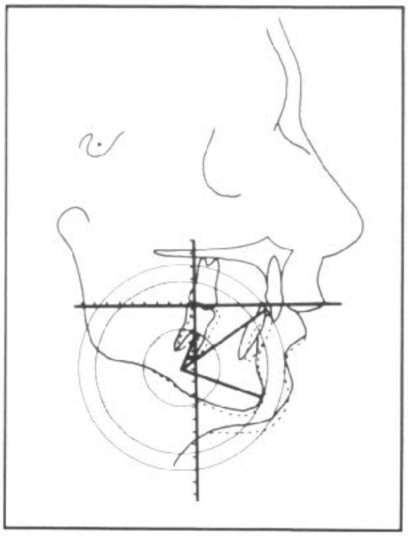

Figure 3A

Figure 3B

Figure 3C

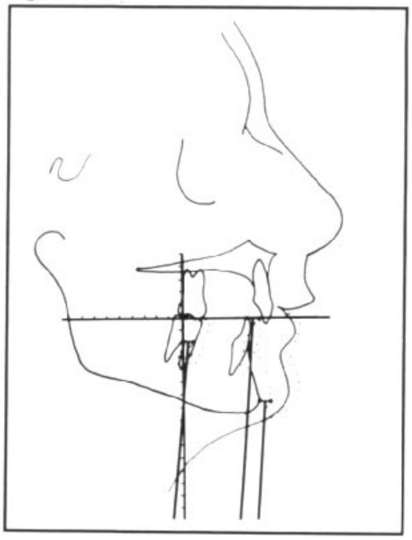

Figure 3D

Figure 3A-D
A.) A C/R near the molar (X axis) reflects maximal distal segment rotation. This produces minimal anteroposterior movement and maximal vertical movement at pogonion. The coordinates are (-4, -27).

B.) This is a preoperative photograph of the patient in Figure 3A. The original surgical prediction was for an anterior advancement at pogonion. Based on other factors, surgery took place prior to complete overbite correction.

C.) The resulting profile change demonstrates an opening rotation with maximum vertical movement at pogonion rather than the desired anteroposterior movement at pogonion.

D.) This surgical prediction demonstrates the desired profile change that would have occurred if overbite correction had been completed prior to surgery. The resulting change at pogonion can be compared to the pogonion change seen in Figure 3A. No rotation of the distal segment occurs and all points move the same amount in the same direction. The C/R is at infinity.

presurgical orthodontics should not correct all of the vertical occlusal curve.[8,10,11,13]

Treatment planning for a BSSO mandibular advancement originally consisted of visualizing the number of millimeters of mandibular molar and incisor advancement necessary for correction to an Angle Class I occlusion, advancing a template of the mandible the corresponding distance on the cephalometric tracing and developing a best estimate of the posttreatment facial form and profile. The amount of overbite correction to be achieved presurgically was not normally factored into the prediction tracing as a controllable variable. Present techniques for predicting the effects of a BSSO for mandibular advancement do not use complete information regarding the actual change in spatial position of all points on the distal segment. Presurgical decisions regarding the indications for adjunctive procedures, e.g. genioplasties, will have a better basis if precise information on the planned postsurgical positions of all points on the mandible is accurately known. This is preferable to deferring such decisions until the time of the actual BSSO in the operating room, or to a second surgical procedure at a later date.[2,12,13] In addition, by using this technique the need for corrective genioplasty may occasionally be obviated.

A C/R near the X axis reflects maximal distal segment rotation (Figure 3A). This results from the presence of a large presurgical overbite and produces the least anteroposterior and maximum vertical movement of pogonion (Figures 3A-C). The result is still a correction of the dental Class II malocclusion, but concurrently with minimal chin advancement and maximum facial height increase. When this concept is ignored, less desirable results are produced. For example, Figures 3A-C show a patient who received an advancement with maximum rotation. The patient would have benefited from more pogonion advancement, which was not achieved due to the presence of a large presurgical overbite. Figure 3D demonstrates the type of result that would have been achieved if the overbite correction had been accomplished prior to surgery. Both the actual result (Figures 3A-C) and the better result (Figure 3D) accomplish the Class II molar correction. The presence or absence of associated rotation or translation of the distal segment produces markedly different results in the postsurgical lower face height.

Analyses of treatment procedures: An additional value of quantifying the rotation of a distal segment during a BSSO advancement is the creation of a uniform reporting method to de-

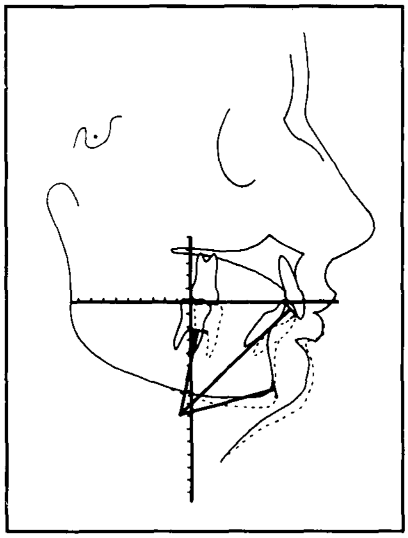

Figure 4

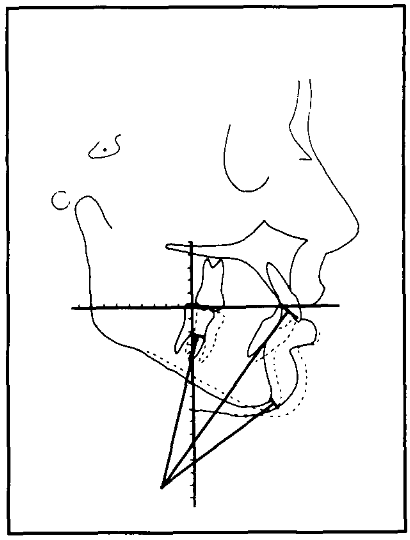

Figure 5

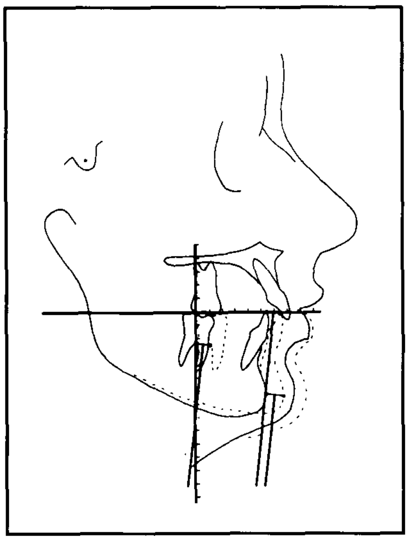

Figure 6A

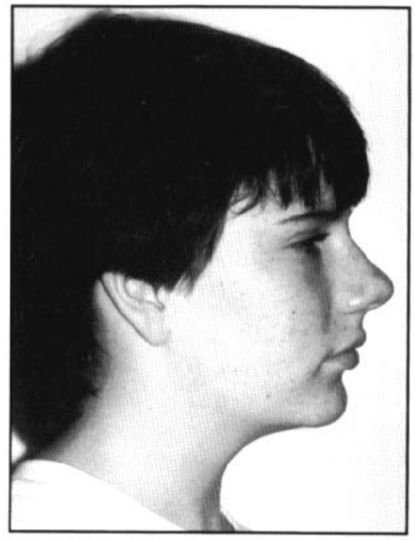

Figure 6B

Figure 4
As the C/R is located further from the X axis, more anteroposterior and less vertical change is produced at pogonion. The coordinates are (-4, -41).

Figure 5
As the C/R is located progressively further from the molar more anteroposterior and less vertical change is produced at pogonion. The coordinates are (-11, -72).

Figure 6A-C
A.) When the C/R is at infinity, the perpendicular bisectors are parallel and the distal segment will translate. No rotation occurs and all points move the same amount and in the same direction. In this case C/R is at infinity.

B.) This is a preoperative photograph of the patient in Figure 6A. The surgical prediction was for a maximum anteroposterior advancement with no lower face height increase. The overbite was totally reduced during presurgical orthodontics. The resulting surgical move produced a C/R at infinity.

C.) This postoperative photograph demonstrates a successful anteroposterior movement at pogonion with minimal vertical movement.

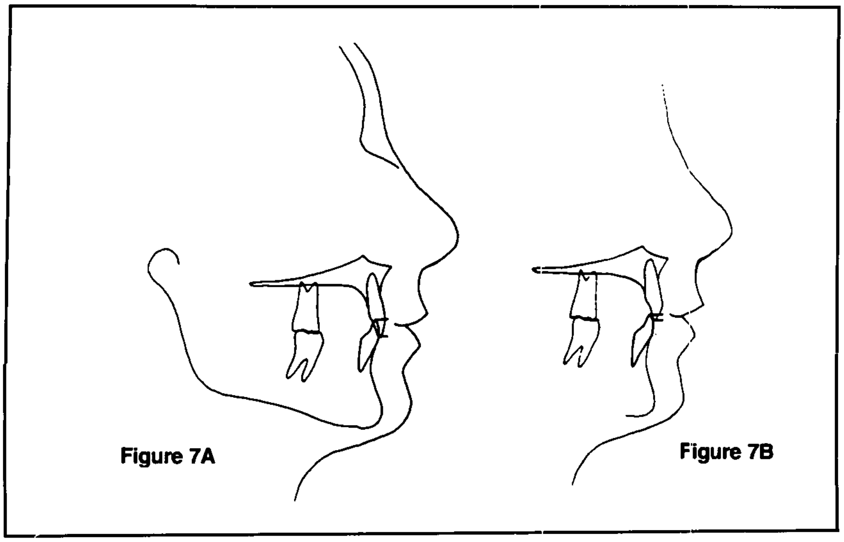

Figure 7A-B
A.) This surgical prediction represents the advancement needed to achieve the desired facial profile for this patient. Since there has been no incisal overbite correction, the surgical advancement would not be possible due to incisor interferences. The horizontal lines at the incisal edges represent the overbite.

B.) This figure represents the same surgical advancement seen in 7A, but with optimal overbite correction. In this case overbite correction would require 2 mm maxillary and 3 mm mandibular incisor intrusion presurgically to obtain optimal overbite and maxillary incisor exposure.

scribe BSSO distal segment movements. This can be done by showing the X,Y coordinates. Using this method, reports from different surgical centers may be more precisely compared. Studies of the long-term stability of treatment have reported on groups of patients based on the assumption that all BSSO mandibular advancements are analogous surgical procedures. The patients in all of the groups, however, underwent different surgical movements with varying degrees of rotation and, consequently, different perturbations of their functional biology.[7,14-17] The amount, direction, and rotation of surgical movement of the distal segment is clearly a variable that has not yet been adequately predicted and described quantitatively. When analysis of BSSO advancement results include patients who have experienced different distal segment rotations, multiple variables may influence the results. When these different variables are not quantified, patients are categorized into dissimilar groups. Recognition and prediction of the change of surgically repositioned segments relative to unchanged structures must be known by clinicians if optimally esthetic as well as stable results are to be achieved consistently. Studies of soft tissue profile changes and dental occlusal changes will potentially benefit by better controlled, more uniform sampling procedures.

Development of computer algorithms: Software programs for orthognathic treatment planning are already available,[14,18,19] and more treatment prediction aids will surely follow. In order for these instruments to provide valuable information, they need an objective data base. Specific, reproducible and predictable quantification of the movement of the distal segment is mandatory. This data must be expressed in terms understandable to both programmers and clinicians. The use of quantified X,Y coordinates to locate the C/R addresses these needs.

Locating the C/R is a precise way of describing the motion of the distal segment. It allows verbal communications that are relatively objective. All that is required is a statement of the X,Y coordinates of the C/R and the number of degrees of rotation occurring around that point. With this information, a computer program can describe the rotation of a distal segment occurring between two time points by using the X,Y location of two reference points on the segment at time point 1, and the same reference points at time point 2. Given this information, it is possible to use a computer program to visually demonstrate the motion of any other point on the distal segment as long as its original X,Y location is known. This, or equivalent information, is mandatory for computer simulation software to be maximally descriptive of treatment changes irrespective of whether the changes are proposed, accomplished or occur during the posttreatment time period.

Summary

The relatively simple technique reported here can be used to quantify the motion of a body associated with orthognathic surgical treatment and relapse. A quantitative method of objectively describing movement of the distal segment of a BSSO: 1) assists in planning and decision making for individual patient treatment, 2) provides comparable data from treatment studies by allowing quantification of the direction and amount of treatment variation produced by similar surgical procedures, and 3) provides an objective way to communicate proposed or accomplished surgical movement of a distal BSSO segment in terminology that is understood by programmers and clinicians alike.

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