

## *Biomechanical considerations in distraction of the osteotomized dentomaxillary complex*

Joong-Gyu Ahn, DDS, PhD,<sup>a</sup> Alvaro A. Figueroa, DDS, MS,<sup>b</sup> Stanley Braun, DDS, MME,<sup>c</sup> and John W. Polley, MD<sup>d</sup>

Chicago, Ill, and Milwaukee, Wis

The completely osteotomized dentomaxillary complex is essentially a free body constrained only by its soft tissue attachments. Therefore the line of action and point of application of any protractive force(s) used during distraction osteogenesis must be considered relative to its center of mass. This is in contrast to the nonsurgically separated dentomaxillary complex, which is a constrained body, and therefore the application of protractive force(s) must be considered relative to its center of resistance. These two centers are not coincident. With knowledge of the location of the center of mass, predictable protraction of the dentomaxillary complex can be achieved. In this study, the center of mass of an adult maxillary specimen osteotomized to emulate a Le Fort I osteotomy was determined. Protractive force(s) through the center of mass will produce linear advancement along its line of action. Protractive movement of the dentomaxillary complex can be adjusted downward and forward or upward and forward by locating the protractive force(s) line of action superior or inferior to the center of mass. A cleft patient is described wherein the surgically separated dentomaxillary complex is protracted downward and forward with a force vector superior to its approximate center of mass. This results in a predictable increase in overbite and overjet with negligible mandibular rotation. (*Am J Orthod Dentofacial Orthop* 1999;116:264-70)

**D**istraction osteogenesis has become an important treatment modality for patients with craniofacial skeletal dysplasias. Distraction devices for the craniofacial bones can be external or internal. In 1973 Snyder et al<sup>1</sup> reported the use of an external bone distraction device for gradual lengthening of the lower jaw in dogs. Various devices for mandibular and maxillary distraction osteogenesis have been used in humans.<sup>2-6</sup> In the nonsurgical correction of skeletal Class III malocclusions via face mask and elastic traction to the maxilla, anterior rotation is commonly observed with a concomitant mandibular backward rotation.<sup>7-12</sup> Rotation of the maxilla is determined by the point of application and line of action of the distraction force(s) relative to its center of resistance.<sup>13-19</sup>

In cleft patients considerable advancement of the dentomaxillary complex is often required because of its

hypoplastic development. Distraction, after a complete Le Fort I osteotomy, has been found effective in treating these patients.<sup>5,6</sup> In a Le Fort I osteotomy, the maxilla is freed of all bony attachments, though it is still supported by the soft tissues: the palatal and vestibular mucosa, lips, and cheeks. It is therefore important to recognize that after a complete Le Fort I osteotomy, the dentomaxillary complex is no longer a constrained skeletal structure, and therefore the location of its center of resistance<sup>20,21</sup> is not applicable in forecasting protractive movement. Rather, the dentomaxillary complex has been altered to a relatively free structure. Consequently, the point of application and line of action of distraction force(s) relative to its center of mass becomes important. The center of mass is not necessarily coincident with, or located near, the center of resistance.

The aim of this report is to identify the center of mass of the osteotomized maxilla so that force systems may be designed for purposeful and controlled advancement of the maxilla during the distraction procedure.

### MATERIAL AND METHODS

Because of its structural complexity, the center of mass of the dentomaxillary complex was determined experimentally by isolating an osteotomized dentomaxillary structure from an adult cadaver (exact age unknown). A discreet single force attached at its cen-

<sup>a</sup>Fellow in Advanced Orthodontics, Department of Orthodontics, University of Illinois at Chicago; Assistant Professor, The Catholic University of Korea, Seoul.

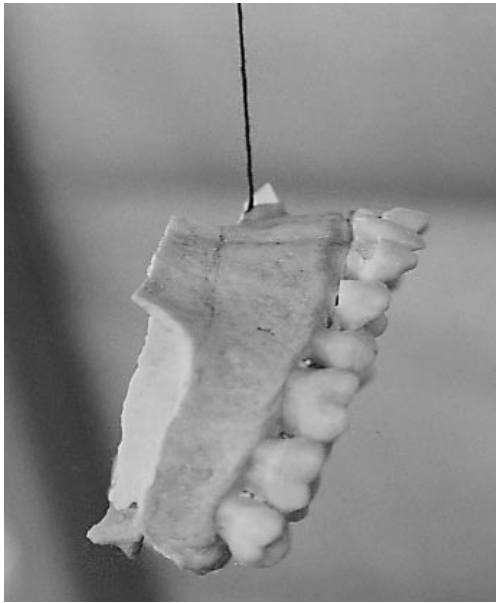
<sup>b</sup>Associate Professor, Craniofacial Center and Orthodontic Department, University of Illinois at Chicago.

<sup>c</sup>Clinical Professor of Orthodontics, Vanderbilt University Medical Center and Marquette University.

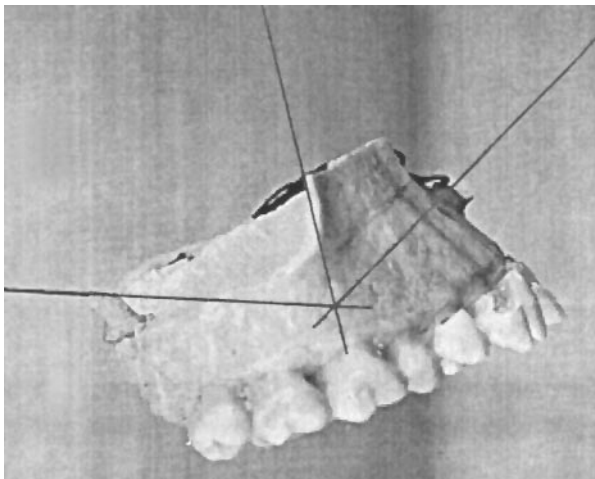
<sup>d</sup>Director, Craniofacial Center, Division of Plastic Surgery, University of Illinois at Chicago.

Reprint requests to: Alvaro A. Figueroa DDS, MS, Craniofacial Center, University of Illinois at Chicago, 811 S Paulina (M/C 588), Chicago, IL 60612; e-mail: AFig@uic.edu

Copyright © 1999 by the American Association of Orthodontists.  
0889-5406/99/\$8.00 + 0 8/1/96709

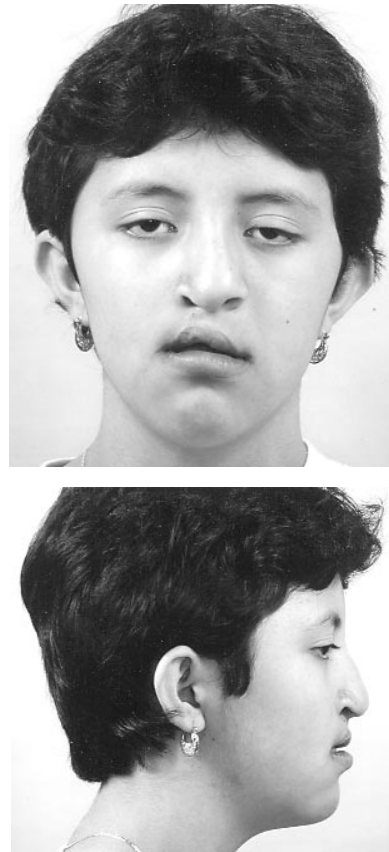


**Fig 1.** Complete high Le Fort I dentomaxillary complex obtained from an adult cadaver freely suspended by a single discreet force.



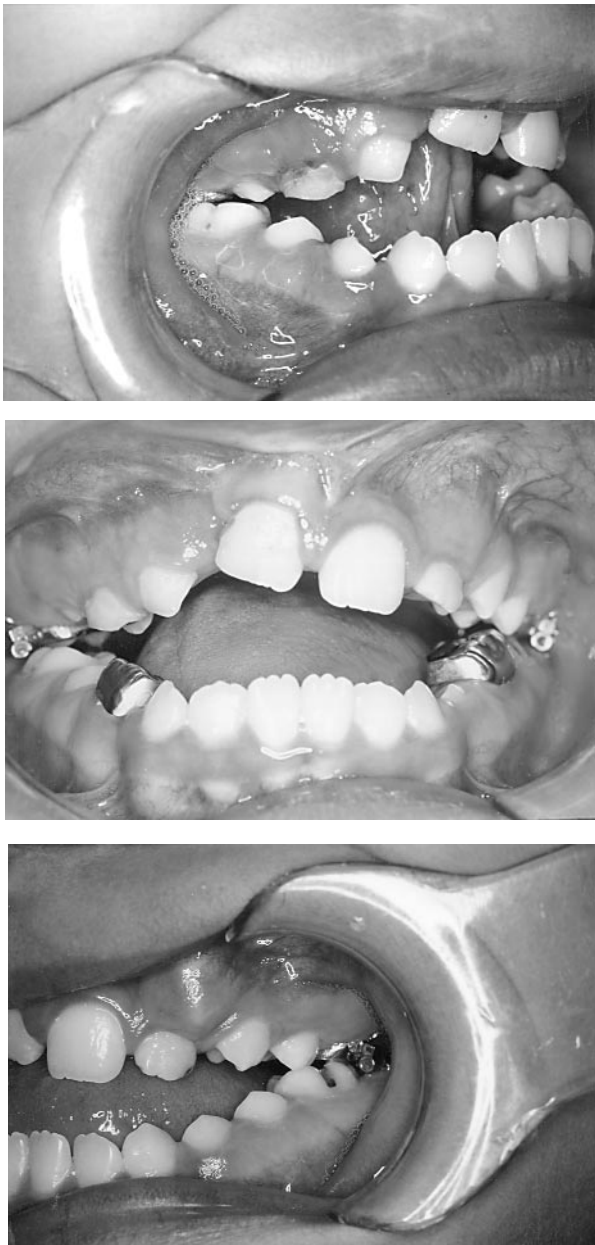
**Fig 2.** Computer superimposition of dentomaxillary complex individually supported by three separate discreet forces.

terline (in the frontal view) close to the anterior nasal spine supported the specimen. The dentomaxillary complex will position itself so that its center of mass will be exactly in line with the supporting force. The structure supported in this manner obeys the laws of static equilibrium<sup>22</sup> (Fig 1). This was recorded in the sagittal view at a fixed focal length and spatially oriented digitized photograph. The dentomaxillary complex was then resupported separately by a second (center of the palatal suture) and third (posterior nasal spine) discreet, single suspending force attached at the



**Fig 3.** Pretreatment frontal and profile photographs.

centerline, and similarly oriented digitized photographs were exposed. Each of the three photographs were then put into a computer and superimposed on the detailed structure of the dentomaxillary complex using the Photoshop 4.0 computer program (Adobe Systems, Inc, San Jose, Calif) (Fig 2). The center of mass in the sagittal view is located at the intersection of any two extended lines of action of the supportive forces. The third digital photograph of the supportive force was used as a check on accuracy. Similar recordings can be made in all three planes of space if the location of the center of mass is desired in three-dimensional space. The photographic/computer magnification factor was calculated at 1.33. The center of mass in the sagittal view of this adult dentomaxillary specimen can then be clinically described as being located on a line along the mesial aspect of the maxillary first molar root 14.66 mm superior to its occlusal surface. With the knowledge of the location of the center of mass as seen in the dentomaxillary specimen, protraction force(s) can be appropriately designed in the clinical situation to provide linear protraction, or downward and forward, or upward and forward rotation of the dentomaxillary complex.



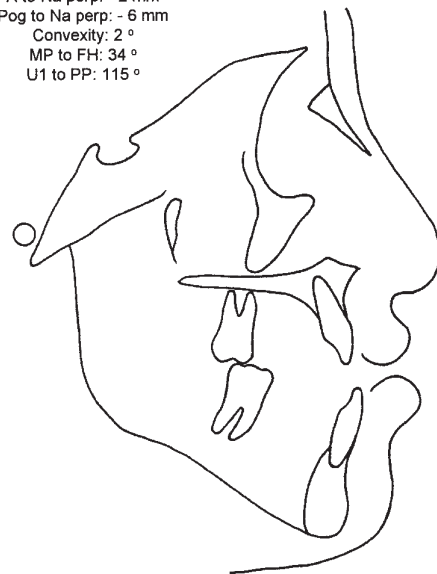
**Fig 4.** Pretreatment intraoral photographs.

#### CASE REPORT

A 10-year-old female patient presented with a previously repaired right unilateral complete cleft lip and palate with secondary grafting of the alveolar cleft. She exhibited underdevelopment of the midface and a concave soft tissue profile (Fig 3). The dentition was mixed and displayed a Class III molar relationship, 6 mm anterior open bite, and 4.5 mm underjet, with a bilateral posterior crossbite (Fig 4). Significant maxillary and moderate mandibular arch length deficiencies were evident. The maxillary right lateral incisor was



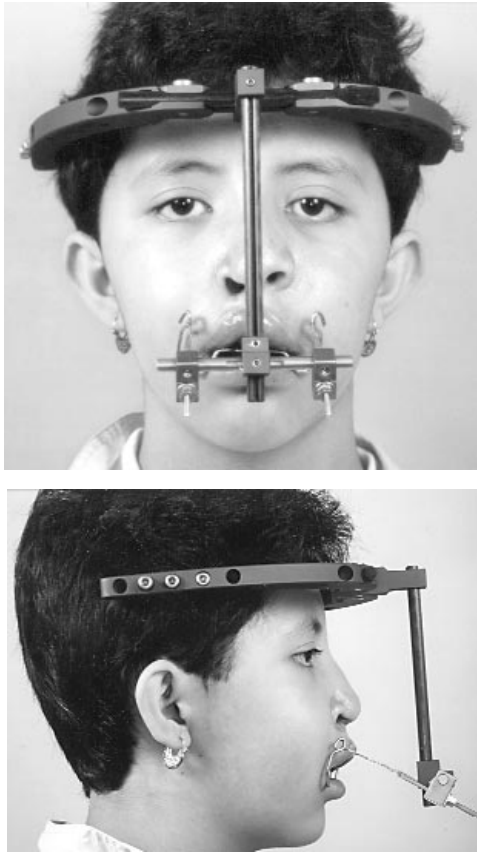
A to Na perp: - 2 mm  
Pog to Na perp: - 6 mm  
Convexity: 2 °  
MP to FH: 34 °  
U1 to PP: 115 °



**Fig 5.** Pretreatment lateral cephalogram and tracing.

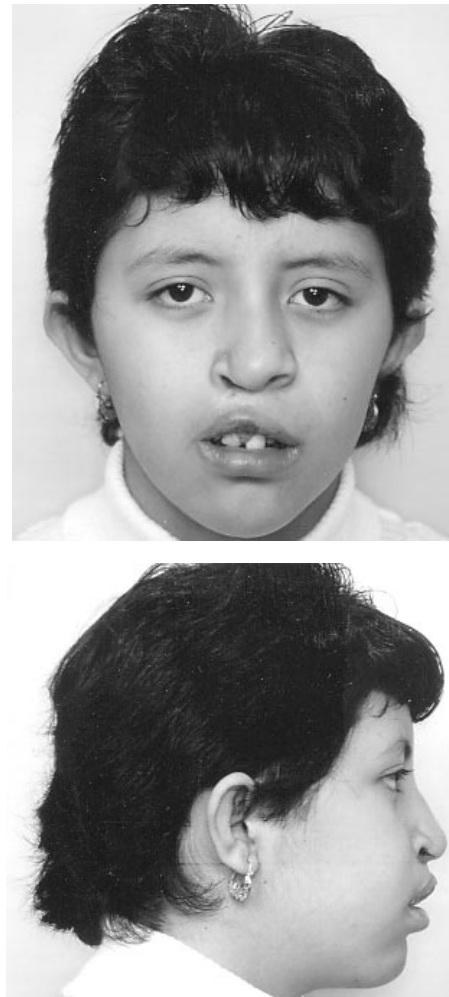
absent. Model analysis demonstrated congruent transverse dimensions. Cephalometric analysis revealed maxillary retrusion and vertical skeletal pattern (Fig 5). The vertical mandibular posture (high mandibular plane angle) ameliorated the severity of the Class III facial profile. Treatment objectives were to advance and rotate the maxilla forward and downward through distraction osteogenesis, reducing the skeletal open bite without a concomitant increase in the lower facial height and to obtain a Class II molar relationship with correction of the anterior and posterior crossbites while improving facial esthetics.

A complete high Le Fort I osteotomy combined



**Fig 6.** Rigid distraction device in place. Frontal view and lateral view.

with the use of a rigid external distraction device was planned. After cementation of an intraoral splint with external hooks placed at the level of the palatal plane,<sup>5,6,23,24</sup> the patient underwent surgery. After septal and pterygomaxillary disjunction, the maxilla was completely mobilized but not advanced or repositioned. Soft tissue closure was performed, and the rigid external distraction device was placed. After a 4 day latency, traction wires were connected from the external hooks of the intraoral splint to the distraction screws mounted on the rigid external distraction device (Fig 6). The direction of the force(s) was parallel to the mandibular functional occlusal plane. Distraction was maintained at the rate of 1 mm per day for 15 days. At the end of distraction, the patient was retained with the rigid external distraction device for 3 weeks. After its removal, elastic traction force(s) of 450 g to a removable face mask were instituted at night for 6 weeks. Immediately after surgery, the mandible rotated clockwise because of the vertical separation of the osteotomized maxilla. After controlled maxillary segment distraction, the mandible rotated toward its original position. The anterior open bite was corrected.

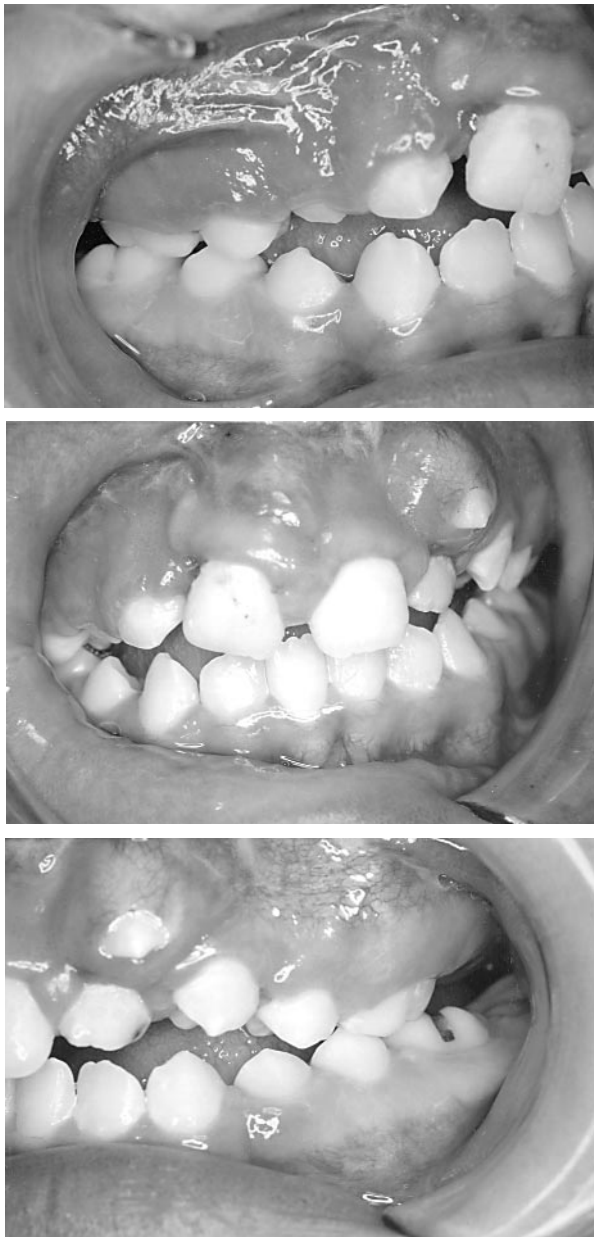


**Fig 7.** Posttreatment frontal and profile photographs.

After treatment, the mandibular plane angle increased 2°, and the facial and skeletal convexity was improved. The nasal tip was advanced 3 mm (Table I and Fig 7). Overjet and overbite were altered to 6 mm and 2 mm, respectively (Fig 8). Pretreatment (T1) and posttreatment (T2) cephalometric radiographs demonstrate a 9 mm maxillary advancement with 7 mm downward positioning of the anterior nasal spine (Fig 9). The treatment objectives were achieved.

#### DISCUSSION

The future position of the completely osteotomized dentomaxillary complex is controlled by the point of application and line of action of the distraction force(s) relative to its center of mass. This is in contrast to a constrained body where the biologic response is determined by the point of application and line of action of the applied force(s) relative to its center of resistance.<sup>20</sup> The center of mass of the dentomaxillary complex is



**Fig 8.** Posttreatment intraoral photographs.

significantly influenced by the disparity in density (mass per unit volume) between its osseous and dental structures.

One should be aware that the location of the center of mass will be affected by the size (maturation) of the osseous structures, the number of teeth present, and the surgical design of the osteotomy. Additional studies are in progress to determine the center of mass, at various ages, of the different bones usually mobilized during craniofacial surgery.

It should also be recognized that the soft tissue

**Table 1.** Pretreatment (T1) and posttreatment (T2) cephalometric values

Measurement	T1	T2
SNA (°)	76	83
SNB (°)	75	74
MP-FH (°)	34	36
LFH/TFH (%)	59	54
ANS (x, y) (mm)*	(56, 53)	(63, 62)
1 (x, y) (mm)*	(45, 78)	(50, 92)
1 to palatal plane (°)	115	113
Facial contour angle (°)	9	18

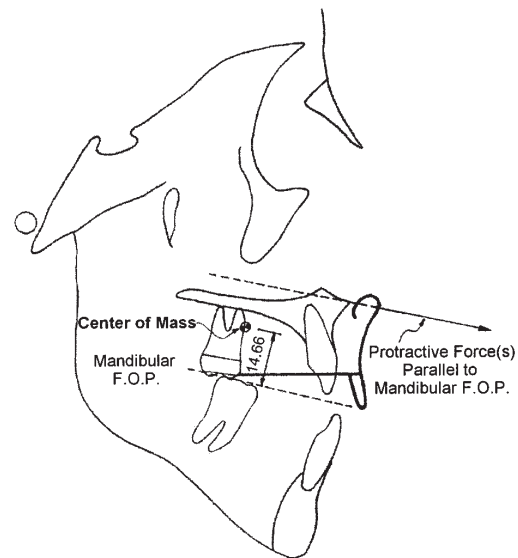
\*Measurement parallel to SN (x), perpendicular to SN through S (y).

envelope and attachments will provide some indeterminate anterior constraint and the forces of occlusion an inferior constraint. The bones above the osteotomy will provide superior constraint.

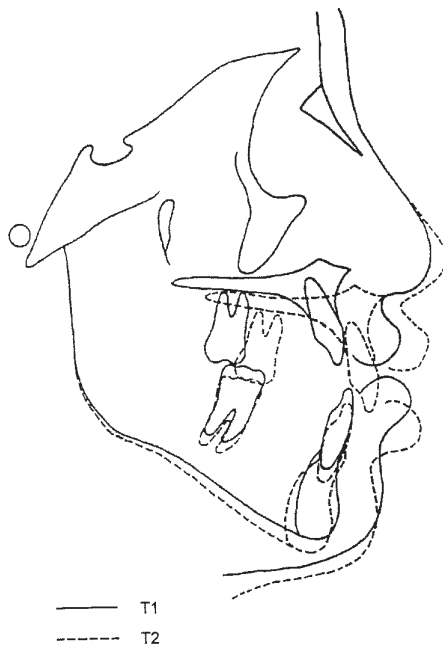
If linear protraction of the osteotomized dentomaxillary complex is desired parallel to the functional occlusal plane, the line of action of the distraction force(s) would pass through the center of mass (in the sagittal view) and be parallel to the functional occlusal plane. (In the case of the nonosteotomized dentomaxillary complex, the line of action of the applied force(s) should pass through the center of resistance of the constrained dentomaxillary complex for straight advancement.<sup>21</sup>) On the other hand, if downward and forward or clockwise rotation is desired (center of rotation inferior to the center of mass), then the line of action of the applied force(s) would be placed superior to the center of mass and parallel to the functional occlusal plane (as in the reported patient). If upward and forward or counterclockwise rotation is desired, the line of action of the applied protractive force(s) would be parallel to the functional occlusal plane and below the center of mass. This will provide a center of rotation superior to the center of mass.

The clinician should be aware that the moment arm created by locating the line of action of the force(s) superior or inferior to the center of mass should not be large. The moment arm fundamentally controls its magnitude. If the moment arm is large, the center of rotation will approach the center of mass.

In the reported patient, the line of action and point of application of the protractive force(s) was above the approximate center of mass (Fig 10). The osteotomized complex will thus rotate about a point inferior to the center of mass. The osteotomized dentomaxillary complex is connected through external hooks of the intraoral splint to the distraction screws via traction wires. The position of the external traction hooks and the direction of the traction wires determine the point of



**Fig 10.** Protraction force(s) relative to the center of mass of the dentomaxillary complex.



**Fig 9.** Posttreatment lateral cephalogram and superimposed cephalometric tracings of pretreatment (T1) and posttreatment (T2).

application and line of action of the applied forces relative to its center of mass.

### CONCLUSIONS

Distraction osteogenesis has been successfully used for maxillary advancement in cleft patients with a rigid

external distraction device in combination with an osteotomized dentomaxillary complex.<sup>5,6</sup> Because the dentomaxillary complex is free of its bony attachments, the location of the center of mass is critically important versus the center of resistance of the nondetached dentomaxillary complex. The use of the extraoral hooks eliminates lip constraints and allows for adjustment of the line of action and point of application relative to the center of mass when combined with adjustment (up or down) of the rigid external distraction screw system.<sup>23,24</sup>

In this report the approximate center of mass of an osteotomized dentomaxillary complex was determined using a cadaver specimen. With prior knowledge of the approximate location of the center of mass, distraction force(s) can obtain reasonably predictable displacement of the dentomaxillary complex. Location of the distraction force(s) through the center of mass will produce linear advancement along its line of action. Motion can be altered downward and forward or upward and forward by locating the protractive force line of action superior or inferior to the center of mass. Control of the rotation of the dentomaxillary complex is essential to prevent or to correct a skeletal open bite.

### REFERENCES

1. Snyder CC, Levine GA, Swanson HM, Browne EZ. Mandibular lengthening by gradual distraction: preliminary report. *Plast Reconstr Surg* 1973;5:506-8.
2. McCarthy JG, Schreiber J, Karp N, Throne CH, Grayson BH. Lengthening of the human mandible by gradual distraction. *Plast Reconstr Surg* 1992;89:1-8.
3. Diner PA, Kollar EM, Martinez H, Vazquez MP. Intraoral distraction of mandibular lengthening a technical innovation. *J Cranio Maxillofac Surg* 1996;24:92-5.
4. Cohen SR, Burstein FD, Stewart MB, Rathburn MA. Maxillary-midface distraction in

- children with cleft lip and palate: a preliminary report. *Plast Reconstr Surg* 1997; 99:1421-8.
5. Polley JW, Figueroa AA. Management of severe maxillary deficiency in childhood and adolescence through distraction osteogenesis with an external, adjustable, rigid distraction device. *J Craniofac Surg* 1997;8:181-5.
  6. Polley JW, Figueroa AA. Rigid external distraction: its application in cleft maxillary deformities. *Plast Reconstr Surg* 1998;02:1360-72.
  7. Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. *J Clin Orthod* 1988;22:314-25.
  8. Mermigos J, Full CA, Andreasen G. Protraction of the maxillofacial complex. *Am J Orthod Dentofacial Orthop* 1990;98:47-55.
  9. Baccetti T, McGill JS, Franchi L, McNamara JA, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face mask therapy. *Am J Orthod Dentofacial Orthop* 1998;113:333-43.
  10. Sarnas KV, Rune B. Extraoral traction to the maxilla with face mask: a follow-up of 17 consecutively treated patients with and without cleft lip and palate. *Cleft Palate J* 1987;24:95-103.
  11. Roberts CA, Subtelny JD. Use of the face mask in the treatment of maxillary skeletal retrusion. *Am J Orthod Dentofacial Orthop* 1988;93:388-94.
  12. Tindlund RS, Rygh P, Boe OE. Orthopedic protraction of the upper jaw in cleft lip and palate patients during the deciduous and mixed dentition periods in comparison with normal growth and development. *Cleft Palate Craniofac J* 1993;30:182-94.
  13. Nanda R, Bruce G. Biomechanical approaches to the study of alterations of facial morphology. *Am J Orthod* 1980;78:213-26.
  14. Hata S, Itoh T, Nakagawa M, Kamogashira K, Ichikawa K, Matsumoto M, et al. Biomechanical effects of maxillary protraction on craniofacial complex. *Am J Orthod Dentofacial Orthop* 1987;91:305-11.
  15. Ishii H, Morita S, Takeuchi Y, Nakamura S. Treatment effect of combined maxillary protraction and chin cap appliance in skeletal Class III cases. *Am J Orthod Dentofacial Orthop* 1987;92:304-12.
  16. Tindlund RS, Rygh P. Maxillary protraction: different effects on facial morphology in unilateral and bilateral cleft lip and palate patients. *Cleft Palate Craniofac J* 1993; 30:208-21.
  17. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. *Am J Orthod Dentofacial Orthop* 1998;113:204-12.
  18. Miki M. An experimental research on the direction control of the nasomaxillary complex by means of external force: two-dimensional analysis on the sagittal plane of the craniofacial skeleton. *J Tokyo Dent Coll* 1979;79:1563-97.
  19. Hirato R. An experimental study on the study of resistance on the nasomaxillary complex: two-dimensional analysis on the coronal plane of the dry skull. *J Tokyo Coll* 1984;84:1225-62.
  20. Lee K, Ryu Y, Rudolph DJ. A study of holographic interferometry on the initial reaction of the maxillofacial complex during protraction. *Am J Orthod Dentofacial Orthop* 1997;111:623-32.
  21. Braun S, Lee K, Legan HL. A re-examination of various extraoral appliances in light of recent research findings. *Angle Orthod* 1999;81-4.
  22. Marcotte MR. *Biomechanics in Orthodontics*. Philadelphia: BC Decker, Inc; 1990.
  23. Figueroa AA, Polley JW. Orthodontic procedure for maxillary distraction. In: Diner PA, Vazquez MP, editors. *International congress on cranial and facial bone distraction processes*. Bologna: Monduzzi Editore; 1997. p. 247-53.
  24. Figueroa AA, Polley JW. Management of severe cleft maxillary deficiency with distraction osteogenesis: procedure and results. *Am J Orthod Dentofacial Orthop* 1999; 115:1-12.

#### **BOUND VOLUMES AVAILABLE TO SUBSCRIBERS**

Bound volumes of the *American Journal of Orthodontics and Dentofacial Orthopedics* are available to subscribers (only) for the 1998 issues from the Publisher, at a cost of \$96.00 (\$115.56 Canada and \$108.00 international) for Vol. 113 (January-June) and Vol. 114 (July-December). Shipping charges are included. Each bound volume contains a subject and author index and all advertising is removed. Copies are shipped within 60 days after publication of the last issue of the volume. The binding is durable buckram with the journal name, volume number, and year stamped in gold on the spine. Payment must accompany all orders. Contact Mosby, Inc, Subscription Services, 11830 Westline Industrial Drive, St Louis, MO 63146-3318, USA; telephone (314)453-4351 or (800)325-4177.

**Subscriptions must be in force to qualify. Bound volumes are not available in place of a regular Journal subscription.**