13

Standard Analytic Model Planning for Orthognathic Surgery

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Unlike most surgical procedures, orthognathic surgery involves not just the thorough medical assessment of the patient but also precise preoperative dental, radiographic, and facial aesthetic planning. The surgeon must carry out a detailed face-to-face examination of the patient to determine variations from normal (Fig. 13-1).

Immediate presurgical records include the following: 1) dental impressions of the maxilla and mandible 2) an accurate bite registration in centric relation (CR) 3) a face-bow recording of maxillary orientation in relationship to the condyles and the upper face and 4) the measurement of specific facial landmarks that includes deviations from normal (Figs. 13-2 and 13-3).

The maxillary model is mounted on a semi-adjustable articulator in accordance with the face-bow recording. The mandibular model is occluded to the mounted maxillary cast with the use of the CR bite[1,2,14,17,18,21,30,52,62,63] (Fig. 13-4). The mounted dental casts are then used to complete model planning[12,50] (Figs. 13-5 through 13-8). Splints made of acrylic are fabricated and used intraoperatively to further ensure the reliable execution of predetermined facial aesthetic and functional objectives (Figs 13-9 through 13-11).

Although clinical decision making regarding the preferred aesthetic reorientation and repositioning of the jaws in the operating room remains both an art and a science (see Chapter 12), the technical aspects of planning should be precise and consistent. Analytic model planning and the use of prefabricated splints continue to represent the standard of care for bimaxillary and segmental maxillary osteotomies.[8,9,15,16,22,26,44,55,77,78,80,85,86]

Despite the benefits of this time-honored approach, there is the potential to introduce error. For example, during bimaxillary surgery, if an inaccurate bite registration is obtained from the patient preoperatively in the clinic setting, this will be transferred to the articulated models; this leads to inaccurate splint construction and then to intraoperative errors when the splints are relied on during surgery. The surgeon's ability to obtain an accurate and reproducible bite registration in CR during the immediate

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• **Figure 13-1** A 19-year-old man of Asian descent presented with a maxillary deficient and relative mandibular excess growth pattern. He has an Angle Class III anterior open bite with negative overjet malocclusion as well as a lifelong history of obstructed nasal breathing. The maxillofacial dysmorphology causes difficulties with speech, chewing, swallowing, breathing, and lip closure/posture, and it also negatively affects his facial aesthetics. The upper facial skeleton is symmetric and proportionate; the soft-tissue envelope is distorted but not malformed. There is a good range of motion of the neck and mandible without temporomandibular disorder. After evaluation, a comprehensive orthodontic and surgical approach was discussed and approved. Orthodontic (dental) decompensation required 10 months of active treatment. No extractions were required. Six weeks before surgery, the patient returned for a direct visual examination and the taking of records that included alginate impressions of the maxilla and mandible, centric bite registration, face-bow registration, and the transfer of the data to a semi-adjustable articulator. Decisions were made regarding critical measurements for the surgical repositioning of the jaws. The procedures carried out included the following: a Le Fort I osteotomy in segments (horizontal advancement, cant correction, arch expansion, and clockwise rotation); bilateral sagittal split ramus osteotomies (mandibular adjustment); osseous genioplasty (minimal vertical shortening and horizontal advancement); and septoplasty and inferior turbinate reduction. **A,** Frontal view in repose and occlusal views before treatment. **B,** A Panorex radiograph. This is useful to assess basic condylar morphology and to look for mandibular and dental pathology, including root resorption.

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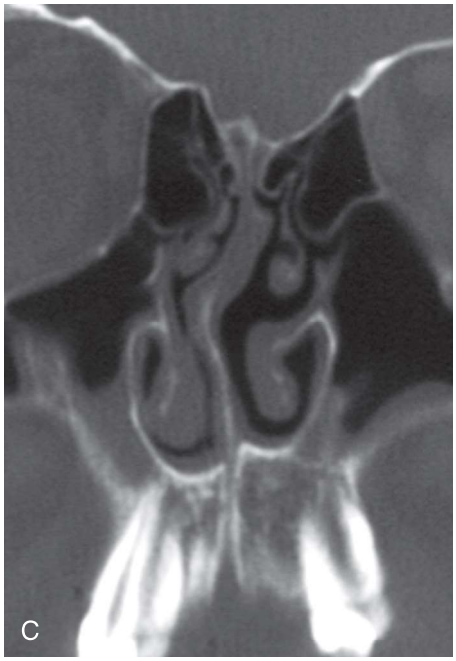
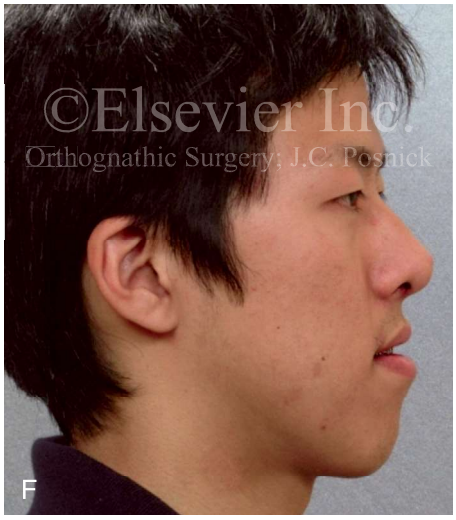


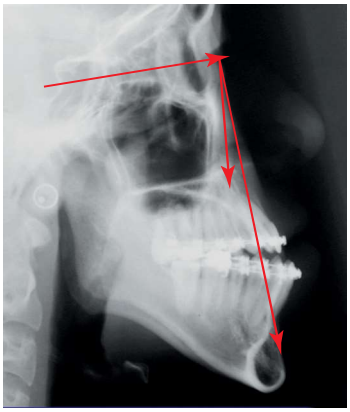
Assess intranasal anatomy
- Septal deviation? "Yes"
- Inferior turbinate hypertrophy? "Yes"
- Tight nasal inlet? "Yes"
- Elevated nasal floor? "No"

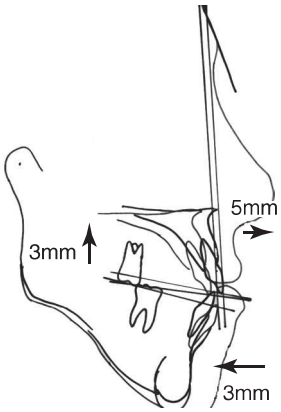
• **Figure 13-1, cont'd C,** The patient's history of lifelong nasal obstruction—in combination with an intranasal speculum and a sinus computed tomography scan examination—confirms a deviated septum (bone and cartilage) and hypertrophic inferior turbinates. Both of these conditions required surgical correction to improve the airway. **D,** Frontal view with smile and occlusal views with orthodontic decompensation in progress.

Maxillary Surgical Plan

Frontal View:	
Maxillary midline	No change needed
Cant correction	2 mm → +1 mm (L), −1 mm (R)
Anterior vertical	No change needed







Maxillary clockwise rotation (3 mm) to enhance profile aesthetics

• **Figure 13-1, cont'd** **E,** A frontal facial view confirms that the maxillary midline matches the upper facial midline; that there is a satisfactory lip–tooth relationship in repose and with smile; and that there is canting of the maxilla at the molars (2 mm) as compared with the upper face. **F,** Analysis of the facial profile and the lateral cephalometric radiograph before surgery provides useful information about facial height, incisor inclination, A-point to B-point relationship, maxillary and mandibular projection, and chin morphology.

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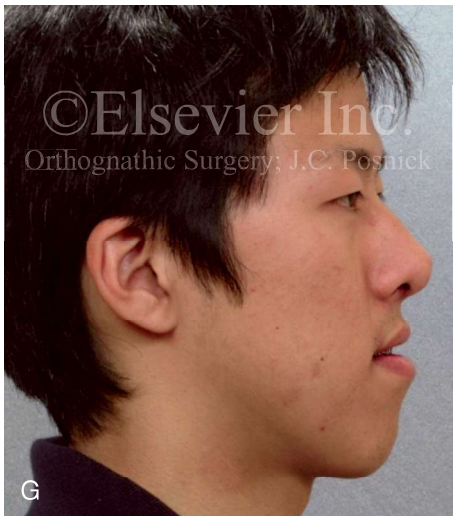
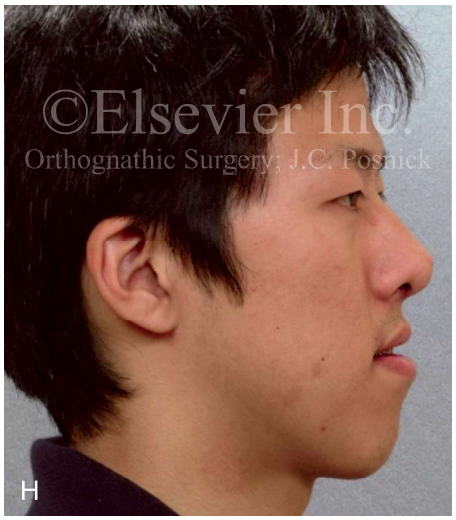


Maxillary Surgical Plan	
Profile View:	
Anterior vertical	no change
Posterior vertical	3-mm intrusion
Horizontal	5-mm advance

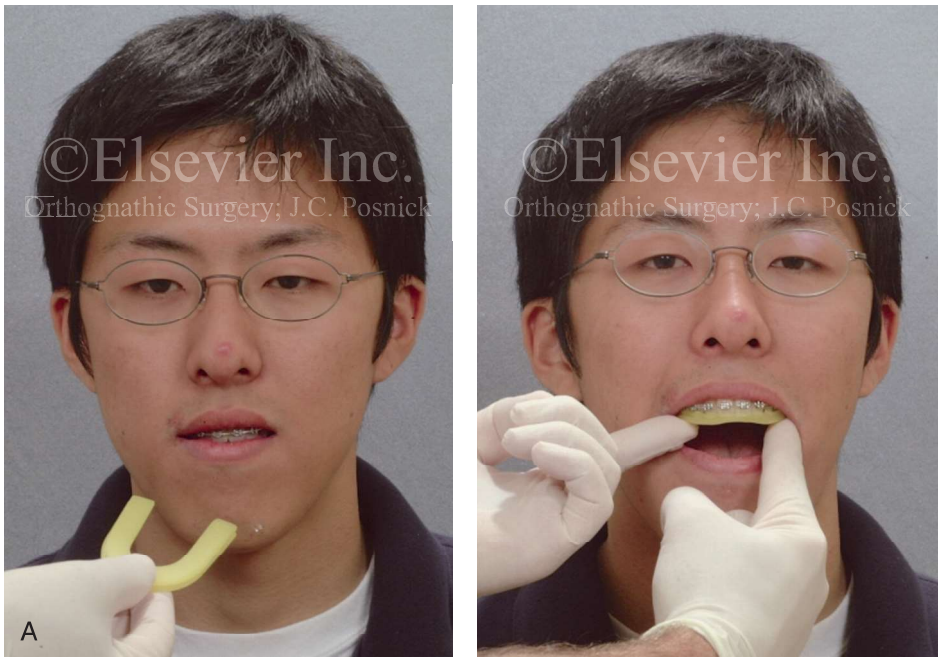
Maxillary clockwise rotation (3 mm) to enhance profile aesthetics



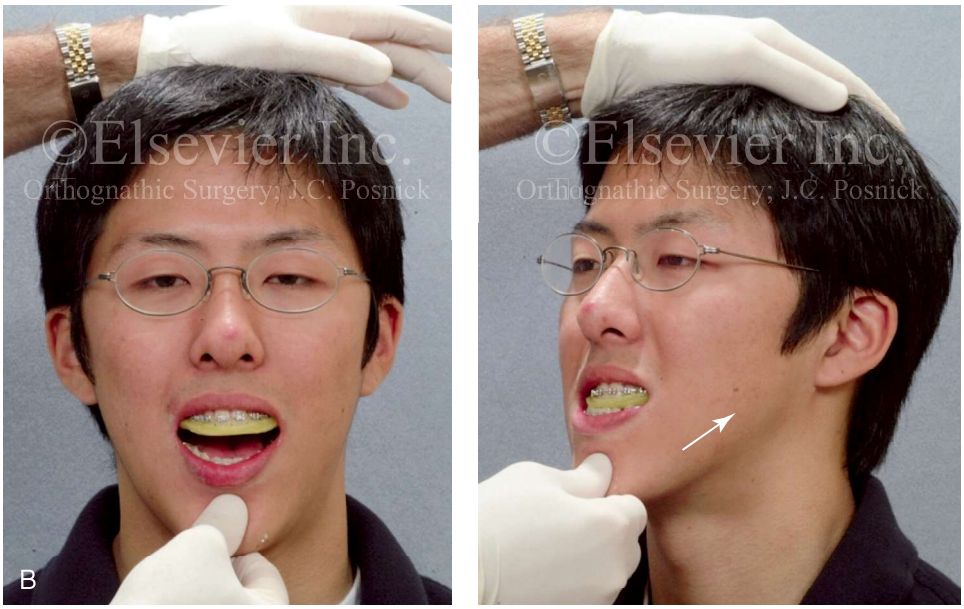
Maxillary Surgical Change	
Horizontal change at incisors	+5
Vertical change at incisors	0
Midline change at incisors	0
Cant correction -*TOTAL*	2
↑−1 on right ↓+1 on left	
Maxillary plane change -*TOTAL* (Clockwise) Counterclockwise	3
Vertical change at T#3 (right) molar (Base + Cant + Plane)	0 −1 −3 = −4
Vertical change at T#14 (left) molar (Base + Cant + Plane)	0 +1 −3 = −2

Measurements are used to spatially reposition the maxilla. The mandible is then set into occlusion with the repositioned maxilla.

• **Figure 13-1, cont'd G,** The direct visual examination of this patient in profile as well as Andrew's analysis confirms the following: an advantage of horizontal advancement at the maxillary incisors (5 mm); no need for vertical change at the maxillary incisors; an advantage of 3-mm clockwise rotation of the maxillary plane (3-mm intrusion at the first molars); and no need for horizontal change at the mandibular incisors. Note that 5-mm horizontal advancement at the incisors will correct the negative overjet and that 3-mm clockwise rotation of the maxillary plane (intrusion at the first molars) will be helpful to restore profile aesthetics and to overcome maxillary incisor procumbancy. **H,** The planned maxillary surgical change is recorded on the orthognathic data sheet. These measurements will be used to spatially reposition and reorient the maxilla first on the articulator for intermediate splint construction and then at the time of Le Fort I osteotomy. During surgery, through sagittal split ramus osteotomies, the mandible will then be set into occlusion with the repositioned maxilla.



"Chin-point guidance" technique for centric relation



"Chin-point guidance" technique for centric relation

• **Figure 13-2** The chin-point guidance technique is used to capture (register) the centric relation bite. The patient is seated upright and in the natural head position. The chin-point guidance technique is accomplished by using one hand to apply pressure to the subject's chin and the other hand to apply counter pressure to their occiput. This allows the clinician to apply posterior and superior "vectored" force on the anterior aspect of the mandible. By doing so, the condyles will be seated in a superior-anterior location within each glenoid fossa (i.e., centric relation). **A,** The registration of the patient's maxillary occlusion into soft wax. **B,** Applying pressure to the chin with the patient's muscles relaxed. The condyles are seated, and the mandible is rotated up until the teeth first occlude. It is essential to avoid a shift (slide) from the centric relation into a centric occlusion. This may occur in a patient with malocclusion if he or she is allowed to fully clench the teeth together.

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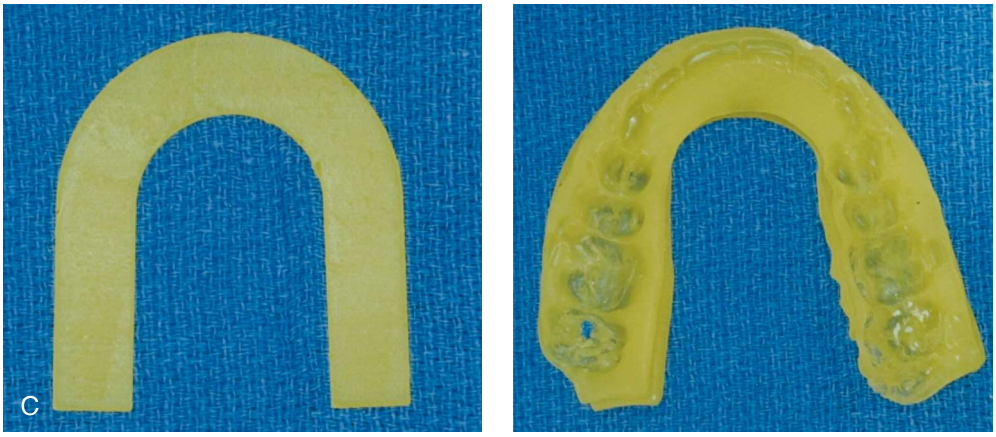
Centric relation (CR) bite (wax)

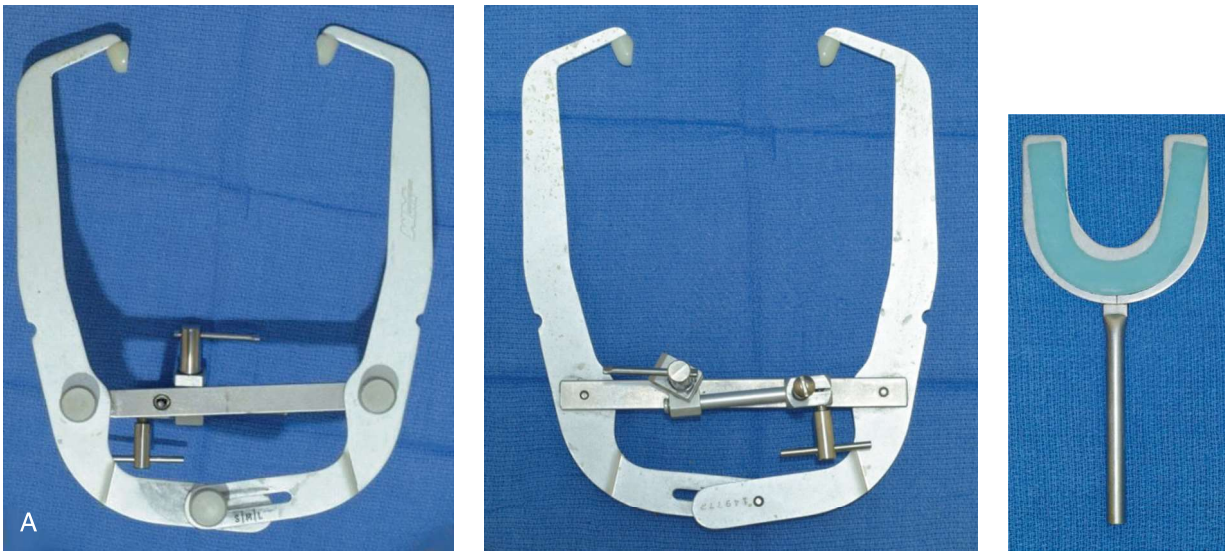


Wax wafer

Bite registration

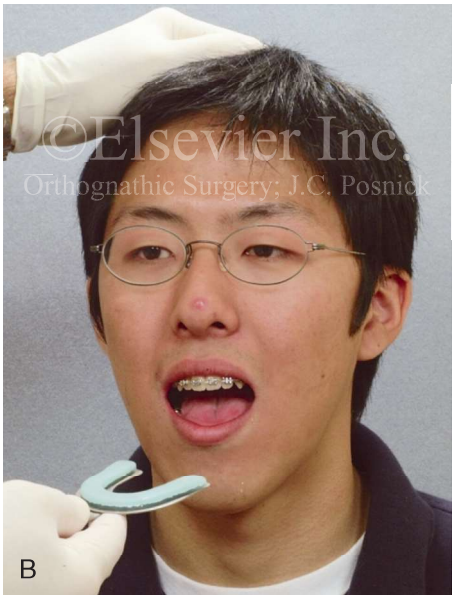
• **Figure 13-2, cont'd C,** Wax wafer before and after bite registration.

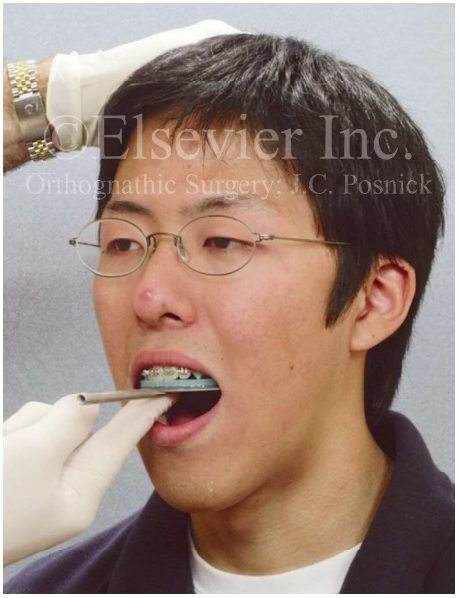
Face-bow registration → For transfer of relationships to articulator



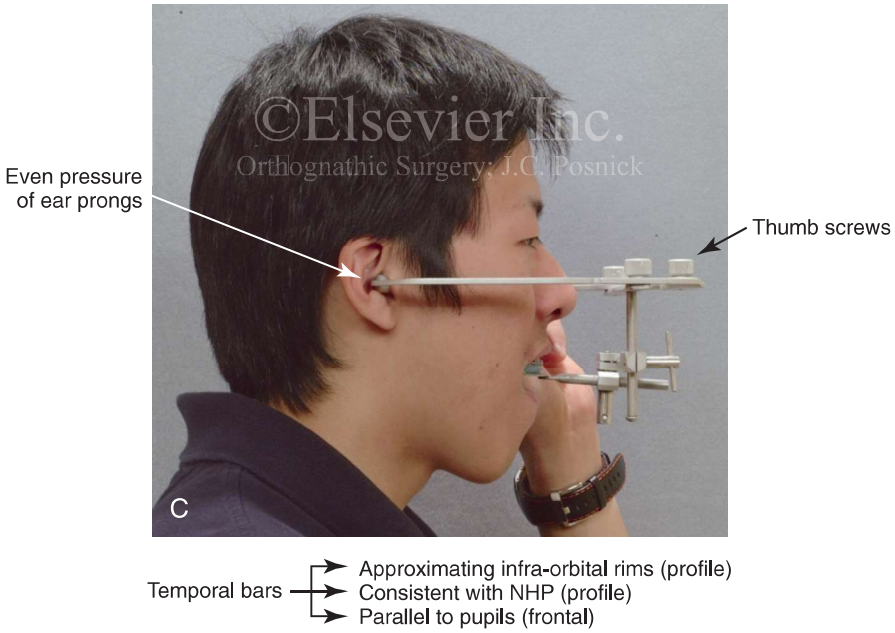
Register spacial orientation between → Condyles/ear canals
Maxilla/maxillary occlusal plane
Skull base/facial plane

• **Figure 13-3 A,** Bite fork with soft wax placed on the upper side is demonstrated. The face-bow apparatus is shown from both the bird's-eye view and the worm's-eye view.





Register patient's maxillary occlusion into soft wax on bite fork



• **Figure 13-3, cont'd** **B,** The patient's maxillary occlusion is registered into soft wax on the bite fork. **C,** The face bow apparatus is held in place through even pressure of the ear prongs in each ear canal. The three thumbscrews are then tightened.

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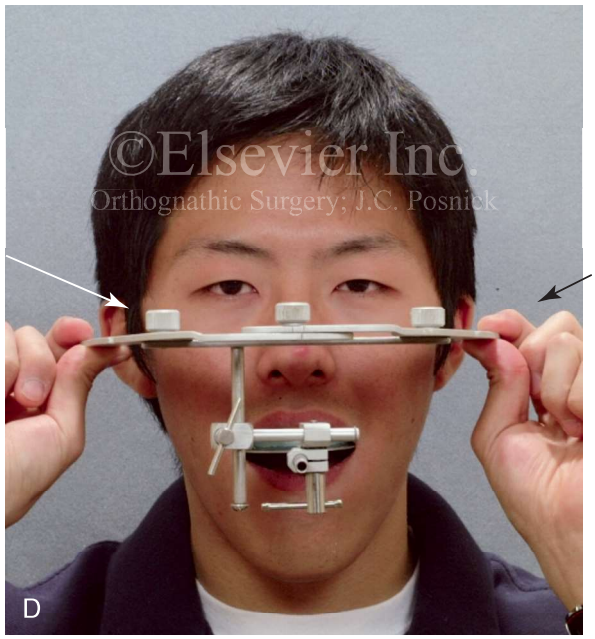
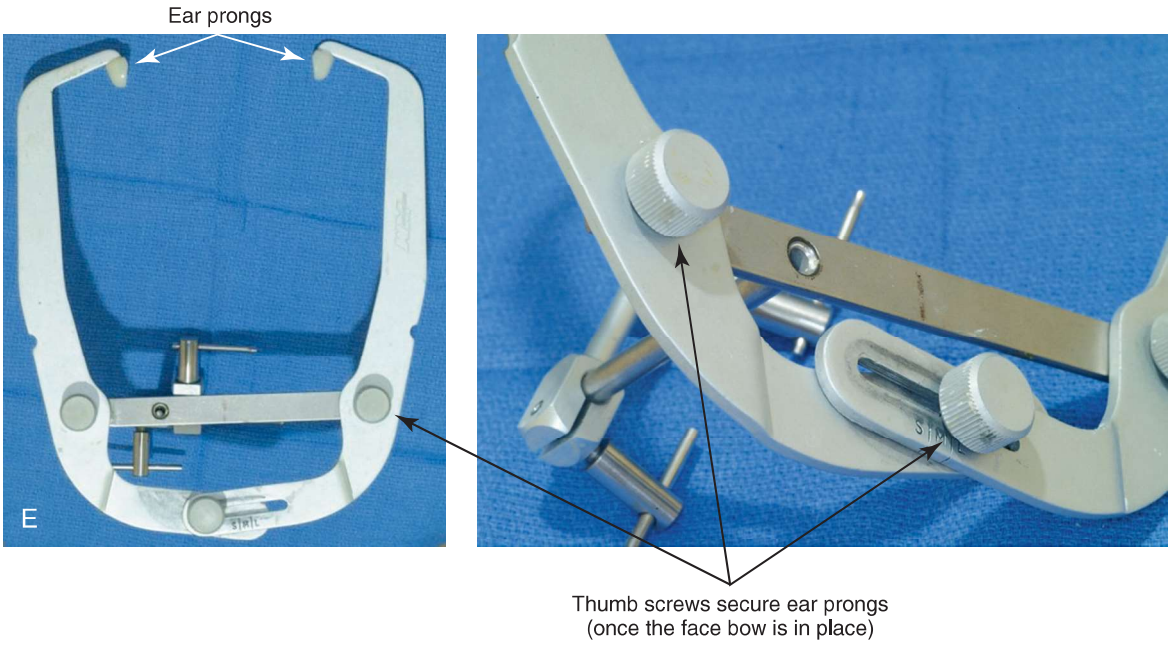
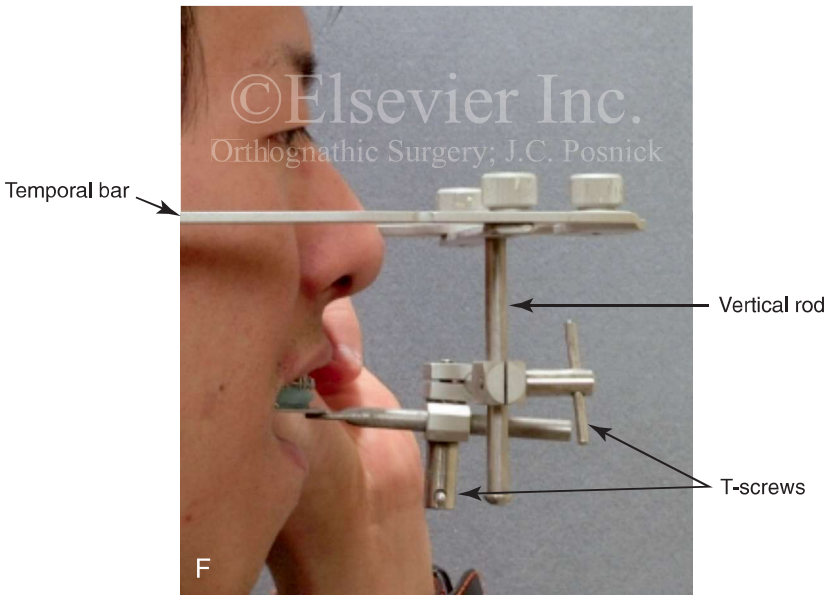
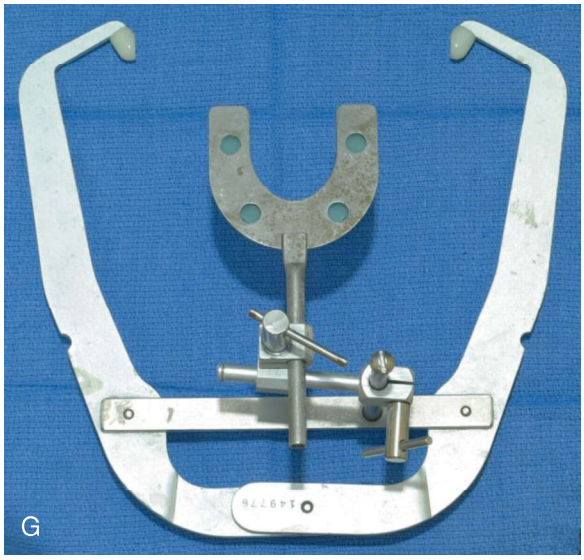




• **Figure 13-3, cont'd D,** The temporal bar is set parallel with the interpapillary line and consistent with the natural head position. **E,** A close-up view is shown of the thumbscrews that secure the ear prongs in place.



T-screws secure bite fork to vertical rod of face bow



Face-bow apparatus removed from patient
Ready to place on semi-adjustable articulator

• **Figure 13-3, cont'd F,** T-screws secure the bite fork to the vertical rod of the face-bow apparatus. The T-screws are turned clockwise to secure the face bow after confirming that the temporal bar extensions are parallel to the interpupillary line (frontal view) and consistent with the natural head position (profile view). **G,** With the T-screws tight, the thumbscrews are loosened to release the face-bow apparatus from the patient. The face bow is now ready to place on the articulator.

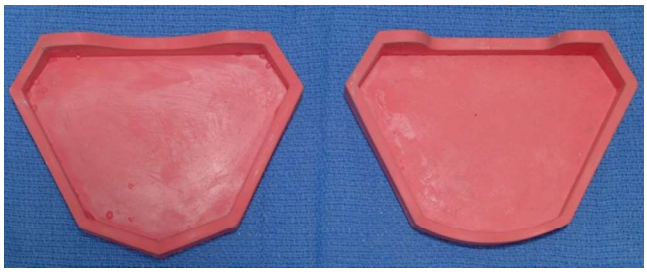
Continued

Alginate impressions of mandible and maxilla

Use vibrator to limit air bubbles

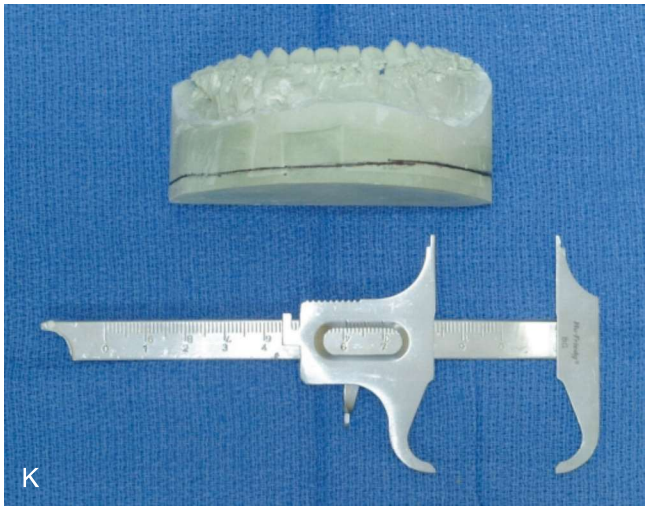
Pour up alginate impressions in green dental (die) stone

• **Figure 13-3, cont'd H,** Impression trays are selected to fit the patient's arch form. The alginate is mixed, placed in the trays, and then taken to the maxillary and mandibular arches, in turn. Negative impressions of the dentition are recorded in the alginate. **I,** The alginate impressions are "poured up" in green dental (die) stone. The use of a vibrator during this process will limit air bubbles.



Base forms are helpful

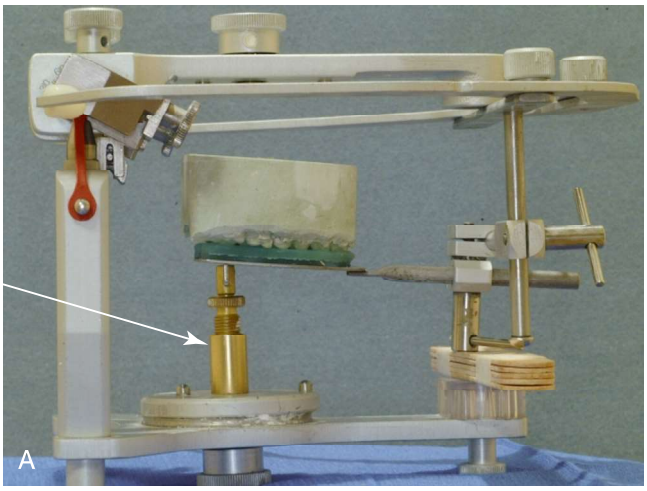
Incorporate at least 30 mm of stone base



Trim each model

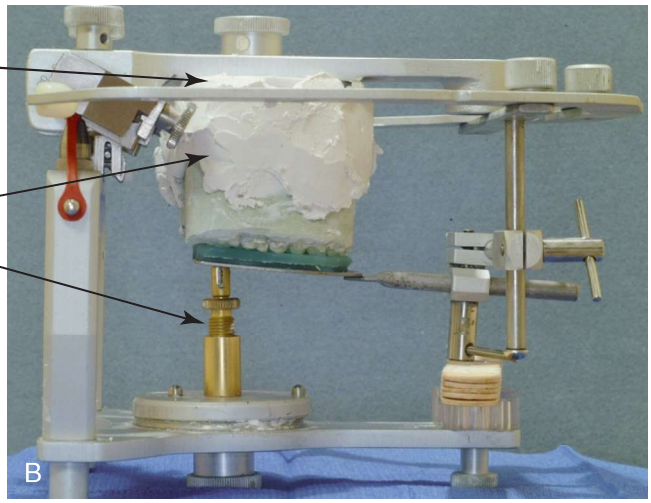
Measure (25-30 mm) down from
- First molar cusp tip
- Canine cusp tip
- Central incisor cusp tip

• **Figure 13-3, cont'd** **J,** Base formers are useful when incorporating additional dental stone to achieve at least 30 mm of height for each dental cast. **K,** After the die stone is set (≈30 min), the models can be trimmed to achieve a consistent 25-mm base on the maxillary cast and a 30-mm base on the mandibular cast.

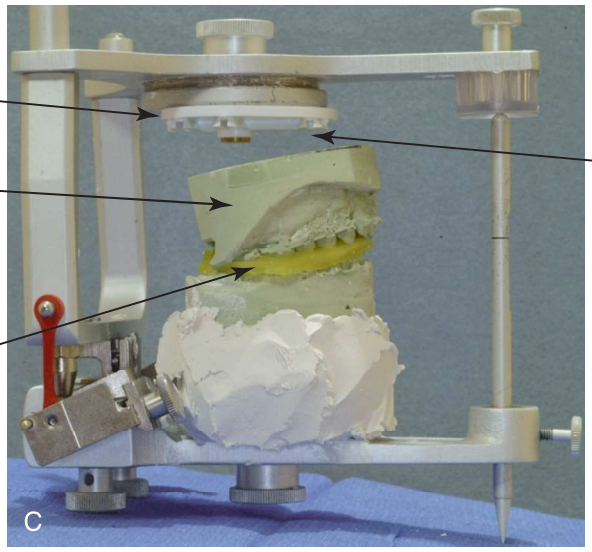


Mounting maxillary cast on articulator using white plaster bite fork support prevents sagging

Base plate

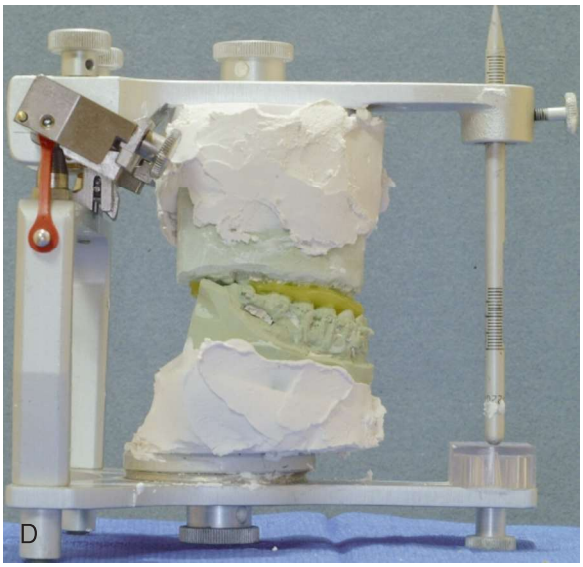


Maxillary cast secured to base plate with plaster



With maxillary unit dry – turn articulator upside down
Use CR wax bite to occlude mandibular cast to maxillary unit

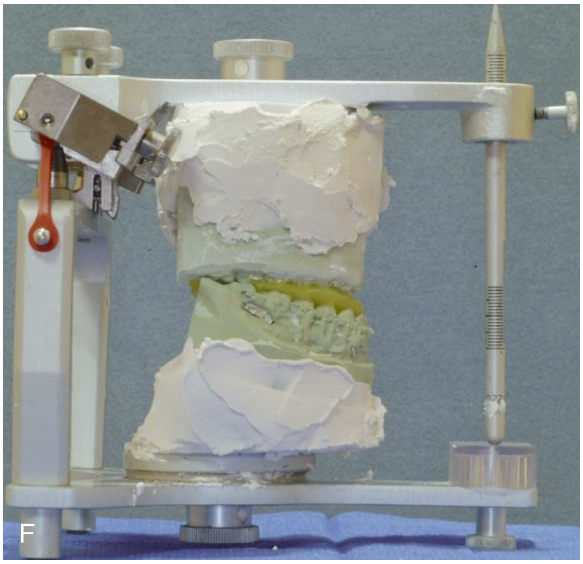
• **Figure 13-4 A,** The trimmed dental casts are then mounted on the semi-adjustable articulator with the use of the face-bow apparatus. The temporal arms of the face bow are maintained parallel to the upper aspect of the articulator and the counter top. Base plates for the maxillary and mandibular units are secured to the articulation. A bite-fork support is useful to prevent the sagging of the face-bow apparatus when mounting the maxillary cast. **B,** The plaster is mixed and added in between the maxillary dental cast and the base plate. **C,** With the maxillary unit initially set (≈15 min), the articulator is turned upside down. The centric relation wax bite is occluded to the maxillary cast. The trimmed mandibular cast is then occluded to the other side of the wax bite.



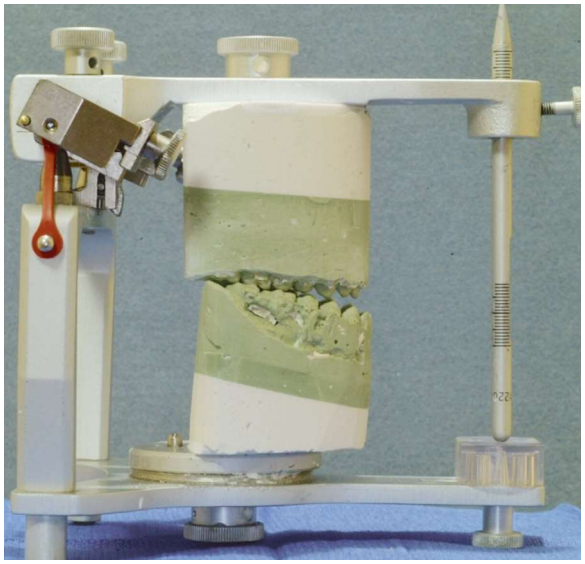
Mandibular and maxillary casts secured to articulator

• **Figure 13-4, cont'd D,** With the base plate secured to the articulator, the space that separates the mandibular dental cast from the base plate is filled with white plaster. **E,** The maxillary and mandibular units are removed from the articulator and taken to the grinder for trimming. **F,** The mounted dental casts are shown on the semi-adjustable articulator before and after trimming.

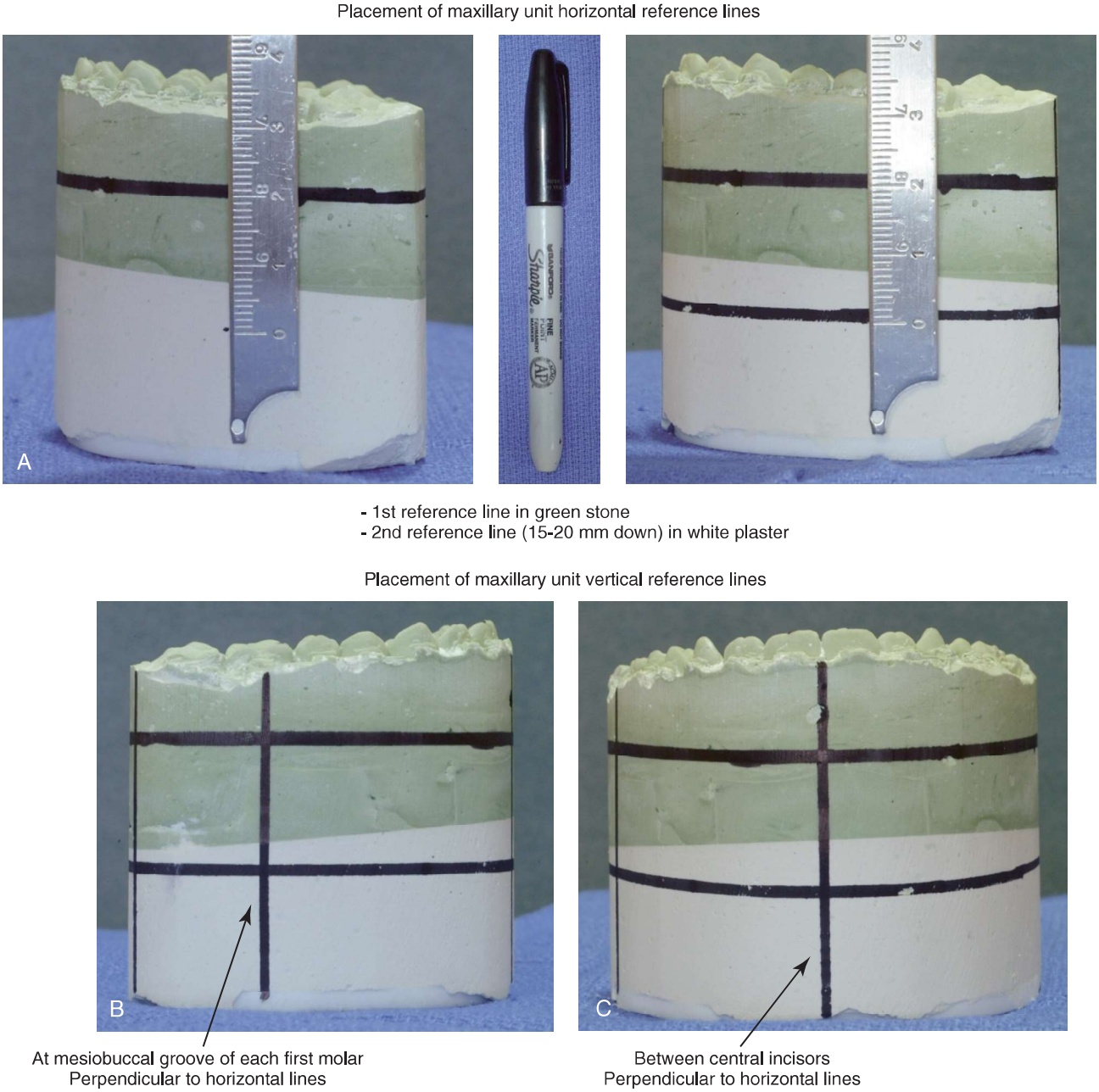
Remove maxillary and mandibular units from articulator, trim each independently on grinder



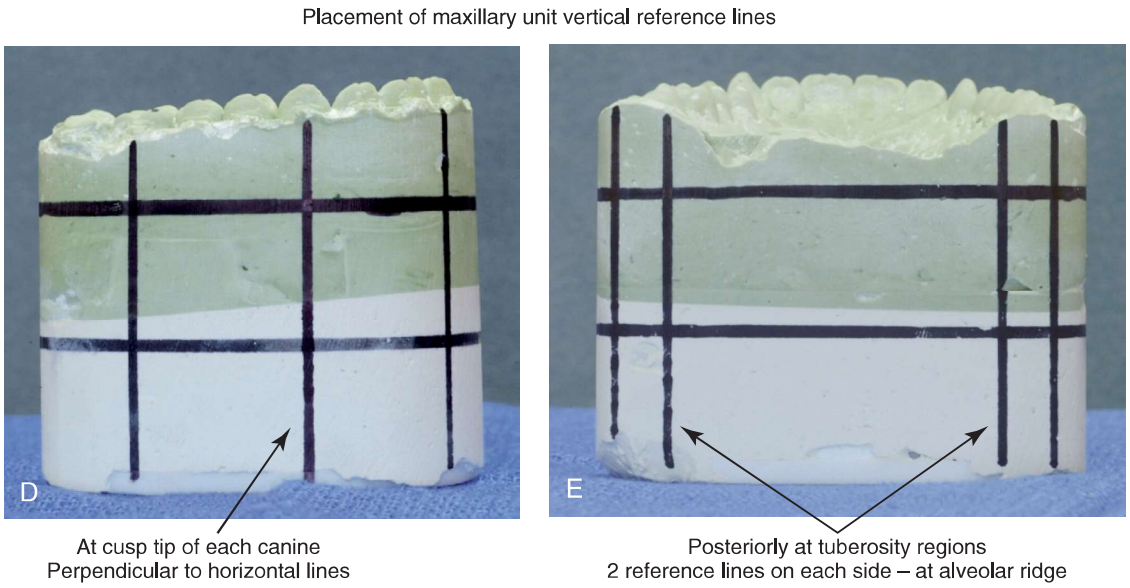
Prior to trimming



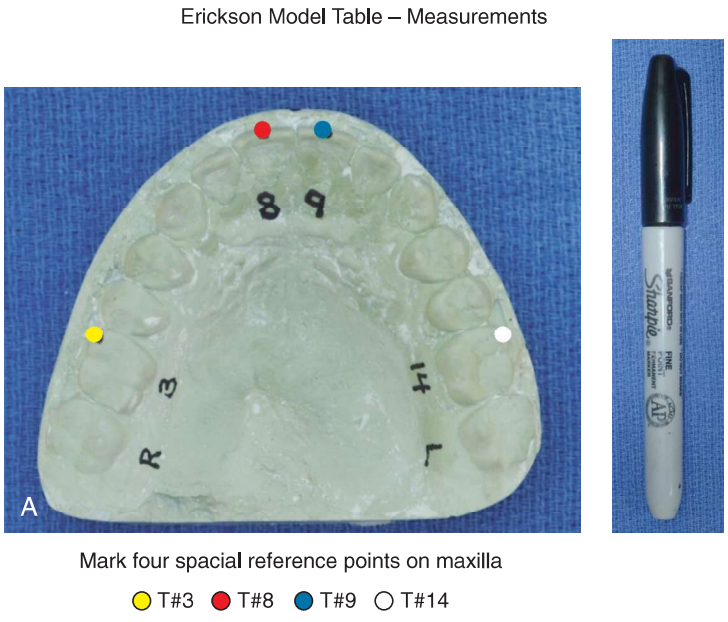
After trimming



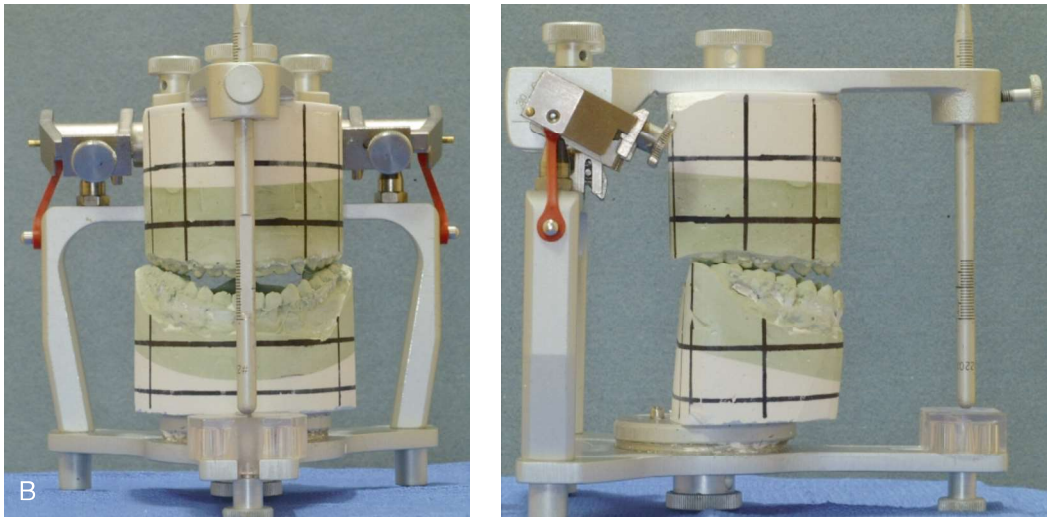
• **Figure 13-5** Marking horizontal and vertical reference lines on the articulated dental casts. **A,** The maxillary unit horizontal reference lines are placed parallel to the base plate. The first horizontal reference line is placed entirely in the green stone. The second is placed entirely in the white plaster, with 15 mm to 20 mm of separation between the lines. **B,** A maxillary unit vertical reference line is placed at the mesiobuccal groove at each first molar, perpendicular to the horizontal lines. **C,** The next maxillary unit vertical reference line is placed between central incisors, perpendicular to the horizontal lines.



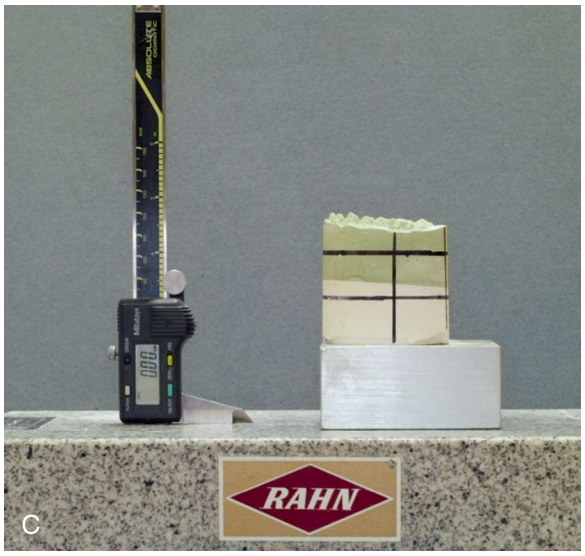
• **Figure 13-5, cont'd** **D,** Additional maxillary unit vertical reference lines are placed at the cusp tip of each canine, perpendicular to the horizontal lines. **E,** Vertical maxillary unit reference lines are also placed posteriorly in the tuberosity regions. Two reference lines are generally placed on each side, adjacent to the alveolar ridges. Similar horizontal and vertical reference lines are placed on the mandibular unit.



• **Figure 13-6** The Erickson Model Table (EMT) is used to register the baseline maxillary orientation in all three planes in space. The baseline measurements are then used to assist with the accurate repositioning and reorienting of the maxilla in accordance with clinical requirements. **A,** With a Sharpie marking pen, a reference dot is placed at the mesiobuccal cusp tip of each maxillary first molar and the midpoint of each maxillary central incisor. *Continued*



Articulated dental casts with reference lines



• **Figure 13-6, cont'd** **B,** The articulated dental casts with horizontal and vertical reference lines already marked are now ready for baseline maxillary reference measurements taken from the EMT. **C,** The maxillary unit is attached to the EMT base mount from which measurements will be made.

ORTHOGNATHIC SURGERY : ANALYTIC MODEL PLANNING

Data entry form

Patient name: _____

Surgical date: _____

Orthodontist: _____

Surgical wire date: _____

Final model date: _____

Dentist: _____

ERIKSON TABLE MEASUREMENTS

MAXILLARY HORIZONTAL

	Baseline (mm)	Change (mm)	Final
Right #8	_____	_____	_____
Left #9	_____	_____	_____

MAXILLARY VERTICAL

	Baseline (mm)	Change (mm)	Final
Right #3	_____	_____	_____
Right #8	_____	_____	_____
Left #9	_____	_____	_____
Left #14	_____	_____	_____

MAX-MIDLINE (Right-side down)

	Baseline (mm)	Change (mm)	Final
#ML	_____	_____	_____

MAX-MIDLINE (Left-side down)

	Baseline (mm)	Change (mm)	Final
#ML	_____	_____	_____

MAX TRANSVERSE (Arch width)

	Baseline (mm)	Change (mm)	Final
#6-11	_____	_____	_____
#3-14	_____	_____	_____

MANDIBULAR HORIZONTAL

	Baseline (mm)	Change (mm)	Final
#ML	_____	_____	_____

MAXILLARY SURGICAL CHANGE

Horizontal change at incisors _____

Vertical change at incisors _____

Midline change at incisors _____

Cant correction-*Total* _____

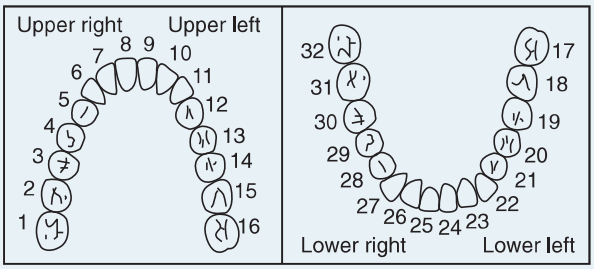
↑↓_____ on right ↑↓_____ on left

Maxillary plane change-*Total* _____
Clockwise - counterclockwise

Vertical change at T#3 (right) molar ____ ____ ____=_____
(Base+cant+plane)

Vertical change at T#314 (left) molar ____ ____ ____=_____
(Base+cant+plane)

OCCLUSAL EQUILIBRATION/MISSING TEETH



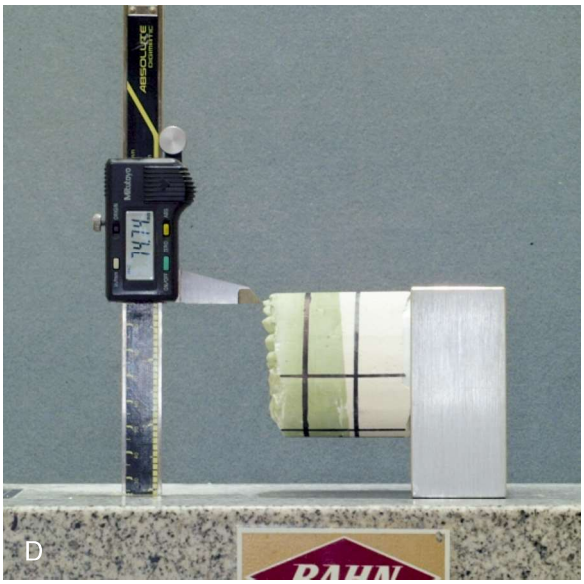
OVERALL SURGICAL PLAN

☐ Le Fort I ☐ 2 seg ☐ 3 seg
☐ Sagittal splits of mandible
☐ Genioplasty
☐ Septoplasty
☐ Reduction of inferior turbs
☐ Wisdom teeth removal
☐ Anterior neck rejuvenation
☐ Graft required
☐ Iliac ☐ Allograft ☐ HA

C

• **Figure 13-6, cont'd** C, The standard orthognathic surgery model-planning data sheet is shown.

Continued



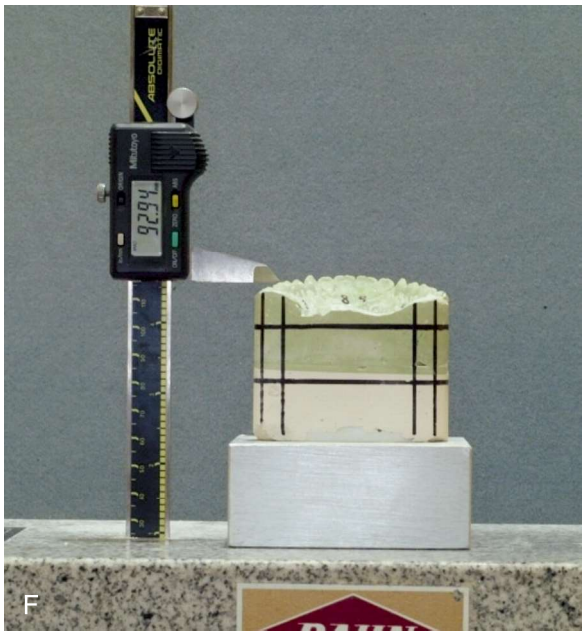
Maxillary Horizontal			
	Baseline (mm)	Change (mm)	Final
Right #8	74.5	+5	79.5
Left #9	74.5	+5	79.5

Baseline (horizontal) position of incisors (mm)

Maxillary Anterior Vertical			
	Baseline (mm)	Change (mm)	Final
Right #8	96.2	0	96.2
Left #9	95.8	0	95.8

Baseline (vertical) position of incisors (mm)

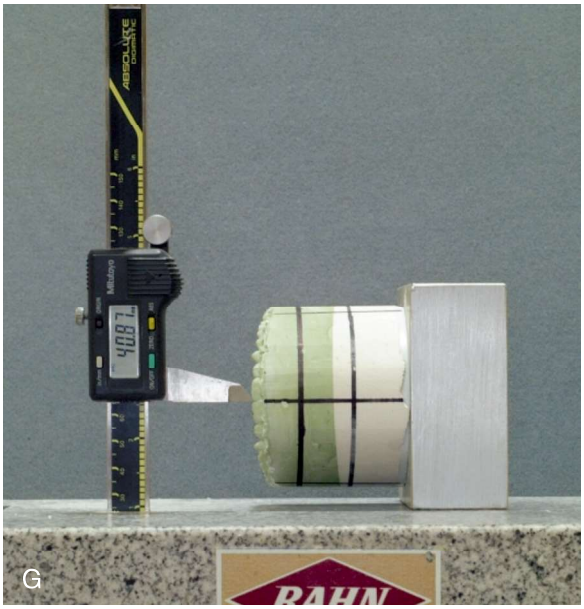
• **Figure 13-6, cont'd D,** The EMT is used to measure the baseline horizontal position of the incisors in millimeters. This is the distance between the base of the EMT and the incisal edge of each maxillary central. The millimeter number is recorded on the data sheet. The desired horizontal surgical change at the maxillary incisors is also written on the data sheet. The final preferred horizontal position of the maxillary incisors, as a result of model planning, is calculated and recorded. **E,** The EMT is used to measure the baseline vertical position of the incisors in millimeters. This is the distance between the base of the EMT and the incisal edge of each maxillary central incisor. The millimeter number is recorded on the data sheet. The desired vertical surgical change at the maxillary incisors is also written on the data sheet. The final preferred vertical position of the maxillary incisors, as a result of model planning, is calculated and recorded.



Maxillary Posterior Vertical			
	Baseline (mm)	Change (mm)	Final
Right #3	93.1	−3/−1	89.1
Left #14	91.7	−3/+1	89.7

(plane/cant)

Baseline (vertical) position of first molars (mm)

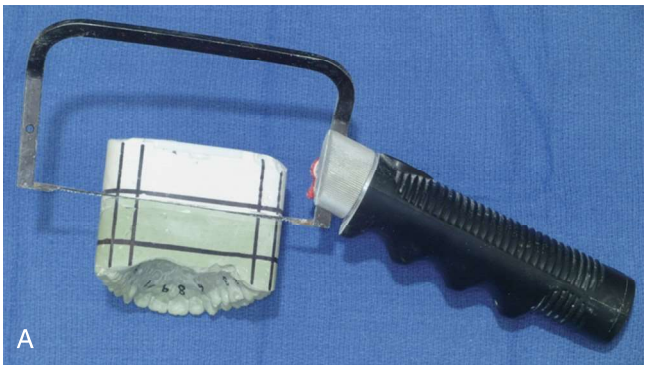


Max-Midline (Right-Side Down)			
	Baseline (mm)	Change (mm)	Final
#ML	43.6	0	43.6

Max-Midline (Left-Side Down)			
	Baseline (mm)	Change (mm)	Final
#ML	41.1	0	41.1

Baseline transverse (midline) position of incisors (mm)

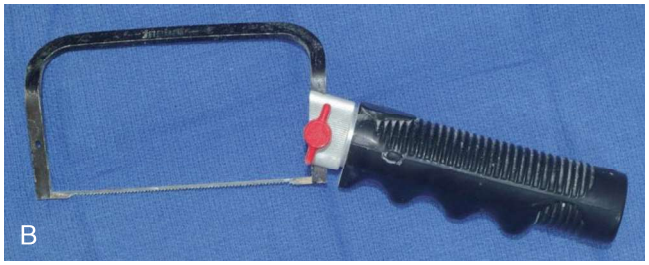
• **Figure 13-6, cont'd F,** The EMT is used to measure the baseline vertical position of each maxillary first molar. This is the distance between the base of the EMT and the mesiobuccal cusp tip of each maxillary first molar. The millimeter number is recorded on the data sheet. The desired vertical surgical change at each maxillary first molar is also written on the data sheet. The final preferred vertical position of the maxillary molars, as a result of model planning, is calculated and recorded. **G,** The EMT is used to measure the baseline transverse midline position of each incisor in millimeters. This is an indication of the maxillary dental midline position from both the right side down and left side down directions. The base measurement is recorded on the data sheet. The desired transverse change at the maxillary incisor is written on the data sheet. The final preferred transverse midline position of the maxillary incisor, as a result of model planning, is calculated and recorded.



Remove the maxillary unit from the articulator
Then separate the maxillary cast from its base

3–segments?

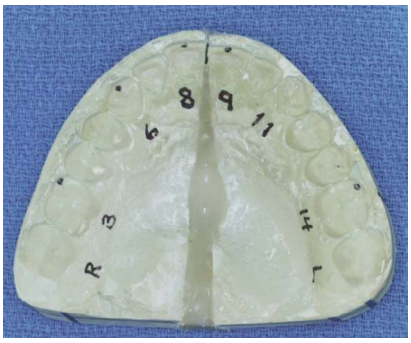
2–segments?



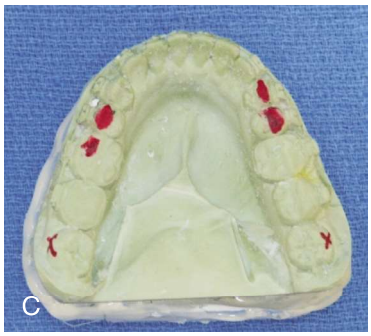
Use die saw to segment maxilla

• **Figure 13-7** The maxillary unit is now removed from the articulator. **A,** The maxillary cast is separated from its base. This is accomplished with the use of a die saw to cut a groove and a knife that is placed into the groove, which is then hit with a hammer. **B,** If indicated, segmentation of the maxillary cast is carried out. This is done in accordance with patient-specific needs to correct the maxillary arch form. Segmentation is generally carried out either as two parts (i.e., between the central incisors and then through the hard palate) or as three parts (i.e., between the lateral incisor and the canine on each side and then through the hard palate). The maxilla is cut by hand with a die saw instrument.

3–segment alignment



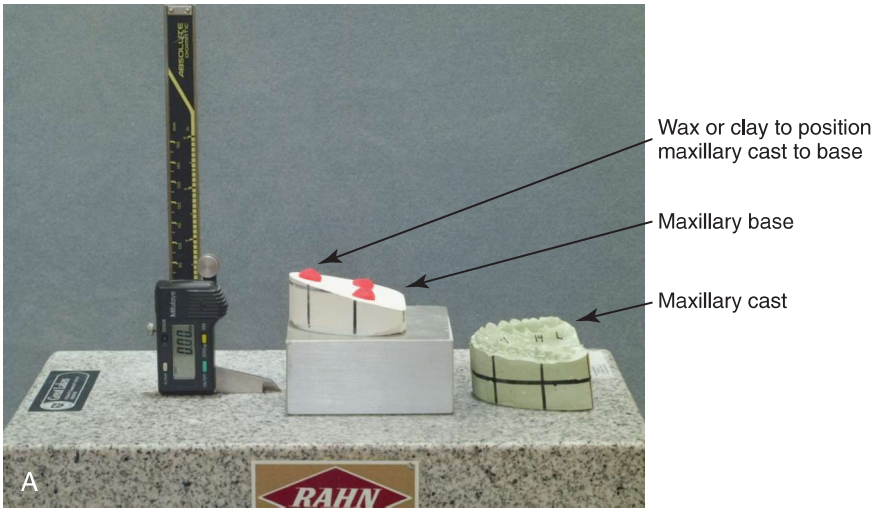
2–segment alignment



Mandibular cast

• **Figure 13-7, cont'd C,** If segmentation of the maxillary cast is required, the cut segments are placed into the corrected arch form by aligning the segments over the mandibular arch. It is important to maintain a physiologic orientation of the interdental papilla, with tight contact between the teeth. Ideally, the adjacent roots are also parallel, with minimal divergence. The maxillary segments are secured together in the corrected arch form with the use of hot glue from a glue gun.

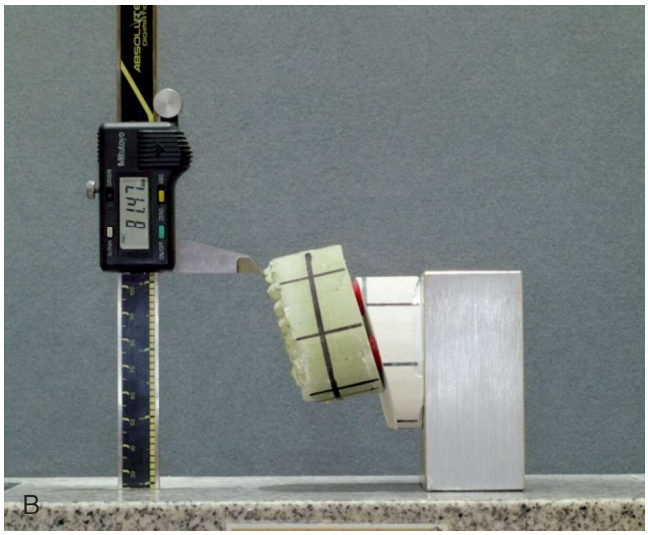
NOTE: If occlusal equilibration is required to achieve the preferred articulation, it is completed on the casts and recorded at this time. The actual occlusal equilibration procedure is completed during surgery.



Maxillary cast is repositioned on maxillary base according to clinical assessment/surgical plan

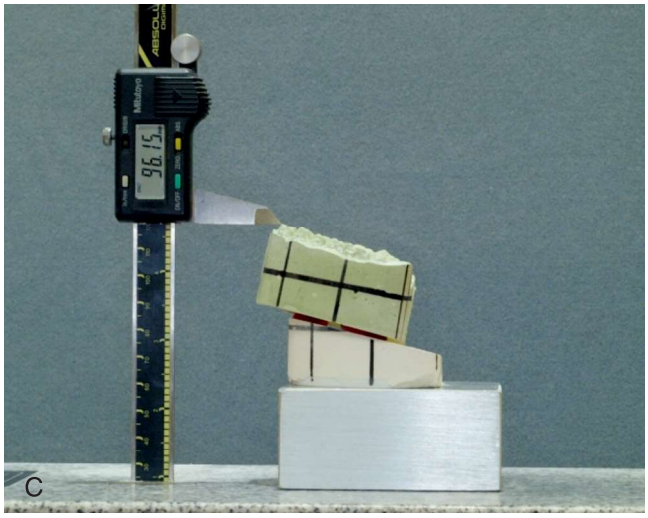
• **Figure 13-8 A,** The maxillary cast is next repositioned and reoriented on the maxillary base in accordance with the clinical assessment and the surgical plan. The Erickson Model Table (EMT) is used to ensure the correct spatial reorientation of the maxillary cast to achieve the clinical objectives.

Continued



Maxillary Horizontal			
Baseline (mm)		Change (mm)	Final
Right #8	74.5	+5	79.5
Left #9	74.0	+5	79.5

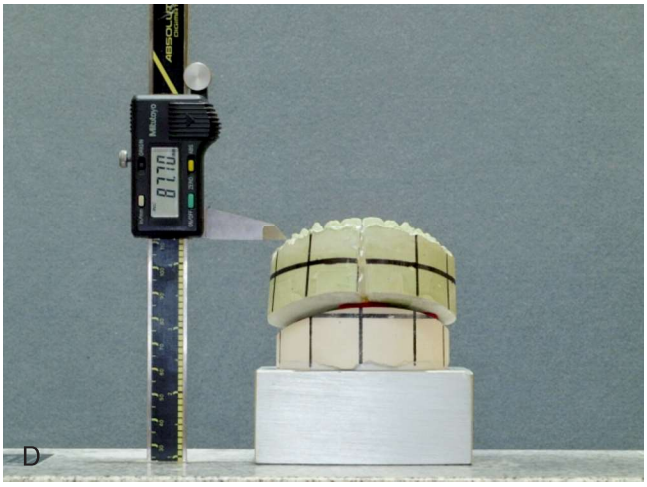
Maxillary horizontal change at incisal edge (5.0-mm advance)



Maxillary Anterior Vertical			
Baseline (mm)		Change (mm)	Final
Right #8	96.2	0	96.2
Left #9	95.8	0	95.8

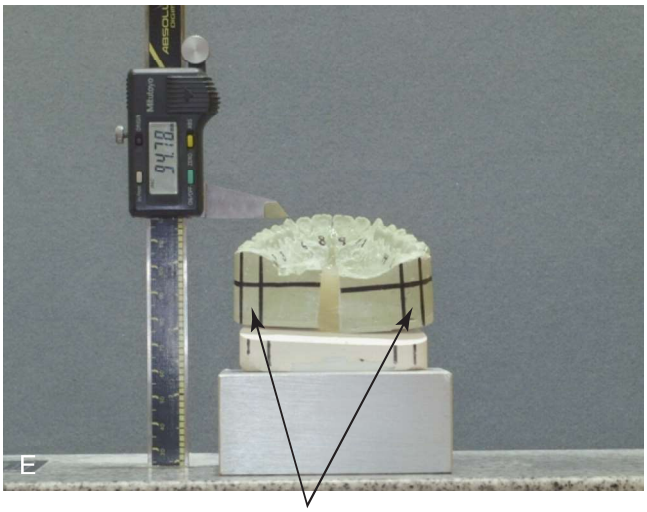
Maxillary vertical change at incisal edge (no change)

• **Figure 13-8, cont'd** **B,** The EMT is used to accurately reposition the maxilla. For this patient (see Fig. 13-1), the maxillary horizontal change at the incisal edge is a 5-mm advancement. **C,** In this case, the EMT also confirms that no vertical change will occur at the maxillary incisal edge.

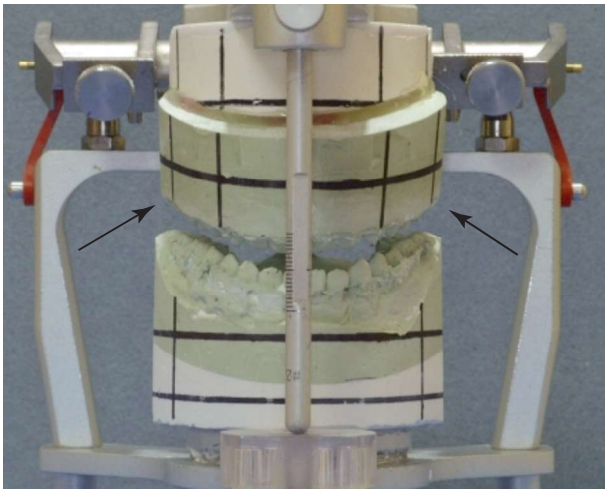


Maxillary Posterior Vertical			
Baseline (mm)	Change (mm)	Final
Right #3 93.1	−3/−1	89.1
Left #14 91.7	−3/+1	89.7

- Maxillary plane change
  - − 3.0 mm vertical (plane) change at right 1st molar
  - − 3.0 mm vertical (plane) change at left 1st molar
- Maxillary cant correction
  - − 1.0 mm vertical (cant) change at right 1st molar
  - + 1.0 mm vertical (cant) change at left 1st molar



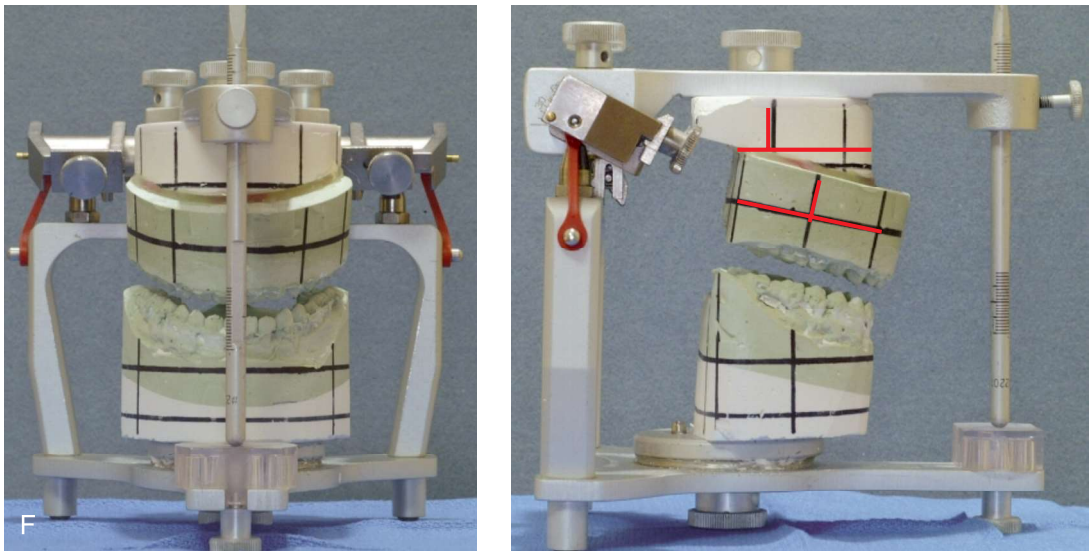
Equal change at both tuberosities
to avoid altering in yaw orientation



Check "yaw" effect
at the occlusal level!!

• **Figure 13-8, cont'd D,** The EMT is used to accurately reposition the maxilla at the molars. The confirmation of correct positioning at the mesiobuccal cusp tip of each first molar is essential. The vertical change incorporates the desired three-dimensional roll and pitch changes. **E,** When repositioning the maxilla, the EMT is useful to check for any yaw effect. Establishing equal side-to-side changes at both tuberosity regions is required to avoid a yaw change of the posterior maxilla. The reoriented maxillary unit is placed back onto the articulator for viewing.

Continued



Desired A-pt B-pt alteration to enhance aesthetics (3 mm clockwise rotation of maxilla)

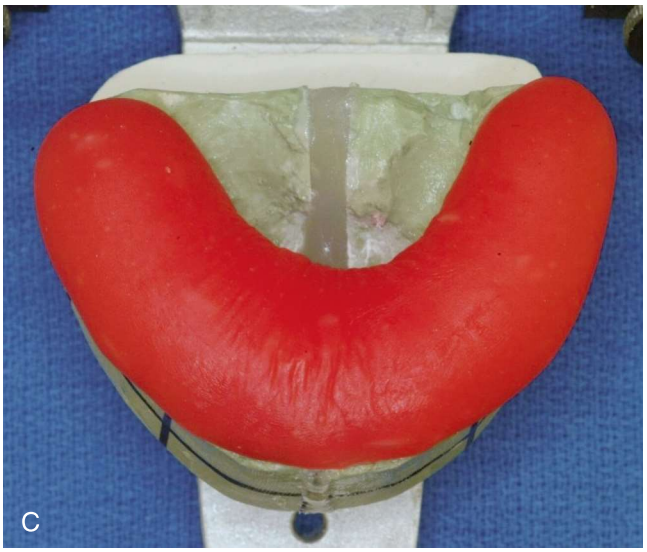
• **Figure 13-8, cont'd F,** The vertical pin on the articulator should remain neutral throughout the process.

NOTE: Before going forward with intermediate splint construction, confirming the yaw orientation of the maxilla relative to the mandible is essential.

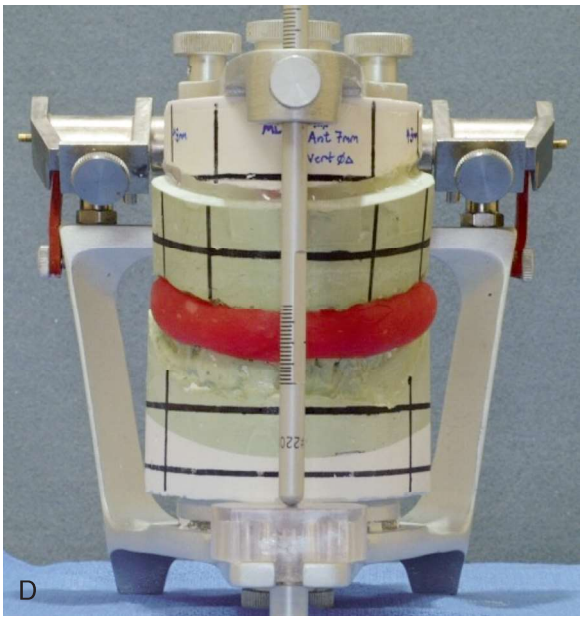
Apply Vaseline to maxillary and mandibular teeth

Use pink acrylic liquid and resin powder

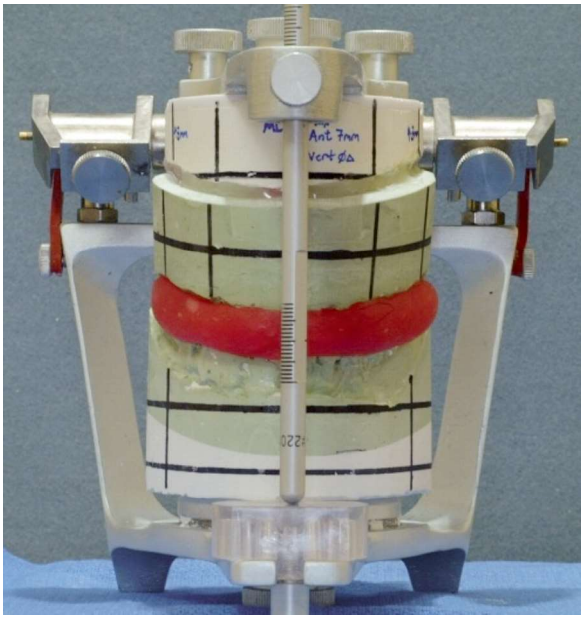
• **Figure 13-9** Construction of the intermediate splint. **A,** Apply a thin coat of Vaseline to the maxillary and mandibular teeth. **B,** Use pink acrylic liquid and orthodontic resin powder, and mix them until the mass does not slump.



Adapt mass to the maxillary occlusal surface



- Close articulator until pin touches
- Mandibular occlusal imprint will result

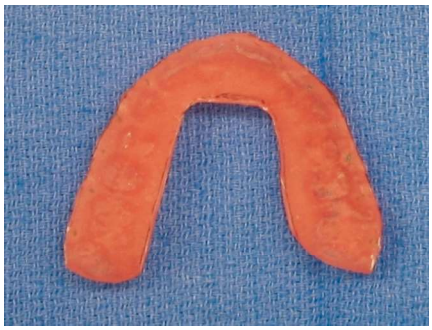


Carefully trim soft acrylic with scissors

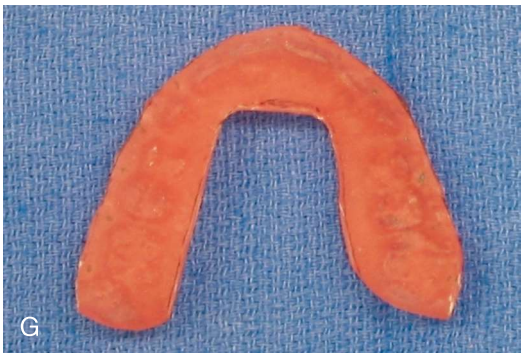
• **Figure 13-9, cont'd C,** Roll the mixed acrylic mass into a log shape. Adapt the mass to the maxillary occlusal surface. **D,** Close the articulator until the vertical pin touches in a neutral location. A mandibular occlusal surface imprint will result. **E,** Limit "undercuts" from brackets by carefully trimming the soft acrylic with scissors.

Continued

Use lathe to trim excess hardened acrylic

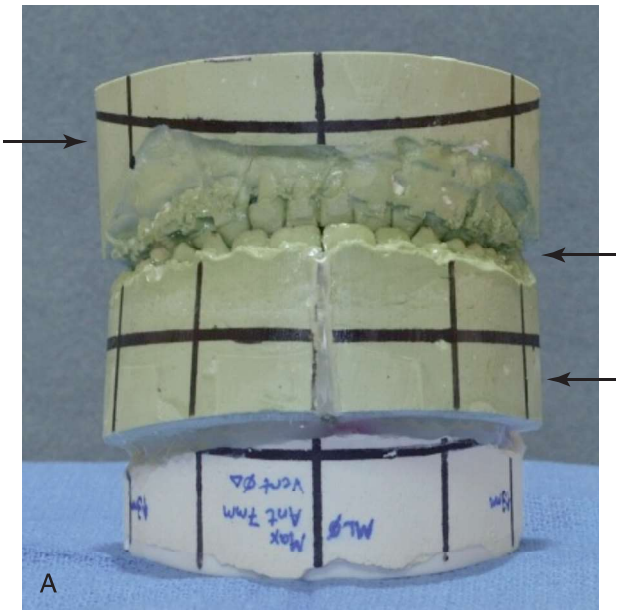


Maintain adequate strength!

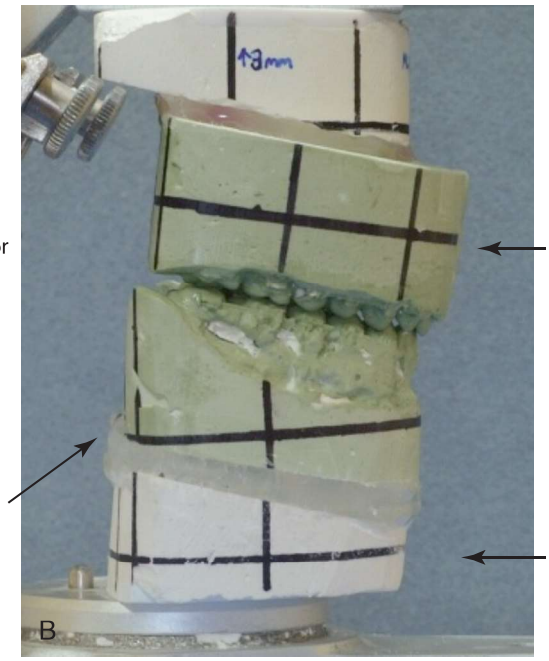


Use Dremel drill (acrylic burr) to trim excess hardened acrylic

• **Figure 13-9, cont'd F,** When the acrylic is dry, use a lathe to trim excess hardened acrylic. Maintain adequate strength of the splint to prevent bowing or breakage during surgery. **G,** Use a rotary drill (e.g., a Dremel drill) with an acrylic bur to further trim excess hardened acrylic.



Remove maxillary unit from articulator
Separate mandibular cast from plaster base
Articulate mandibular cast to maxillary unit in "final" occlusion

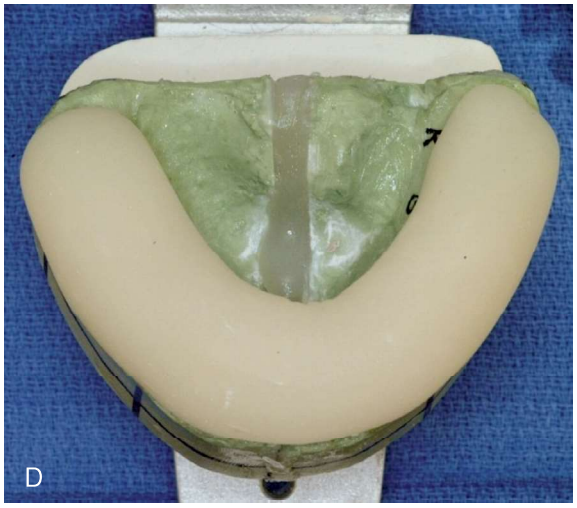


Secure mandibular cast to base with hot glue
Then separate max/mand casts and confirm "final" occlusion

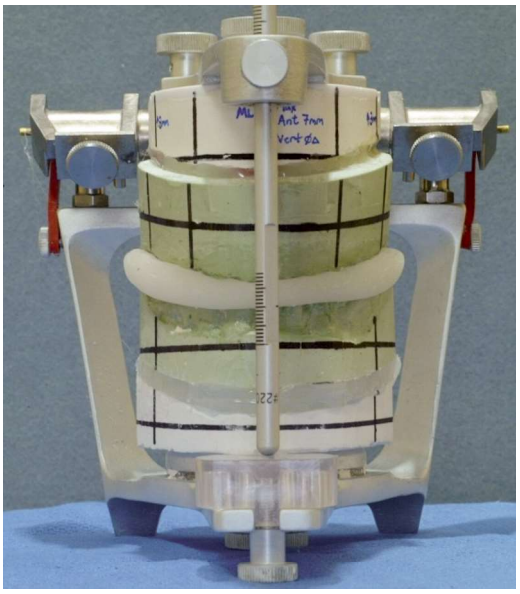
• **Figure 13-10** Construction of the final splint. **A,** Remove the maxillary unit from the articulator. Separate the mandibular cast from the plaster base as previously described for the maxillary unit (see Fig. 13-7, *A*). Next, articulate the mandibular cast with maxillary unit in the final desired occlusion. Secure the final occlusion with hot glue from a glue gun. **B,** Secure the mandibular cast back to the base with the use of either hot glue from a glue gun or white plaster. Maintain the articular pin in a neutral position to achieve this objective. It is generally necessary to remove as least some plaster from the mandibular base during this process; only then is the hot glue or additional plaster used to secure the mandibular cast back to the base. The dried glue that secured the occlusion together is now released. The desired occlusion is confirmed to be accurate before the construction of the final splint.

Continued

Use clear acrylic liquid and resin powder

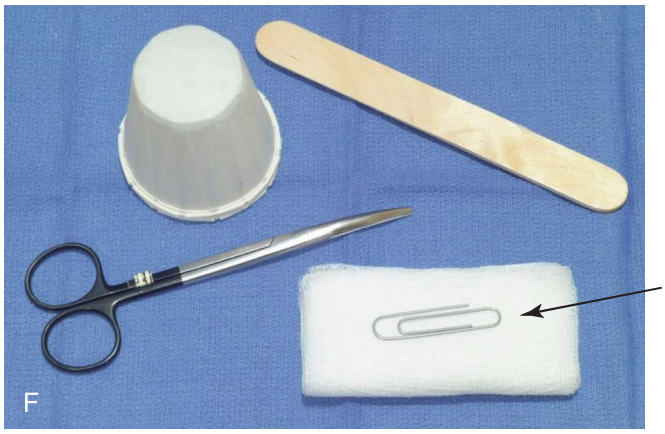


Adapt mass to the maxillary occlusal surface

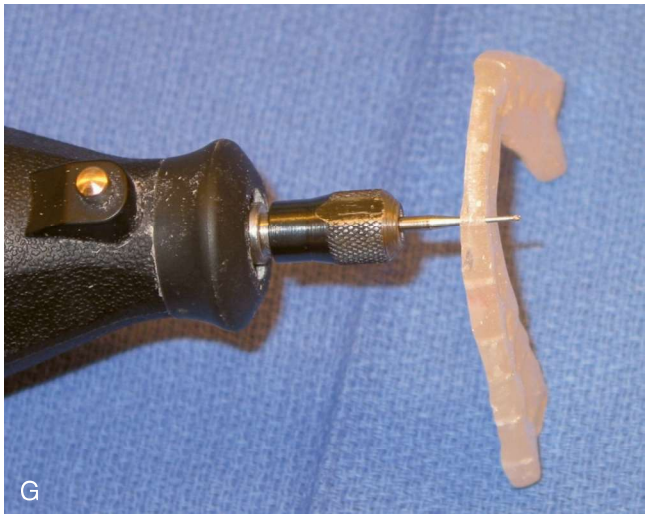


Trim soft acrylic with scissors

• **Figure 13-10, cont'd C,** Use clear acrylic liquid and orthodontic resin powder for the final splint. Mix the two together until the mass does not slump. **D,** Roll the mixed acrylic mass into a log shape. Adapt the mass to the maxillary occlusal surface. **E,** Close the articulator until the vertical pin touches in a neutral position. The mandibular occlusal surface will imprint into the acrylic as a result. Limit "undercuts" from the brackets by carefully trimming the soft acrylic with scissors.



Use additional acrylic to place wire
to reinforce palatal aspect of splint as needed



Drill holes (1.0-mm diameter) in both intermediate and final splints

Polish splints on lathe

• **Figure 13-10, cont'd F,** Use additional acrylic to place a metal wire, if needed, to reinforce the palatal aspect of splint. This will prevent bowing or breakage of splint when segmental osteotomies are carried out and when extensive arch expansion is required. **G,** Use a lathe and a rotary drill (e.g., a Dremel drill) to trim excess acrylic from the hardened final splint. Next, place each splint (i.e., intermediate and final) in turn on the maxillary cast, and determine the best location and direction for each interdental drill hole. Complete 1-mm drill holes with the use of a rotary drill (e.g., a Dremel). **H,** Polish the splints on a lathe with the use of a cloth buffing wheel (i.e., pumice and Acrilustre) (Robert Bosch, 1800 W. Central Road, Mt. Prospect, IL).

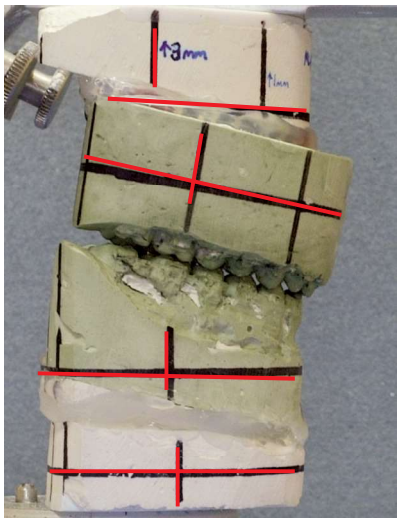
Intermediate splint

Final splint

Preoperative articulated casts

Maxilla repositioned

Maxilla and mandible repositioned



Articulated dental casts after analytic model planning

• **Figure 13-11** Dental casts on the semi-adjustable articulator to demonstrate model planning and a view of the finished splints. **A,** Intermediate and final splints finished and ready for use. **B,** Lateral views of articulated dental casts first mounted in a centric relation bite and then after maxillary and final mandibular repositioning. **C,** Frontal and side views of articulated dental casts demonstrating model planning. In this case, note the extent of the maxillary clockwise rotation (3 mm) needed to achieve a preferred A-point to B-point relationship and also to overcome the procumbency of the maxillary incisors.

presurgical clinical examination, is one of the essential steps to avoid unintended errors.[10,28-35,42,43,49,58,60,64,65,71-76,82]

Controversies Surrounding Model Planning for Orthognathic Surgery

Articulator and Face-Bow Device Options

Face bow devices were developed in conjunction with *simple and semi-adjustable hinge articulators* to assist with the registering of the maxillary arch position in relation to the axis of the condylar hinge in three planes of space. The mechanics of the *face-bow device* require a tripod localization. This includes two posterior references to approximate the temporomandibular joints and then an anterior point to relate the maxillary cast three dimensionally to a selected horizontal *facial reference plane*. The posterior reference points that are generally used are the external auditory canals. The anterior point is often aligned with the orbitale (i.e., the infraorbital rims). Selection of the anterior point (e.g., the orbitale) governs the *horizontal facial reference plane*. This will in turn affect the steepness of the recorded maxillary occlusal plane on the articulator; this is discussed later in this chapter.

For orthognathic surgery, analytic model planning typically involves the use of an articulator that provides an approximation of the anatomic relationship between the hinged axis and the incisors. This type of articulator mechanism is designed to approximate the individual's actual mandibular autorotation. This is especially important for bimaxillary surgery, when autorotation of the maxillomandibular complex helps to dictate the position of the maxilla before the mandibular osteotomies are completed. Marko conducted research to demonstrate that the mathematical difference in the horizontal projection achieved when such advancement is carried out in combination with a maxillary impaction of 5 mm is significantly affected by the type of articulator that is used.[46] An average error of 2 mm was found with use of the Galetti articulator *(simple hinge),* whereas only 0.2 mm of error occurred with the Hanau articulator *(semi-adjustable).*[46]

NOTE: The use of a semi-adjustable articulator in bimaxillary surgery will be more accurate and is therefore preferred to the use of a simple hinge articulator.

O'Malley and Milosevic compared three face-bow semi-adjustable articulator systems to measure any differences in the recorded steepness of the occlusal plane that was produced.[52] The three articulators studied were the Dentatus type ARL; the Denar MkII; and the Whip Mix Quickmount 8800. The recorded measurement of the steepness of the occlusal plane was taken as the angle between the face-bow bite fork and the horizontal arm of the articulator. This measurement was then compared with the angle of the maxillary occlusal plane to the Frankfort plane as measured via lateral cephalometry. Of the three semi-adjustable articulators tested, the Whip Mix Quickmount 8800 came closest to achieving the maxillary occlusal plane (with respect to the Frankfort plane) as measured via lateral cephalometry; it flattened the occlusal plane by only 2 degrees ($P < .05$). The results of the Dentatus and Denar MkII articulators demonstrated flattening of the occlusal plane by 5 degrees and 6.5 degrees, respectively. Ellis also demonstrated how commonly used methods of face-bow registration may erroneously capture the spatial relationship of the maxilla with the Frankfort horizontal plane.[18] This is likely to be problematic if the surgeon intends to use the Frankfort horizontal from the patient's cephalogram as the reference plane from which facial aesthetic objectives will be planned.

A critical step in model planning is the accurate recording of the relationship (i.e., angle and orientation) between a *designated facial plane* and the *maxillary occlusal plane*. As stated, capturing this orientation is accomplished with a face-bow device that is used in the clinic setting. (Note: I use the #8645 Quick Mount Face-Bow, Whip Mix Products, Louisville, KY.) The face-bow registration is then transferred to the semi-adjustable articulator for the mounting of the maxillary model. (Note: I use the #8500 Articulator, Whip Mix Products, Louisville, KY.)

I prefer to judge the desired facial (surgical) change (i.e., horizontal, vertical, roll, pitch, and yaw) and register the face bow from the *natural head position (NHP)* rather than the *Frankfort horizontal plane*.

I prefer to use the NHP orientation as it is the same view from which aesthetics of the face are typically judged by others at conversational distance. Many clinicians prefer to plan angular and linear surgical change for the patient's face from the Frankfort horizontal plane rather than the NHP. If this is done, the surgeon should register the face bow as precisely to the Frankfort line (i.e., the line between the porion and the orbitale) as possible. He or she should then meticulously attempt to mount the cast to match the orientation of the maxilla with that of the Frankfort horizontal plane.

NOTE: The importance of the face-bow semi-adjustable articulator system to the process of accurately capturing the occlusal plane with respect to Frankfort plane orientation is only relevant if the surgeon is planning facial aesthetic changes according to a strict cephalometric analysis (i.e. that also depends on Frankfort plane orientation).

Centric Relation: Definition and Capture

Definition of Centric Relation

In 1987, the definition of CR underwent a change in terminology from being considered a mandibular position in which the condyles are seated in the most "posterior

superior" position to one in which they are placed in the most "superior anterior" position in the glenoid fossa.[72] For analytic model planning in preparation for orthognathic surgery, defining the position of the condylar head during mandibular protrusion and lateral excursions is not critical. However, it is essential to locate a mandibular position that is reproducible with the teeth in occlusion. This must be obtained without the assistance of the patient (i.e., with fully relaxed masticatory muscles), and it needs to be reliably accomplished both preoperatively in the clinical setting and intraoperatively with the patient under anesthesia. This position of the mandible with the teeth in occlusion is usually registered in wax (i.e., a wax bite) and then transferred to the articulator. This is an important step for analytic model planning to be accomplished accurately.

An erroneous inconsistent recording of CR will lead to the malpositioning of the maxilla or mandible during surgery. A survey study conducted by Truitt and colleagues confirmed that 98% of oral and maxillofacial surgeons define CR as the most posterior superior positioning of the mandible.[79] Interestingly, a majority of the orthodontists surveyed agree with the surgeons' definition of CR, but there was less consistency.[79] According to the survey, surgeons and orthodontists do agree that dental casts of the teeth for orthognathic planning should be mounted in CR.

Capturing of Centric Relation

Hellsing and McWilliam used a *subtraction technique* to assess the repeatability of the CR recorded with a *one-handed push-back technique*.[31] They found that the mandibular condyles can be seated in a reproducible position, which is well suited for the registration of CR. Campos and colleagues compared the *swallowing technique* with the *chin-point guidance technique* with the patient in both upright and supine body positions and found that both techniques established a physiologic CR in a reproducible manner.[86] Interestingly, when the chin-point guidance method was used, the work of these authors suggested that reliability was greater with the patient in the upright, seated patient as compared with the supine position.

Simon and Nicholls compared the chin-point guidance, *chin-point guidance with ramus support,* and *bimanual manipulation* techniques.[68] They found that there were no significant differences in the range of mandibular positions that were observed. Interestingly, their study patients did not include individuals with jaw deformities. It is known that patients with specific patterns of jaw deformity (e.g., Class II mandibular retrognathism) are more likely to involuntarily posture the mandible forward during the swallowing technique.[32,33]

The *chin-point guidance technique* is accomplished by using one hand to apply pressure to the subject's chin and the other hand to apply counter pressure to their occiput. This allows the surgeon to apply posterior and superior "vectored" force to the anterior aspect of the mandible. By doing so, the condyles will be positioned in a superior-anterior location within each glenoid fossa (i.e., CR) (see Fig. 13-2).

NOTE: I find the *chin-point guidance technique*—when used both preoperatively in the clinic setting and intraoperatively by the same surgeon—to be both reliable and convenient for the orthognathic surgery patient. This is the method that I have adopted and that I use successfully in clinical practice.

Bite Registration Material

The material used to record CR (e.g., soft wax) is also considered as a potential source for the introduction of error. Adrien and Schouver studied mandibular model-mounting errors; they demonstrated that wax can create error and that the error is directly proportional to the wax's thickness.[2] They suggest that the wax between the approximating teeth be as thin as possible. In addition, the wax should not be punctured, because this may result in sliding from CR to centric occlusion (CO). The wax should also retain its rigidity to avoid the distortion of contact points. The wax bite must be protected after it is removed from the mouth, because it is easily deformed. Ideally, it is used without significant delay to the time that the models are mounted on the articulator (see Fig. 13-2).

Inaccuracies of Osteotomy Site Measurements when used in Isolation to Reorient the Maxilla in Bimaxillary Surgery

The *face-bow device* is used to spatially orient patients' dental models on a *semi-adjustable articulator*. The belief that measurements may then be made at the equivalent of the Le Fort I osteotomy site to accurately reposition or reorient the maxillary cast on the articulator without the use of the *Erickson Model Table* is flawed. The errors of this model surgery and splint-construction approach would then be further compounded if the surgeon relied on actual Le Fort I osteotomy site measurements during operation as a gauge of where to reorient the maxilla without the assistance of *external facial reference landmarks* and measurements.[13,28,36,40,41,53,56,57,59,69] The use of these methods (i.e. osteotomy site measurements) to reposition the maxilla in the dental laboratory before splint fabrication and then during surgery before plate and screw fixation may work for uncomplicated movements (e.g., limited horizontal and vertical repositioning), but it is likely to become grossly flawed when trying to accomplish complex yaw, pitch, and roll orientation changes of the midface.

Accuracy of Current Analytic Model-Planning Techniques to Achieve Desired Results

The *Erickson Model Table* is a device that is used to document the baseline three-dimensional orientation of

the mounted maxillary model on the semi-adjustable articulator. (Note: I use the Erickson Model Block and Platform Model Measuring Kit designed by Great Lakes Orthodontics Products, Tonawanda, NY.) The Erickson Model Table is then used to assist the three-dimensionally reposition and reorient the maxillary cast to the desired facial (surgical) change.[19,20] The reoriented maxillary model on the articulator is then used to construct the intermediate splint. In the operating room, the use of the *prefabricated intermediate splint* in conjunction with precise *measurements of the anterior vertical dimension of the midface* (e.g., direct vertical measurement from the medial canthus to the maxillary incisor on each side of face) has eliminated many of the inaccuracies that were previously experienced during model planning and surgical execution (see Fig. 13-6, *C*).[20,27,36,40,41,51,53,56,57,66,81]

Interestingly, the few studies published in the literature show a wide range of variation between what was planned by the clinician before surgery and what is then actually achieved during operation with reference to the advancement of the maxilla after Le Fort I osteotomy during bimaxillary surgery. An exception is the study of **Gil and colleagues,**[28] who completed a retrospective study to evaluate the predictability of maxillary repositioning (i.e., vertical and horizontal change measured at the maxillary incisors) after Le Fort I osteotomy during bimaxillary surgery. They used analytic model-planning techniques, including the following: 1) face-bow transfer 2) the use of a semi-adjustable articulator 3) the use of Erickson Model Table measurements 4) intermediate splint construction and 5) the use of external facial height reference points during surgery. A consecutive series of patients (n = 32) were analyzed, with measurements taken with consistent lateral cephalometric radiographs before and 1 week after surgery.[69] The results indicate less than a 1-mm difference between the planned and the early postoperative results for both vertical and horizontal repositioning in all patients. **Stanchina and colleagues** also carried out a retrospective study to measure the accuracy of external reference points in conjunction with model planning to reposition the maxilla during bimaxillary surgery.[69] The study subjects (n = 41) showed a surprisingly consistent mean difference between predicted and achieved vertical repositioning of the maxilla (0.36 mm; standard deviation, 0.26 mm). Their success with horizontal repositioning was less accurate. The mean horizontal variance was 1.4 mm (standard deviation, 1.63 mm).

NOTE: The reasons for variation between the planned and actual maxillary advancement in most published studies remain unclear. This is because the descriptions of the key steps that they used are generally not fully described.

Review of Key Steps for Successful Analytic Model Planning and Surgical Execution

1. *The direct visual examination of the patient by the surgeon in the clinic setting.* With the use of facial analysis, key measurements of the individual's maxilla in relationship to the upper face (i.e., the forehead, external ears, and orbits) are recorded. These measurements will confirm variations from normal and define the surgical objectives (see Fig. 13-1, *H*).
2. *The use of a face-bow device to record the spatial orientation of the upper face and condyles with regard to the maxilla.* This is generally done with the use of the external auditory meatus for two of the reference landmarks. The anterior aspect of the face bow (i.e., the frontal view) is adjusted to be parallel with the interpupillary line. With the patient's head and neck in the NHP, the lateral aspects of the face bow are then adjusted to orient the temporal arms to be parallel with the floor (see Fig. 13-3 C and D).
3. *The transfer of the spatial orientation of the maxilla to the semi-adjustable articulator.* This is done with the arms of the face-bow and the upper arm of the articulator parallel to the floor (counter top) (see Fig. 13-4 A).
4. *The taking of an accurate CR bite registration of the patient in the clinic setting.* This is then used to orient the dental models to each other on the semi-adjustable articulator (see Figs. 13-2 and 13-4, *C*).
5. *The use of the Erickson Model Table in the dental laboratory to establish the baseline spatial orientation of the maxillary cast* (see Fig. 13-6, *C*).
6. *The use of the Erickson Model Table to accurately reorient the upper jaw model on the articulator into the desired surgical position* (see Fig. 13-8, *A*).
7. *The fabrication of a splint for use during surgery* to achieve the planned maxillary reorientation (see Fig. 13-9)
8. *The use of external facial measurements* (e.g., the distance from the medial canthus to the maxillary incisor) during operation to establish the baseline vertical position of the maxilla within the upper face and then to accurately reorient the upper jaw to achieve surgical objectives (see Fig 15-18, *A*).
9. *The accurate location of the terminal hinge position of the condyles during operation.* This is done to reproduce the position of the condyles when taking the CR bite registration in the clinic setting, and it is essential before rigid fixation is secured across each osteotomy site (see Fig 15-37, *B*).

COMMENT: The surgeon no longer attempts to correlate millimeter changes at the Le Fort I osteotomy site with the expected facial morphologic outcome. When properly executed, the accuracy of analytic model-planning techniques as described for precise orthognathic surgery has been documented. This is discussed in more detail later in this chapter.

The Role of Computer-Aided Software Design and Model Planning

For a variety of reasons, some patients with complex maxillofacial skeletal deformities undergo treatment that achieves suboptimal results. Despite the surgeon's best efforts, it can be difficult to assess the preferred surgical spatial reorientation of the jaws for the achievement of ideal facial projection and symmetry. Although standard analytic model planning (as described in this chapter) has proven to be effective for most orthognathic surgical problems, three-dimensional deformities of pitch, roll, and yaw continue to confound the ability to achieve predictable results in each and every patient. The current standard treatment planning process is also felt to be time consuming and labor intensive, especially for those clinicians who do not evaluate dentofacial deformities and execute orthognathic surgery as significant components of their practice.

Recently, surgeons have begun looking to computer-aided design and computer-aided modeling software to assist with the planning and implementation of orthognathic procedures.[3-5,7,11,23,24,25,45,47,48,61,67,70,83,84] These technologies allow clinicians to import two-dimensional computed tomography data in a digital imaging format at a computer work station and to then generate a three-dimensional representation of the patient's skeletal and soft-tissue anatomy. The data set can be used to mill a stereolithographic model, or it can be manipulated on the computer screen for purposes of analysis and treatment planning. The ability of virtual model planning (as opposed to analytic model planning, as described in this chapter) to routinely achieve an improved end result for the orthognathic patient has yet to be confirmed. It is also unclear whether the higher costs of virtual model surgery planning can be offset by savings in the clinician's time that would otherwise be required for analytic model planning.

A successful orthognathic outcome is often judged by the achievement of a preferred occlusion, an open upper airway, and enhanced facial aesthetics. Any methods that are proven to better achieve these objectives over the long term with efficiency and reliability are welcomed. Unfortunately, current virtual model surgery planning still requires that alginate impressions of the maxilla and mandible be taken, that plaster models be made of the maxillary and mandibular arches, and that ideal occlusion be hand articulated and marked by the surgeon into the set final occlusion. If segmental osteotomies are required, the surgeon must also cut the plaster models and secure them together as required to achieve the set final position. Furthermore, a computer-generated surgical splint has not yet been proven to be fully reliable for complex, double-jaw surgical cases.[11] Problems that remain to be addressed include the following: the identification of internal reference systems; the making of three-dimensional measurements; the management of interferences by metal (orthodontic) hardware; the orientation of computed tomographic models to the NHP; and the necessity of capturing the computed tomography data while the patient is in CR.

Standard Facial Records for Orthognathic Surgery

- Standardized facial and occlusal view photographs
- Lateral cephalometric radiograph
- Panoramic radiograph
- Alginate impressions of the maxilla and mandible
- CR wax bite registration
- Face-bow registration for transfer to a semi-adjustable articulator
- Facial measurements taken via a direct visual examination (Fig. 13-1H).
- Analytic model planning data entry form (Fig. 13-6C)
- Cone-beam computed tomography scanning (patient specific)
- Full-mouth periapical radiographs (patient specific)

Key Measurements Obtained via Direct Visual Examination to Define Planned Maxillary Surgical Change

- Horizontal change at incisors _____ (mm)
- Vertical change at incisors _____ (mm)
- Midline change at incisors _____ (mm)
- Maxillary plane change (total) _____ (mm)

Clockwise—Counterclockwise

- Maxillary cant correction (total) _____ (mm)

  ↑ ↓ _____on right ↑ ↓ _____on left

- Vertical change at T#3 (right) molar ___ + ___ + ___ = ___ (mm)
  (Base + Cant + Plane)
- Vertical change at T#14 (left) molar ___ + ___ + ___ = ___ (mm)
  (Base + Cant + Plane)

Face-Bow Registration and Transfer to the Semi-Adjustable Articulator

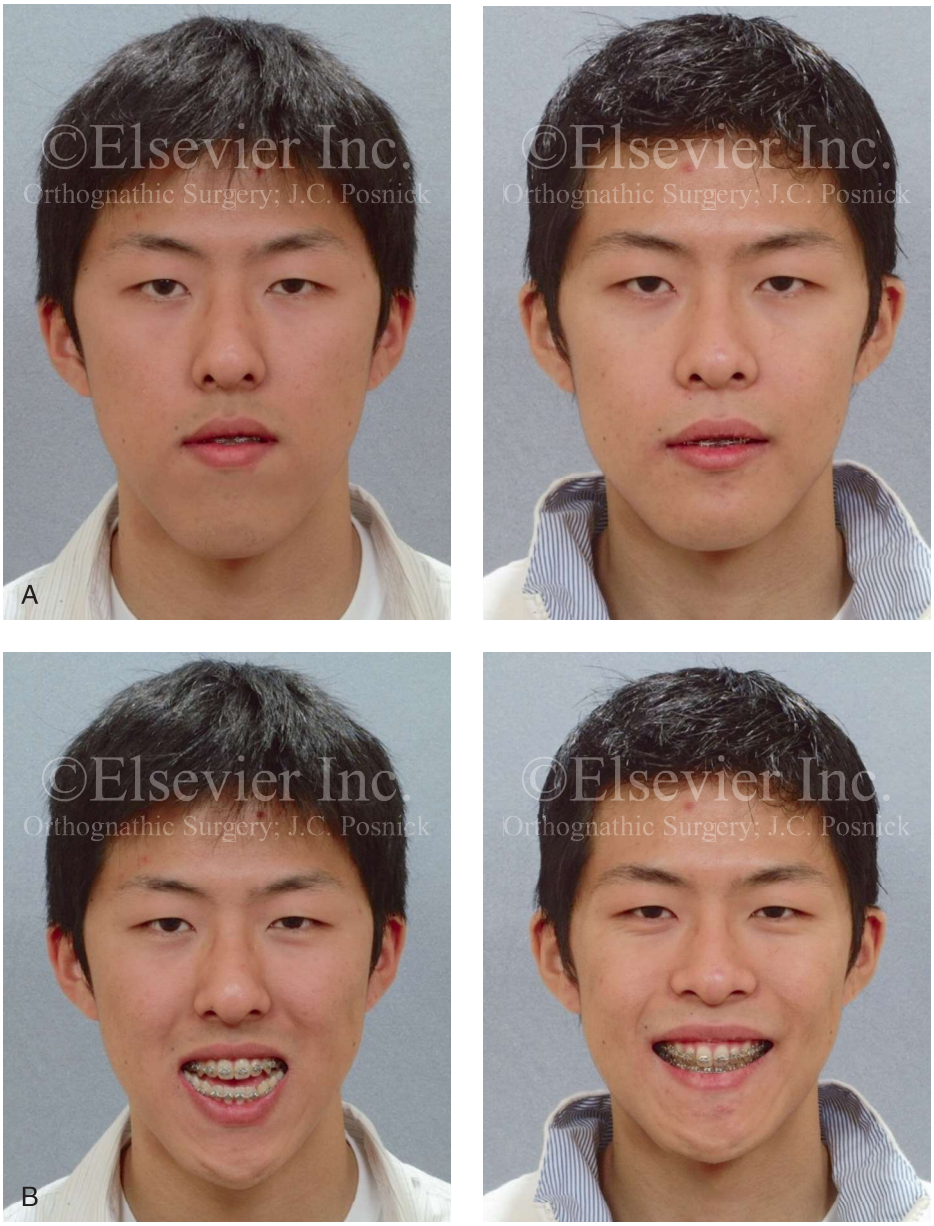
An 18-year-old recent high school graduate who presented to this surgeon for the evaluation of an uncorrected dentofacial deformity that was characterized as maxillary deficiency with relative mandibular excess is described. He is shown to demonstrate the technique of analytic model planning as typically carried out (see Figs. 13-1, 13-12, and 13-13).

Face-Bow Registration
(see Figs. 13-2, *A*, through 13-3, *G*)

- Place soft wax on upper side of the face-bow bite fork.
- The midpoint between the central incisors (interproximal) should match the center of the bite fork.
- Register the patient's maxillary occlusion into the soft wax on the bite fork.

- Place an ear prong in each ear canal, and hold the temporal extensions with even pressure medially, superiorly, and forward. Tighten the three thumb screws of the temporal extensions.
- In the frontal view, the face bow is initially adjusted to be parallel with the pupils and in proximity to the infraorbital rims.
  - If the orbits are asymmetric (e.g., in a patient with hemifacial microsomia or the Klippel–Feil anomaly), do not use the interpupillary line as a frontal reference plane. Instead, use the NHP as the facial reference plane.
- In the profile view, the face bow is adjusted to be parallel with the floor while the patient is in the NHP.
  - If the ear canals are asymmetric, do not rely on them for face-bow orientation. For example, for a patient with hemifacial microsomia, if the ear canal on one side is not present or is abnormally located, then place the face-bow ear prong in the appropriate position to approximate the contralateral ear canal. The face bow should be parallel with the floor while the patient is in the NHP (i.e., the NHP is the reference plane).

Text continued on p. 415

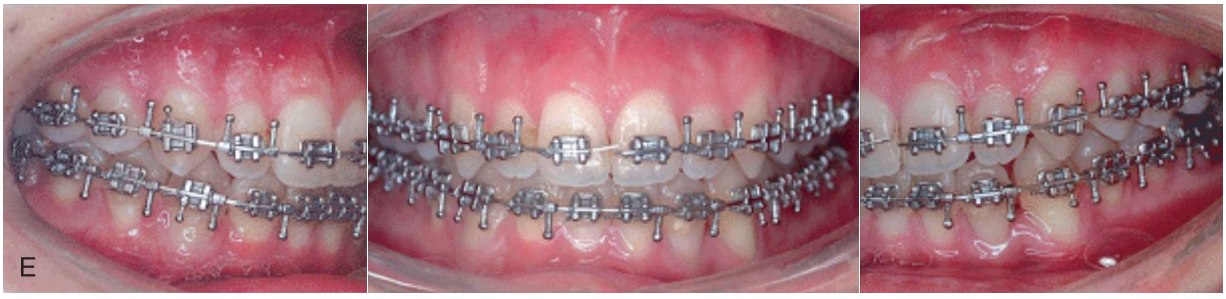


• **Figure 13-12** The patient is shown before and just 5 weeks after surgery. At this time, adequate bone healing has occurred to allow for a return to a more normal diet and physical activity level. The patient is also returned to the care of his orthodontist. **A,** Frontal views in repose before and 5 weeks after surgery. **B,** Frontal views with smile before and 5 weeks after surgery. *Continued*

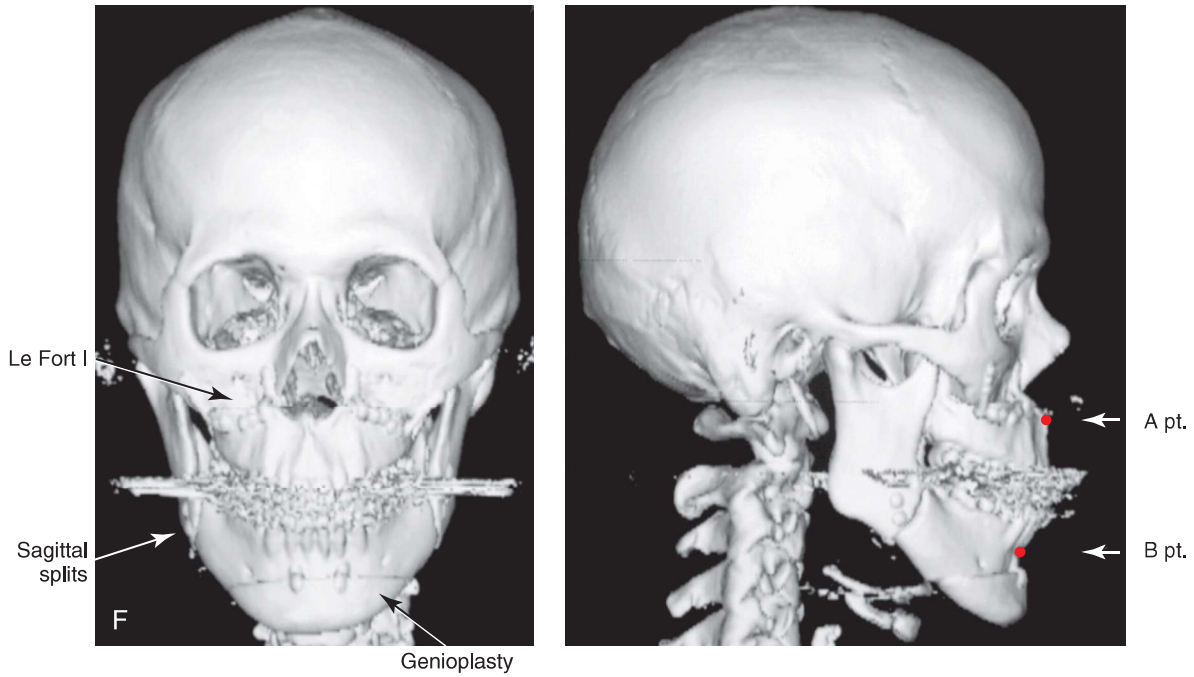
• **Figure 13-12, cont'd C,** Oblique facial views before and 5 weeks after surgery. **D,** Profile views before and 5 weeks after surgery.

Prior to orthodontics

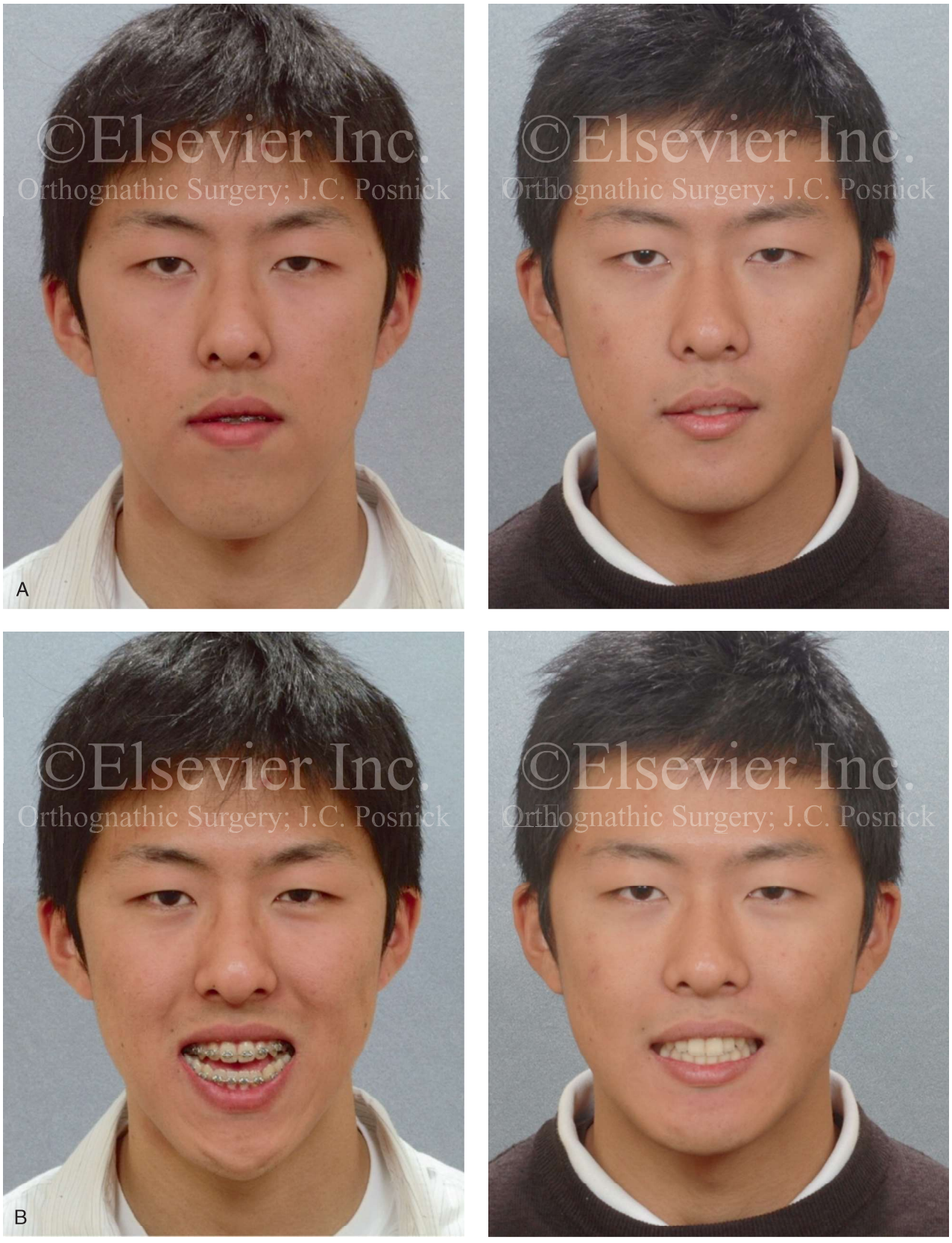
Pre surgery



5 weeks after surgery



• **Figure 13-12, cont'd E,** Occlusal views before treatment, immediately before surgery, and just 5 weeks after surgery at the time of splint removal. **F,** Computed tomography scan views 5 weeks after surgery. The sites of the maxillary, mandibular, and chin osteotomies and the location of standard fixation can be seen.



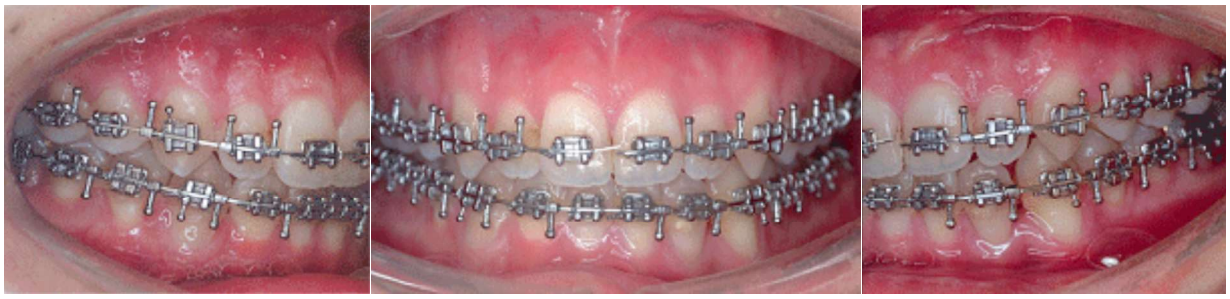
• **Figure 13-13** The same patient is shown before and then 1½ years after surgery. **A,** Frontal views in repose before and 1½ years after surgery. **B,** Frontal view with smile before and 1½ years after surgery.

• **Figure 13-13, cont'd C,** Oblique facial views before and 1½ years after surgery. **D,** Profile views before and 1½ years after surgery.

Continued

Prior to orthodontics

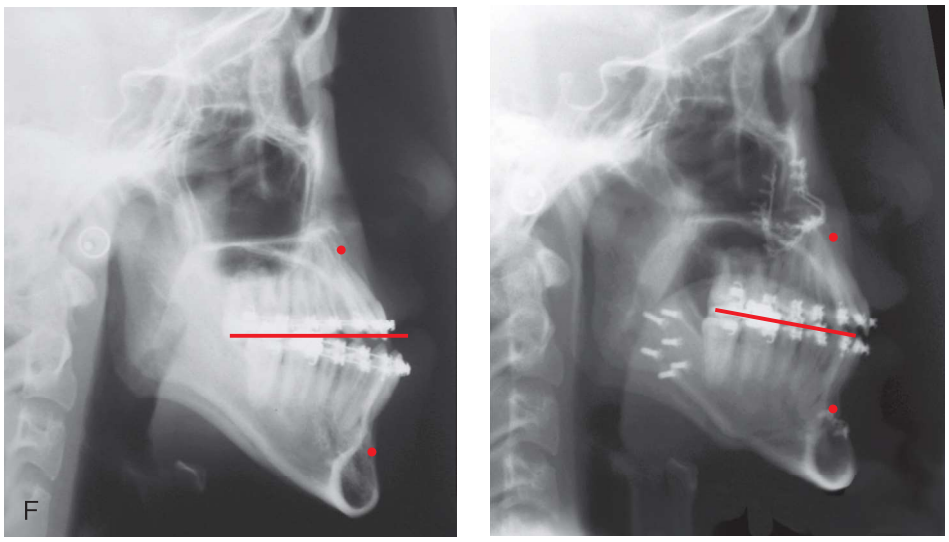
Pre surgery



5 weeks after surgery

1½ years after surgery

• **Figure 13-13, cont'd E,** Occlusal views before treatment, immediately before surgery, and then 5 weeks and 1½ years after the completion of treatment.



• **Figure 13-13, cont'd F,** Lateral cephalometric views before and after surgery.

- Firmly hold the bite fork to the maxillary occlusal surfaces (through the soft wax). Pressure is applied to the bite fork by the patient with the use of a thumb from each hand. When this is accomplished, do the following:
  - Loosely connect the bite fork, (which is held firmly to the patients maxillary teeth), to the face-bow apparatus, (which is held in place by the clinician), with the use of the T-screws on the vertical rod.
  - In profile and with the patient in the NHP, adjust the face-bow temporal extensions to closely parallel the floor.
  - Tighten the two T-screws to secure the bite fork to the vertical rod of the face-bow apparatus.
- Now that the face-bow registration is complete, loosen the three thumb screws of the temporal extensions to release the ear prong from each ear canal. Remove the face bow from the patient for transfer to the semi-adjustable articulator.

Take Alginate Impressions, Pour the Impressions in Stone, and Trim the Casts (see Fig. 13-3, *H* through *K*)

- Take accurate alginate impressions of the maxilla and the mandible.
- Pour the alginate impressions in green stone, and incorporate at least 30 mm of base. Base formers are helpful to accomplish adequate base height. To limit air bubbles, use a vibrator when pouring stone into alginate impressions.

NOTE: The use of stone rather than plaster improves strength, with less porosity and less breakage.

- When the casts are dry (≈15 min), remove the alginate and base former from each stone cast. Measure 30 mm of base on the mandibular cast and 25 mm of base on the maxillary cast. Measure up from the following locations:
  - The first molar cusp tip on each side
  - The canine cusp tip on each side
  - The incisor cusp tip on each side
- Use a model grinder to trim at the 25-mm and 30-mm circumferential markings, respectively, for the maxillary and mandibular casts.
- Remove all blebs from the occlusal surface of the dental casts.

Face-Bow Transfer: The Orientation of the Dental Casts (Maxilla and Mandible) on the Semi-Adjustable Articulator (see Fig. 13-4, *A* through *F*)

- Secure the face-bow device to the semi-adjustable articulator. Adjust both the face-bow device and the upper arm of the articulator to be parallel to the floor and the counter lap.
- Secure the plastic base plate to the dental articulator. Place the maxillary cast on the bite-fork component of the secured face-bow device. Use white plaster to mount the maxillary cast to the base plate.
- Use the bite-fork support device to prevent the sagging of the maxillary cast during this process. Let the plaster initially set (≈15 min), and then remove the face-bow apparatus and the bite-fork support device.
- Turn the articulator upside down, and secure the mandibular cast to the maxillary unit with the use of the CR wax bite registration taken in the clinic setting. Further secure the occlusion in CR with two rubber bands to

compress the maxillary unit and mandibular cast together through the bite registration.
- Place the plastic base plate onto the dental articulator, and then use white plaster to mount the mandibular cast to the base plate. Let the plaster initially set (≈15 min).
- Cut the rubber bands used to secure the occlusion, and remove the wax bite.
- Remove the maxillary unit from the articulator. With the use of a model grinder, trim the maxillary cast, plaster base and the base plate all as one unit.
- Remove the mandibular unit from the articulator. With the use of a model grinder, trim the mandibular cast, the plaster base and the base plate all as one unit.

Placement of Reference Lines on the Maxillary and Mandibular Units (see Fig. 13-5, *A* through *E*)

- With the use of the Erickson Model Table, "score" two horizontal reference lines on the maxillary unit and then on the mandibular unit. Locate the horizontal reference lines on the maxillary and the mandibular units by doing the following:
  - Place the first horizontal line within the green stone.
  - Place the second horizontal line within the white plaster.
  - Ideally, there will be 15 mm to 20 mm of separation between these lines.
- With the use of a thick, black Sharpie pen, mark the "scored" horizontal circumferential reference lines on both the maxillary and mandibular units.
- With the use of a thick, black Sharpie pen, mark the vertical reference lines on both the maxillary and mandibular units. The vertical lines are located perpendicular to the horizontal lines and in the following places:
  - At the cusp tip of each canine
  - At the mesiobuccal groove of each first molar
  - Between the central incisors (i.e., at the dental midline)
  - Posterior at each tuberosity or retromolar area

Use of the Erickson Model Table to Define the Spatial Orientation of the Articulator-Mounted Maxillary Unit* (see Fig. 13-6)

With the use of a thin, black Sharpie pen, locate specific reference points from which measurements will be made. Place a dot at the following reference points:

- The cusp tip of each maxillary canine
- The mesiobuccal cusp tip of each maxillary first molar
- The midpoint of the incisal edge of each maxillary central incisor

Baseline vertical (maxillary) measurements: With the model block on its base, use the electronic caliper to measure the distance (in mm) at the following areas: (see Fig. 13-6 E and F)

- The incisal edge of each maxillary central incisor (#8, #9)
- The mesiobuccal cusp tip of each maxillary first molar (#3, #14)

Baseline horizontal (maxillary) measurements: With the model block on its end, use the electronic caliper to measure the distance (in mm) at the following area: (see Fig. 13-6D).

- The incisal edge of each maxillary central incisor (#8, #9)

Baseline dental midline (maxillary) measurements: With the model block on its side, use the electronic caliper to measure the distance (in mm) at the following areas: (see Fig. 13-6G)

- The dental midline with the left side of the cast down
- The dental midline with the right side of the cast down

Use of the Erickson Model Table to Define the Spatial Orientation of the Articulator-Mounted Mandibular Unit

Baseline horizontal (mandibular) measurement: With the model block on its end, use the electronic caliper to measure the distance (in mm) at the following area:

- The incisal edge of the mandibular central incisors (#24/#25)*

Separation of the Maxillary Cast from the Articulator Base (see Fig. 13-7, *A*)

- Remove the maxillary unit from the articulator. Separate the maxillary cast from the plaster base over a protective surface. You may first use the die saw to cut a groove in between the green stone and the plaster base. Insert a knife into this groove, and tap the knife with a hammer.

*The Erickson Model Table maxillary unit measurements that I find useful are outlined earlier in this chapter. Other measurements can be made in accordance with the clinician's preference.

*This is the only Erickson Model Table mandibular unit measurement that I find useful. Other measurements can be made in accordance with the clinician's preference.

Segmentation of the Maxilla
(see Fig. 13-7, *A*, *B*, and *C*)

Segmentation and Subsequent Reorientation of the Maxilla

- Use a die saw to segment the maxilla, as planned (i.e., two pieces versus three pieces).
- After the maxilla is segmented, align the segments over the mandibular arch into the preferred occlusion. Secure the segments back together with the use of hot glue from a glue gun.
  - Occlusal equilibration may be indicated to achieve the preferred occlusion (e.g., plunging palatal cusps on maxillary molars, bicuspid cusp reduction to level the posterior arch). If so, use a sharp plaster knife to complete adjustments on the occlusal surfaces of the maxillary and mandibular casts. Use a red Sharpie pen to mark the exact locations where enamel adjustments were made. The actual equilibration is carried out in the operating room.
  - When repositioning the maxillary segments into occlusion with the mandibular arch, it is essential to maintain the physiologic positioning of the interdental papilla and the contact points of adjacent teeth at all interdental osteotomy sites. If dental gaps are created or if cervical margins are not reasonably aligned, then periodontal sequelae are more likely.

Measurement of the Maxillary Arch Width Before and After Segmental Osteotomies

Transverse distance between maxillary molars (#3 to #14)
- Initial _____ (mm)
- After segmentation _____ (mm)

Transverse distance between maxillary canines (#6 to #11)
- Initial _____ (mm)
- After segmentation _____ (mm)

Use of the Erickson Model Table Measurements to Reorient the Maxillary Cast
(see Fig. 13-8, *A* through *F*)

- The repositioning of the maxilla on the articulator is meant to accurately match the desired surgical changes. These changes have been determined in accordance with the following: 1) the patient's clinical objectives (i.e., preferred facial aesthetics and improvements in function) 2) by taking into account any biologic skeletal, dental, or soft-tissue limitations and 3) the surgeon's clinical, dental, and radiographic analyses (see Chapter 12).
- After the key desired adjustments to the midface are reproduced on the maxillary unit, they are verified with use of the Erickson Model Table. The key millimeter and angular changes to be confirmed include the following:
  - Maxillary (midface) projection
    - Horizontal change at incisors
  - Maxillary incisor shown in repose and with smile
    - Vertical change at incisors
  - Maxillary plane change (pitch orientation) and cant correction (roll orientation), which are controlled by the following:
    - Vertical change at incisors
    - Vertical change at first molars
  - Maxillary midline position (yaw orientation)
    - Dental midline change (right side down)
    - Dental midline change (left side down)
  - Considerations of lateral tuberosity position (yaw orientation)
    - Analysis of lateral shift (change) at posterior maxilla (tuberosity region)
- Soft wax or clay is used in a tripod fashion to facilitate the initial placement of the maxillary cast back onto the plaster base on the articulator in the preferred position. It is generally necessary to trim the stone or plaster before repositioning. Fine tune the maxilla into the preferred position with the use of the Erickson Model Table (i.e., via horizontal, vertical, and transverse measurements). After these measurements are confirmed, fully secure the preferred maxillary position to the plaster base with hot glue from a glue gun.
- When repositioning the maxilla into the preferred position, take into consideration the yaw orientation. Control the yaw orientation to avoid unwanted asymmetric shifts, which would be visually noticeable in the cheeks of the midface and at the mandibular angles (see Chapter 12).

Intermediate Splint Construction for the Positioning of the Maxilla During Operation (see Fig. 13-9, *A* through *E*)

- With the maxilla secured in the new preferred position but without any changes yet made to the baseline mandibular position, the intermediate (occlusion) splint is constructed.
- Apply a thin coat of Vaseline to the maxillary and mandibular occlusal surfaces with a toothbrush.
- Use pink acrylic liquid and standard acrylic powder. Mix these until the mass does not slump. Apply Vaseline to your hands, and roll the mass into a log shape. Adapt the mass to the maxillary occlusal surface, and close the articulator until the vertical pin touches. This will result in an imprint of the mandible occlusal surfaces on the opposite side.
- Maintain the acrylic just below the level of the base of the maxillary orthodontic brackets and just above the base of the mandibular orthodontic brackets. Use sharp

NOTE: When making the intermediate splint, maintain the vertical pin of the articulator in a neutral position, unless significant inferior positioning (i.e., lengthening) of the maxilla is planned. If so, there are two options: either take the initial CR bite (in the clinic setting) with an increased freeway space (this is equivalent to the clockwise rotation of the mandible while the condyles remain seated in the fossa) or lengthen the vertical pin on the articulator (this is also equivalent to the clockwise rotation of the mandible while the condyles remain seated in the fossa) before making the intermediate splint. Either approach can be used without error as long as the mandibular opening is limited to temporomandibular joint rotational movement. If temporomandibular joint transitional movement occurs, then the splint will no longer reflect the patient's CR bite. If the clinician is uncomfortable with this approach, then a mandible-first approach to analytic model planning should be used (see Chapter 14).

scissors to remove gross excess. This will prevent "undercuts" of acrylic on the brackets.
- Continuously open and close the articulator until the acrylic sets (≈10 min). Maintain the vertical pin in a neutral position and fully closed. This will ensure that no "undercuts" remain.

Trimming of Hardened Acrylic Intermediate Splint (see Fig. 13-9, *F* and *G*)

- Remove excess buccal (labial) acrylic when looking at the model from a bird's-eye view. Use a pencil to mark a line parallel to and just outside of the maxillary orthodontic brackets. Draw a similar line outside of the mandibular brackets. With a lathe and a circular white stone or an acrylic bur, trim excess acrylic, as marked.
- Prevent lingual ramping by removing excess acrylic in the region of the mandibular anterior teeth. This limits interferences that tend to occur as a result of the arc of rotation of the mandible during mouth opening and closing.
- When viewing the splint from the side, mark with a pencil any areas that require further acrylic removal (e.g., just below the base of the maxillary orthodontic brackets, just above the base of the mandibular orthodontic brackets). With a lathe and a circular white stone or an acrylic bur, trim excess acrylic, as marked.

NOTE: If greater strength is needed for the intermediate splint (see Fig. 13-10, *F*), then reinforce with a palatal wire (e.g., use a piece of a heavy paper clip) and additional acrylic.

- If segmental osteotomies are planned, maintain at least 3 mm to 4 mm of lingual acrylic behind the incisors to prevent splint breakage or torque, which may otherwise occur in the operating room.

Reorientation of the Mandibular Cast to Register the Final Occlusion (see Fig. 13-10, *A* and *B*)

- Separate the mandibular cast from the plaster base (as was done for the maxillary cast).
- Articulate the mandibular cast with the maxillary unit in the desired final occlusion, and secure the occlusion with hot glue.
- With the vertical articulator pin remaining in a neutral position, secure the mandibular cast back to plaster base. This may require the removal of interferences in the plaster base or the addition of material (e.g., plaster, hot glue).
- Remove the glue that was used to secure the occlusion, and confirm the accuracy of the final occlusion.

Final Splint Construction for the Positioning of the Mandible During Operation (see Fig. 13-10, *C* through *F*)

- Reapply Vaseline to the maxillary and mandibular occlusal surfaces of the teeth with a toothbrush.
- Mix clear acrylic liquid and standard powder. Mix these until the slumping stops. Vaseline your hands, roll the acrylic into a log shape, and then adapt and readapt it as described for intermediate splint construction.
- Trim the final occlusion splint as described for the intermediate splint. Smooth the lingual edges for patient comfort.
- If segmental osteotomies are planned, maintain at least 3 mm to 4 mm of lingual acrylic behind the incisors to prevent splint breakage or torque, which may otherwise occur in the operating room.

NOTE: If greater strength is needed for the final splint (see Fig. 13-10, *F*), then reinforce with a palatal wire (e.g., use a piece of a heavy paper clip) and additional acrylic.

Finishing of the Prefabricated Acrylic Splints (see Fig. 13-10, *G* and *H*, and Fig. 13-11, *A* and *B*)

- Place each splint in between the maxillary and mandibular units to determine the ideal location and direction of each interdental hole placement. Mark these placements with a pencil.

- Drill holes that are 1 mm in diameter in both the intermediate and final splints at each interdental location for the ease of passage of the wires through the splint. For ease of wire passage, the holes are located below the maxillary orthodontic arch wire.
- Polish the splints on the lathe with a cloth buffing wheel using pumice (i.e., coarse, medium, and then fine) and Acrilustre (Vogel Paint and Wax Co. Inc., 1020 Albany Place, SE; Orange City, Iowa)

Accuracy of the Described Analytic Model Planning Technique: Review of Study

A research study was carried out to assess the accuracy of analytic model planning to achieve the desired maxillary advancement during bimaxillary orthognathic surgery.[54]

Material and Methods

A consecutive series of patients (n = 20) who underwent at a minimum Le Fort I osteotomy with advancement and sagittal ramus osteotomies of the mandible for the correction of dentofacial jaw deformities were included in the study group. The sample consisted of female (n = 9) and male (n = 11) with a mean age of 21 years (range, 14 to 45 years). All study subjects underwent the following: 1) preoperative and 5-week postoperative lateral cephalometric radiographs of acceptable quality with a metric reference frame for analysis; 2) consistent presurgical facial analysis by the surgeon, including millimeter decisions regarding planned horizontal and vertical repositioning and three dimensional reorientation (i.e., pitch, roll, and yaw) of the maxilla; 3) consistent analytic model planning as described in this chapter 4) the construction of intermediate and final splints; 5) the use of the prefabricated intermediate splint to establish the maxillary positioning after Le Fort I osteotomy and before plate and screw fixation, and 6) the use of consistent intraoperative landmarks (i.e., the distance between the medial canthus and the maxillary central incisor measured in millimeters with the use of calipers) to confirm vertical orientation.

The determination of the preferred surgical reorientation of the jaws was based on a combination of the direct visual examination of the patient in the clinic setting, the analysis of the lateral cephalometric radiograph, and the analysis of the profile facial photograph taken in the NHP during the presurgical office visit. The extent of preferred maxillary horizontal advancement in millimeters was ultimately assessed by the surgeon with the patient in the NHP during the direct visual examination, with all gathered data taken into account. The fabrication of an intermediate splint to capture the preferred maxillary horizontal and other vector movements (i.e., pitch, yaw, and roll) with the use of consistent analytic model surgery planning methods was accomplished.

Radiographic Analysis

For each study patient, a presurgical standard cephalometric radiograph was obtained for later analysis. At 5 weeks after surgery, a similar standard cephalometric radiograph was also taken. This was timed to coincide with initial bone healing and the removal of the surgical splint.

Four landmark points (i.e., the sella, the nasion, the porion, and the orbitale) that remained unchanged after Le Fort I advancement were used for this analysis. These points were used to create a consistent reference line from which linear measurements (e.g., a change in the horizontal position of the maxillary incisors) could be made and compared before and after maxillary advancement. To confirm the consistency of the four designated points in the sequential radiographs, a reference angle between SN and FH was verified to remain within 0.5 degrees.

On each cephalometric radiograph, a perpendicular reference line passing through the sella, called the *sella perpendicular (S⊥)*, was then dropped. From S⊥, a direct linear measurement was made parallel to the Frankfort horizontal *(FH)* plane and extended to the maxillary incisal edge *(U1)* (Fig. 13-14).

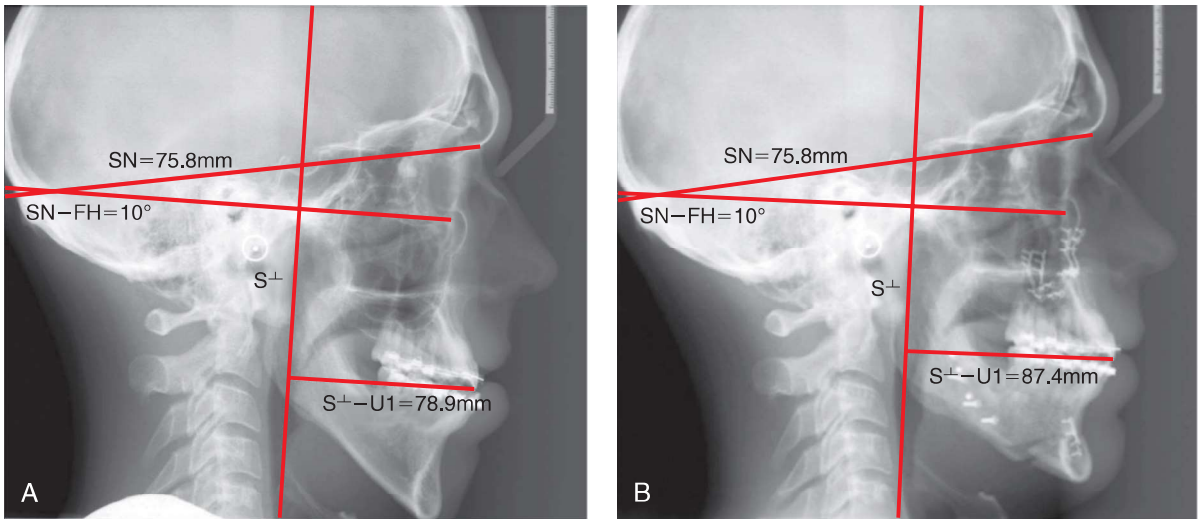
To accurately access the horizontal advancement of the maxillary incisors accomplished during the operation and maintained at 5 weeks, the distance in millimeters from S ⊥ to U1 was measured on both the preoperative and the 5-week postoperative lateral cephalogram. The measurements were then adjusted with the use of a metric reference frame to correct for magnification. Any difference in length of these two data points corresponds with variations in the preoperative and postoperative (i.e., at 5 weeks after surgery) horizontal positions of the maxillary central incisors.

Comparisons between the planned and actually achieved (at 5 weeks after surgery) horizontal positions of the maxillary incisors were made with the paired *t*-test. Statistical significance was set at $P < .05$. Associations between the planned and postsurgical results were investigated with Pearson's correlation.

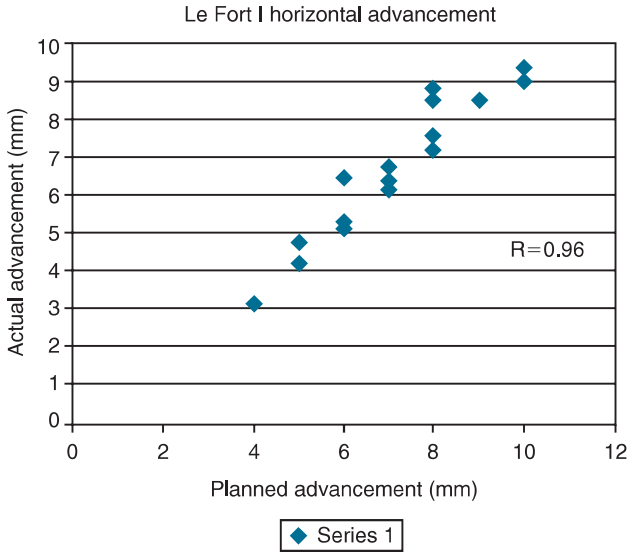
Results

The collected data for all study patients are presented in Table 13-1. In all cases, the surgically achieved and maintained (i.e., at 5 week postoperatively) horizontal advancement measured at the maxillary incisors was within 1.0 mm of what was planned. There was a strong correlation between the two data sets (R = 0.96) (Fig. 13-15). With the use of the absolute measurement values, the mean difference between the planned and actual 5-week postsurgical horizontal advancement of the maxilla was found to be 0.6 mm (range, 0.2 to 1.0 mm). According to the paired *t*-test, this mean difference was not considered to be statistically significant ($P > .05$).

The distribution of the absolute difference in millimeters between the planned, actually achieved, and then



• **Figure 13-14** Example of lateral cephalometric radiographs and measurements taken in study patients showing maxillary advancement in millimeters. Lateral cephalometric radiographs **A,** before and **B,** after Le Fort I advancement. *From Park N, Posnick JC: Accuracy of analytic model planning in bimaxillary surgery,* Int J Oral Maxillofac Surg. *42:807-814, 2013.*



• **Figure 13-15** Data from study patients undergoing Le Fort I advancement. The correlation between the planned and actual advancement at the maxillary incisors is shown (R = correlation coefficient). *From Park N, Posnick JC: Accuracy of analytic model planning in bimaxillary surgery,* Int J Oral Maxillofac Surg. *42:807-814, 2013.*

maintained maxillary advancement is presented in Table 13-2. For the majority of patients, the difference fell within 0.4 to 0.8 mm. In 17 of the 20 patients (85%), there was a small undercorrection; in 3 of the 20 patients (15%) there was a slight overcorrection.

The results of this study confirm that the described method of analytic model planning in orthognathic surgery is reliable in achieving the planned level of maxillary advancement in bimaxillary procedures.

Conclusions

Orthognathic surgery requires a thorough head and neck examination and precise preoperative dental, radiographic, and aesthetic preparation. Although clinical decision making regarding the preferred spatial reorientation of the jaws to achieve improved function and enhanced facial aesthetics remains both an art and a science, the technical aspects of model planning should be precise and consistent. Current methods of analytic model planning and the use of prefabricated splints represent the standard of care for bimaxillary and segmental maxillary osteotomies.

TABLE 13-1 **Maxillary Incisor Vertical Change, Plane Change, and Incisor Horizontal Change: Planned and Actual**

			Horizontal Change		
Patient	Planned Vertical Change	Planned Plane Change	Planned (mm)	Actual (mm)	Difference (mm)
1	–6	0	+8	+8.5	+0.5
2	–3	–3	+4	+3.2	–0.8
3	–2	0	+6	+5.3	–0.7
4	–3	0	+10	+9.0	–1.0
5	0	0	+10	+9.4	–0.6
6	0	+2	+5	+4.8	–0.2
7	–1	+3	+6	+5.2	–0.8
8	–6	0	+7	+6.2	–0.8
9	+2	+2	+5	+4.8	–0.2
10	0	+3	+8	+7.5	–0.5
11	–3	0	+7	+6.4	–0.6
12	–2	–3	+8	+7.6	–0.4
13	+2	+2	+5	+4.2	–0.8
14	+4	+1	+7	+6.8	–0.2
15	+1	+4	+9	+8.5	–0.5
16	–5	–4	+6	+5.2	–0.8
17	–4	0	+6	+6.5	+0.5
18	–5	–2	+8	+7.2	–0.8
19	+3	0	+8	+8.8	+0.8
20	+	0	+10	+9.1	–0.9

Vertical change: +, maxillary lengthening; –, maxillary shortening. Plane change: +, clockwise rotation; –, counterclockwise rotation of maxillary plane.

TABLE 13-2 **Distribution of Difference Between the Planned and Actual Horizontal Advancement at the Maxillary Incisors**

	Difference (mm)				
	0 to 0.2	+0.2 to 0.4	+0.4 to 0.6	+0.6 to 0.8	+0.8 to 1.0
No. of patients (%)	3 (15%)	1 (5%)	6 (30%)	8 (40%)	2 (10%)

From Park N, Posnick JC: Accuracy of analytic model planning in bimaxillary surgery, *Int J Oral Maxillofac Surg*. In press 2013.