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A Modified Approach to "Model Planning" in Orthognathic Surgery for Patients Without a Reliable Centric Relation

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Orthognathic surgery, unlike most surgical procedures, involves extensive presurgical dental laboratory preparation.[1] The surgeon completes a detailed facial and dental evaluation including photographic analysis, imaging studies, and a cephalometric analysis. Presurgical records also include dental impressions; bite registration in centric relation (CR); face-bow transfer; and facial measurements. The dental models are placed on a semiadjustable articulator for further analysis and are used to complete "model surgery." Acrylic splints are fabricated and used intraoperatively to further ensure reliable facial esthetic and occlusal results.[2-4] This approach represents the standard of care.

When performing orthognathic surgery, the introduction of error can occur in many ways. If an inaccurate bite registration is obtained from the patient preoperatively, this will be transferred to the articulated models, leading to inaccurate model surgery and resulting in intraoperative error. Obtaining an accurate and reproducible bite registration in CR is essential if the surgeon is to avoid this error.[5] Unfortunately, there are specific clinical settings in which obtaining an accurate and reliable CR can be problematic. Examples include individuals with absence of a condylar head after tumor resection; loss or severe atrophy of condylar head after condylar fracture; and specific syndromes in which glenoid fossa/condyle–ascending ramus hypo/aplasia exists (eg, hemifacial microsomia with Kaban type III mandibular malformation). For those patients with an unreliable CR, a modified approach to "model surgery" is presented. Three patients illustrate the technique.

Materials and Methods

A standard history and physical examination is undertaken. The craniomaxillofacial and focused dental assessment is completed with particular emphasis on accurately measuring any maxillary occlusal cant, the maxillary and mandibular dental midlines relative to the facial midline, and disproportions in vertical height and horizontal projection of each jaw. A wax bite registration is obtained with the patient seated upright and with relaxed facial musculature. Gentle posterior and superior pressure is applied to the chin, in the absence of muscle forces, allowing the condyles to seat reliably in the glenoid fossa. According to our described model surgery technique, to achieve the "bite" in a patient with a "free-floating" condyle–glenoid fossa relationship (eg, Kaban type III hemifacial microsomia), the mandible is manipulated with the "normal" condyle placed in CR and with the "abnormal" condyle seated in its most posterior position, demonstrating the maximum deformity. A wax bite registration is taken in this position.

A face-bow transfer is obtained with care to accurately reproduce the patient's existing maxillary occlusal plane and cant. If the cranial base and the external auditory canals are in the normal range, this is accomplished in a traditional fashion using the

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face-bow earpiece technique.[6] If the patient's ear canals are abnormally formed or positioned (ie, hemifacial microsomia), adjustments are made using references to the parallelism of the floor, the position of nasion, and the position (and formation) of the orbits. When doing so, the earpieces are placed against the cheek skin (rather than in the dysmorphic ear canals). With the head in the neutral position, the face-bow transfer is recorded.

Two maxillary and one mandibular alginate impressions are made; study casts are poured in stone for each. The first maxillary study model is mounted on the articulator in the standard fashion with the use of the face-bow transfer. The wax bite registration is then used to articulate the maxillary and mandibular casts. The mandibular cast is then mounted on the articulator. The first maxillary mounting is removed, and the second maxillary cast is mounted. This is accomplished with the use of the original bite registration against the already mounted mandibular cast. Vertical and horizontal reference lines are created on each maxillary and mandibular unit.

The original maxillary (die-stone) cast is then separated from its plaster base and 3-dimensionally repositioned (reoriented) according to the treatment plan. This takes into account the preferred location of the maxilla according to horizontal, vertical, midline, cant, occlusal plane, and segmentation needs. The maxillary cast is secured in this new position on the articulator using hot glue to its base.

The mandibular cast is then separated from its base and repositioned into the appropriate final occlusion. It is secured in this new position on the articulator using hot glue applied to its base. At this stage, a "final" surgical splint is created with acrylic.

Next, the repositioned (reoriented) maxillary unit is removed from the articulator and replaced with the "un-cut" second maxillary unit. This indicates the new mandibular location and old (unoperated) maxillary position. The "interim" splint is fabricated with acrylic.

In the operating room (during surgery), the mandibular osteotomies are completed first. The "interim" splint is used to place the distal mandible into its treatment-planned position. If the proximal segments are of sufficient quality, they are independently seated into the terminal hinge position (CR). If the proximal segment on one or both sides is to be constructed from a bone graft (eg, costochondral graft), or if interpositional bone grafts are needed, they can be accomplished at this stage. Stable internal (plate and screw) fixation is applied across each mandibular osteotomy site to achieve a reproducible CR bite. Once the occlusion is confirmed, the "interim" splint is removed, and the maxillary procedures are performed. Once the Le Fort I osteotomy is completed (including segmentation if indicated), the "final" splint is utilized to achieve the treatment-planned maxillary position and occlusion. Stable fixations (plates and screws) are placed across the maxillary osteotomy sites. The occlusion is confirmed and the splint is either removed or left in place depending on the clinical need.

STEP-BY-STEP MODIFIED MODEL SURGERY TECHNIQUE

1. Obtain wax bite registration with the "unaffected" condyle seated in CR and with the "abnormal" condyle positioned posterior and superiorly against the skull base (posterior stop).
2. Record face-bow transfer— use adjusted technique if ear canal(s) is abnormal.
3. Take alginate impressions (2 maxillary, 1 mandibular).
4. Pour alginate impressions in die stone.
5. Mount first maxillary cast onto articulator using face-bow transfer record.
6. Articulate mandibular cast to the already mounted maxillary cast using the (CR) bite registration. Mount mandible cast to base.
7. Remove the mounted maxillary unit and mount second maxillary cast using the same (CR) bite registration.
8. Mark and measure all casts and bases in standard model surgery fashion.
9. Perform model surgery on first maxillary cast (including segmentation if indicated) and remount to articulator base with hot glue in its treatment-planned position.
10. Perform model surgery on mandibular cast to optimal final occlusion with repositioned maxillary cast. Secure mandibular cast to base of articulator with hot glue.
11. Fabricate "final" splint in acrylic in standard fashion.
12. Replace first maxillary (cut) unit with second (uncut) maxillary unit.
13. Fabricate "interim" splint (final mandibular position and unoperated maxillary position) in acrylic in usual fashion.

PATIENT EXAMPLES

Patient 1

A female patient was born with right-sided hemifacial microsomia manifested by mild hypoplasia of the affected soft tissues, paresis of the temporal branch of the facial nerve, a degree of zygoma and orbital hypoplasia, and a Kaban type III mandibular malformation (Fig 1). The right external ear was displaced but with satisfactory formation. She underwent orthodontic alignment during early adoles-

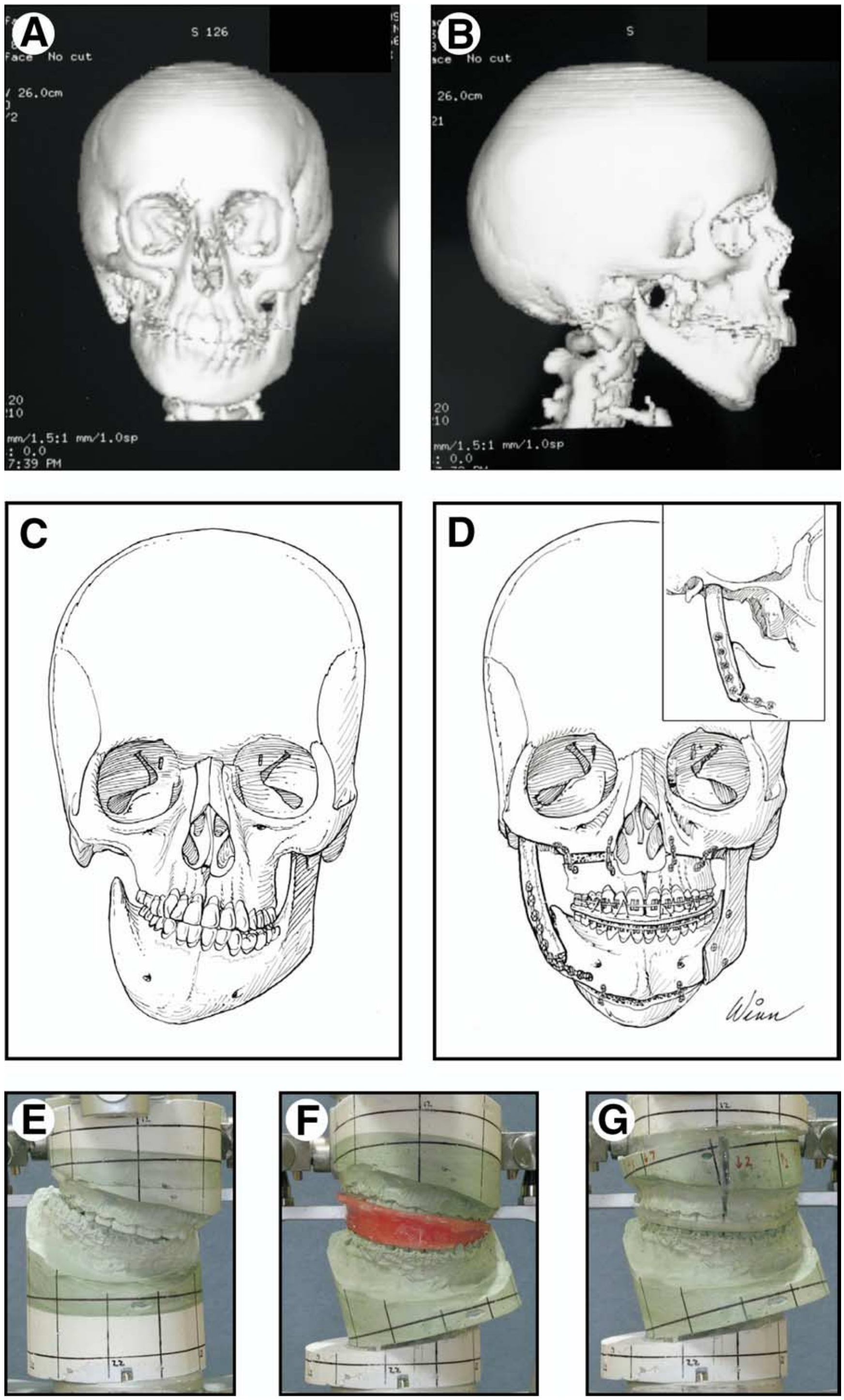

FIGURE 1. Female born with right-sided hemifacial microsomia. At age 16, after completion of orthodontic preparation, she underwent a maxillary Le Fort I osteotomy, (2 segments) sagittal split osteotomy of the left ramus, reconstruction of the right condyle–ascending ramus with an autologous costochondral graft, and an osteotomy of the chin. *A, B,* Craniofacial CT scan views prior to reconstruction. *C, D,* Illustrations of presenting skeletal anatomy and the reconstructive procedures carried out. *E–G,* Articulated dental models demonstrate stages of reverse model surgery planning. **(Figure 1 continued on next page.)**

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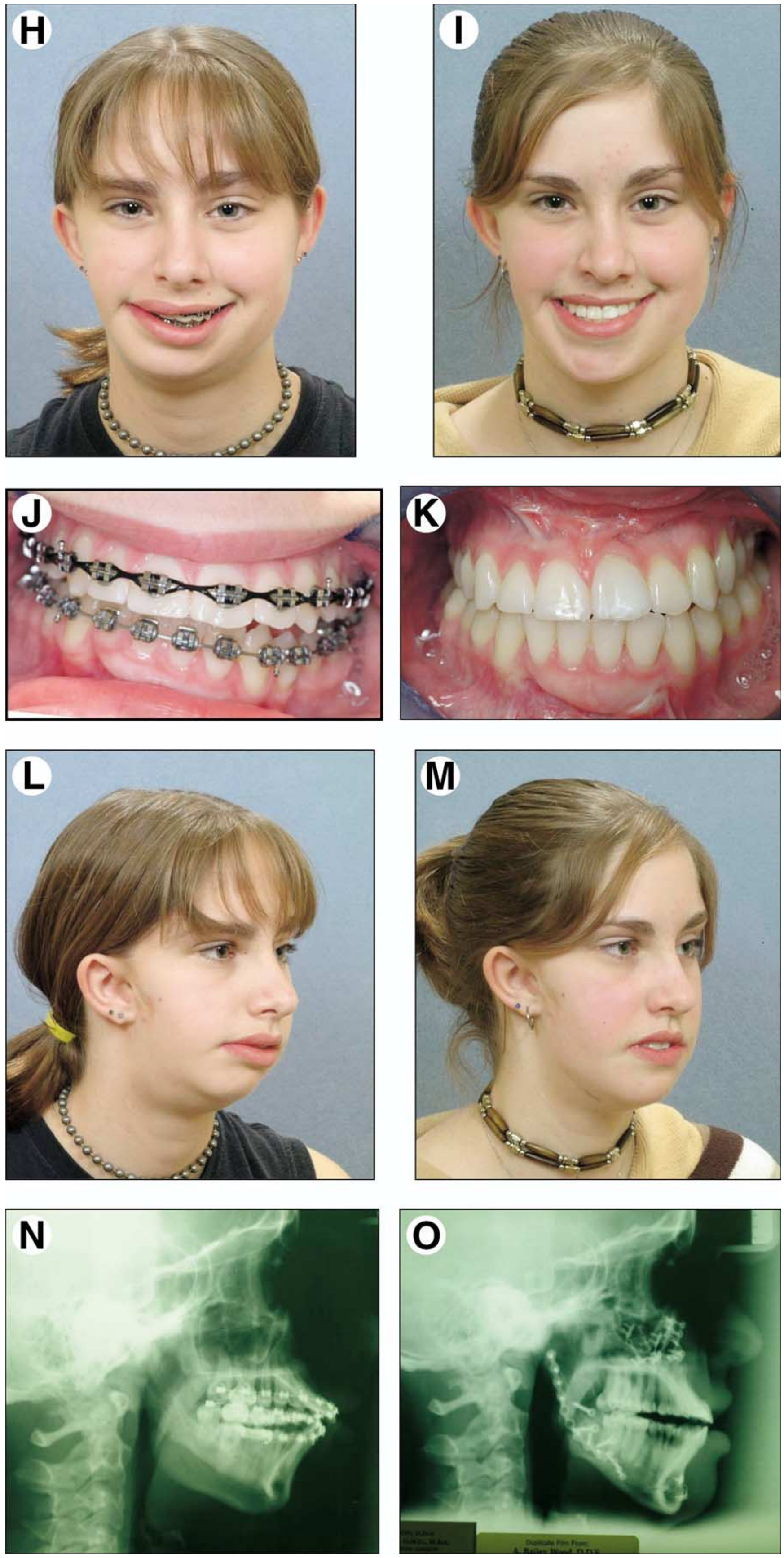

FIGURE 1 (cont'd). *H, I,* Frontal smile views before and after reconstruction. *J, K,* Occlusal views before and after reconstruction. *L, M,* Oblique facial views before and after reconstruction. *N, O,* Lateral cephalometric radiographs before and after reconstruction.

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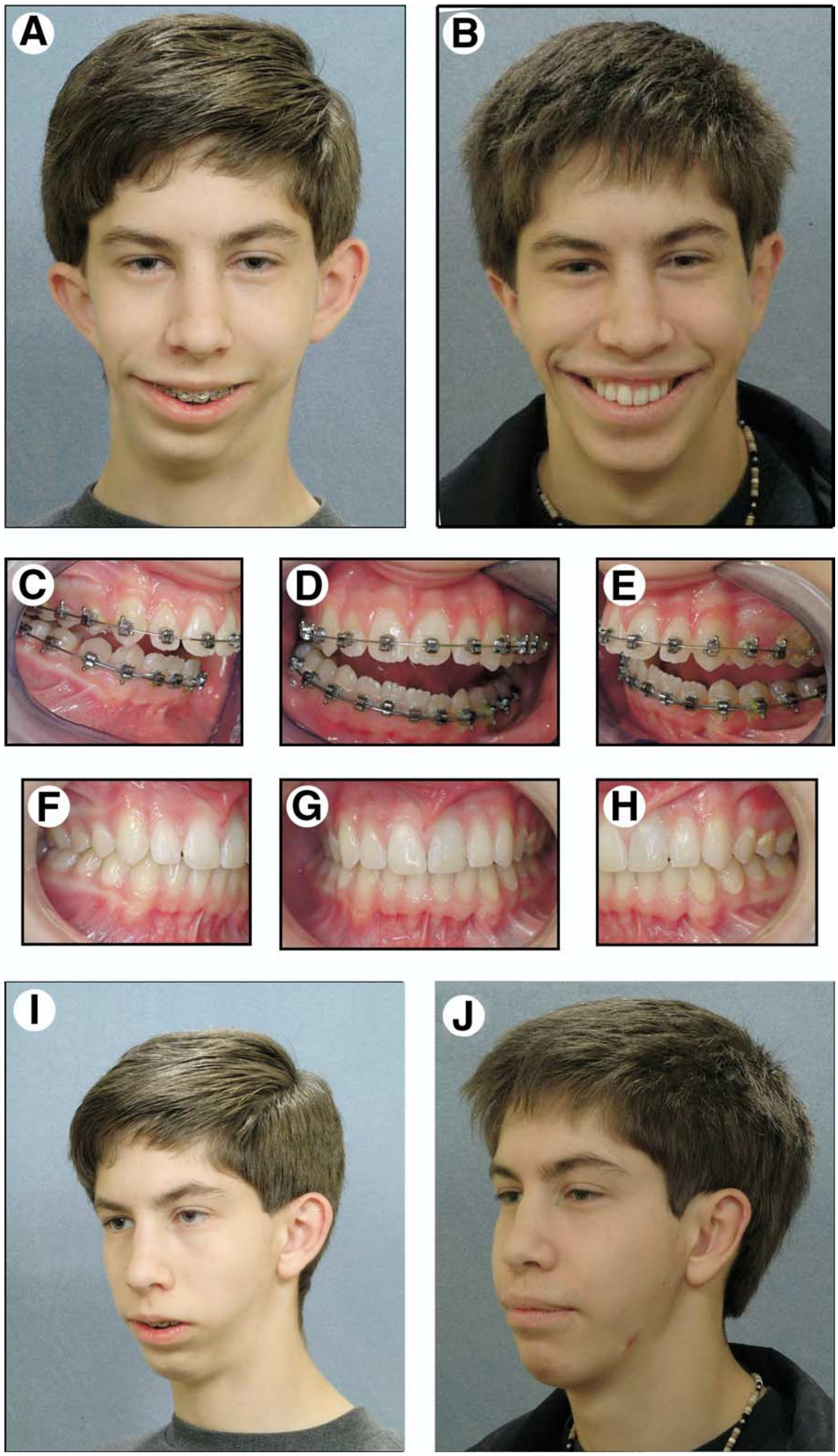

FIGURE 2. A male was born with an asymmetric bilateral form of hemifacial microsomia. At 16 years of age, he underwent a maxillary Le Fort I osteotomy in 2 segments, right coronoidectomy, sagittal split osteotomy of the left ramus, reconstruction of the right ascending ramus with autologous costochondral graft, an oblique osteotomy of the chin, and bilateral otoplasty. *A, B,* Frontal views before and after reconstruction. *C–H,* Occlusal views before and after reconstruction. *I, J,* Facial views before and after reconstruction. **(Figure 2 continued on next page.)**

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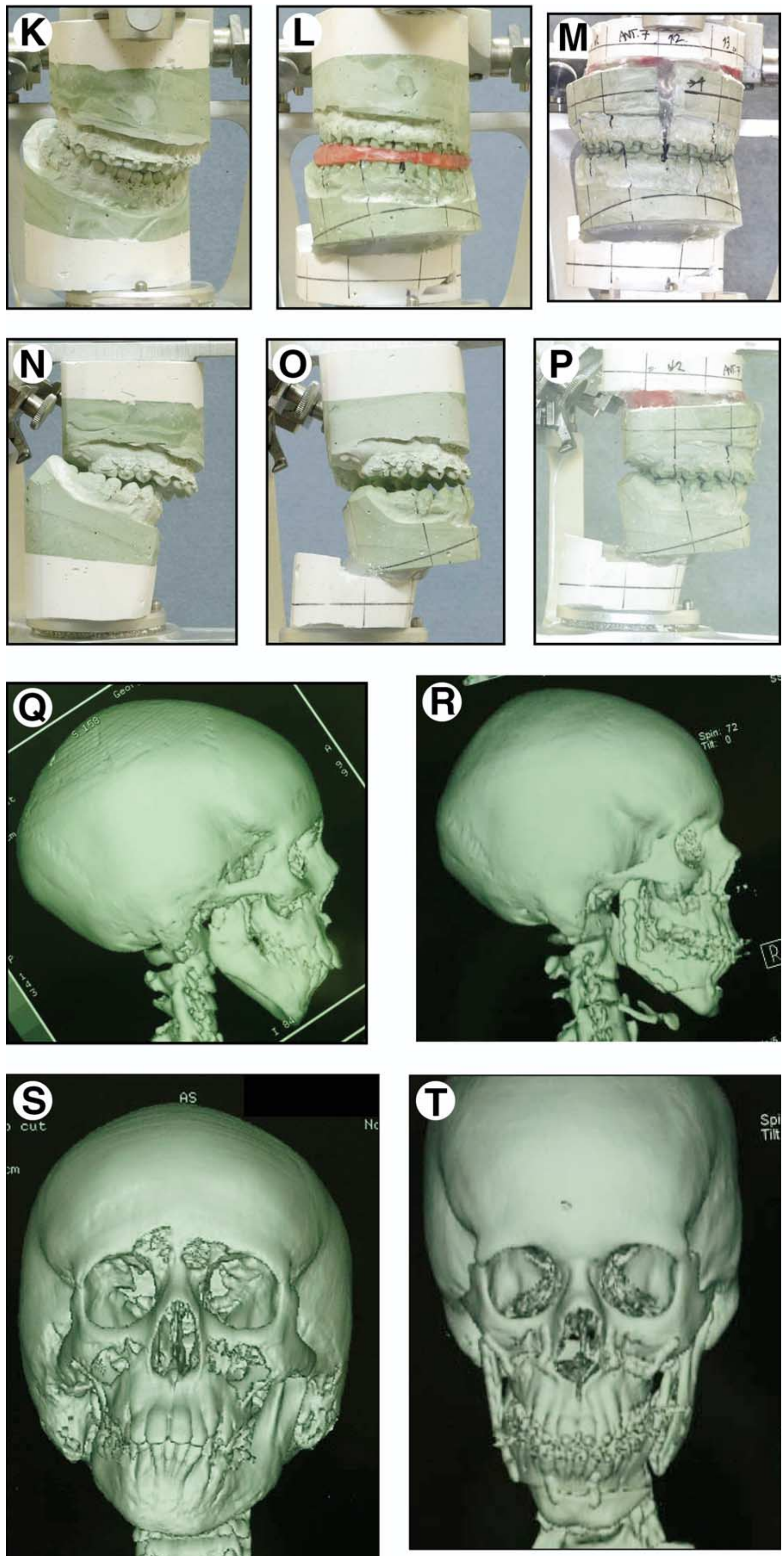

FIGURE 2 (cont'd). *K–M,* Articulated dental models (frontal view) demonstrating stages of reverse model surgery planning. *N–P,* Lateral views of articulated dental models demonstrating reverse model surgery planning. *Q, R,* Lateral craniofacial CT scans before and after reconstruction. *S, T,* Frontal craniofacial views before and after reconstruction.

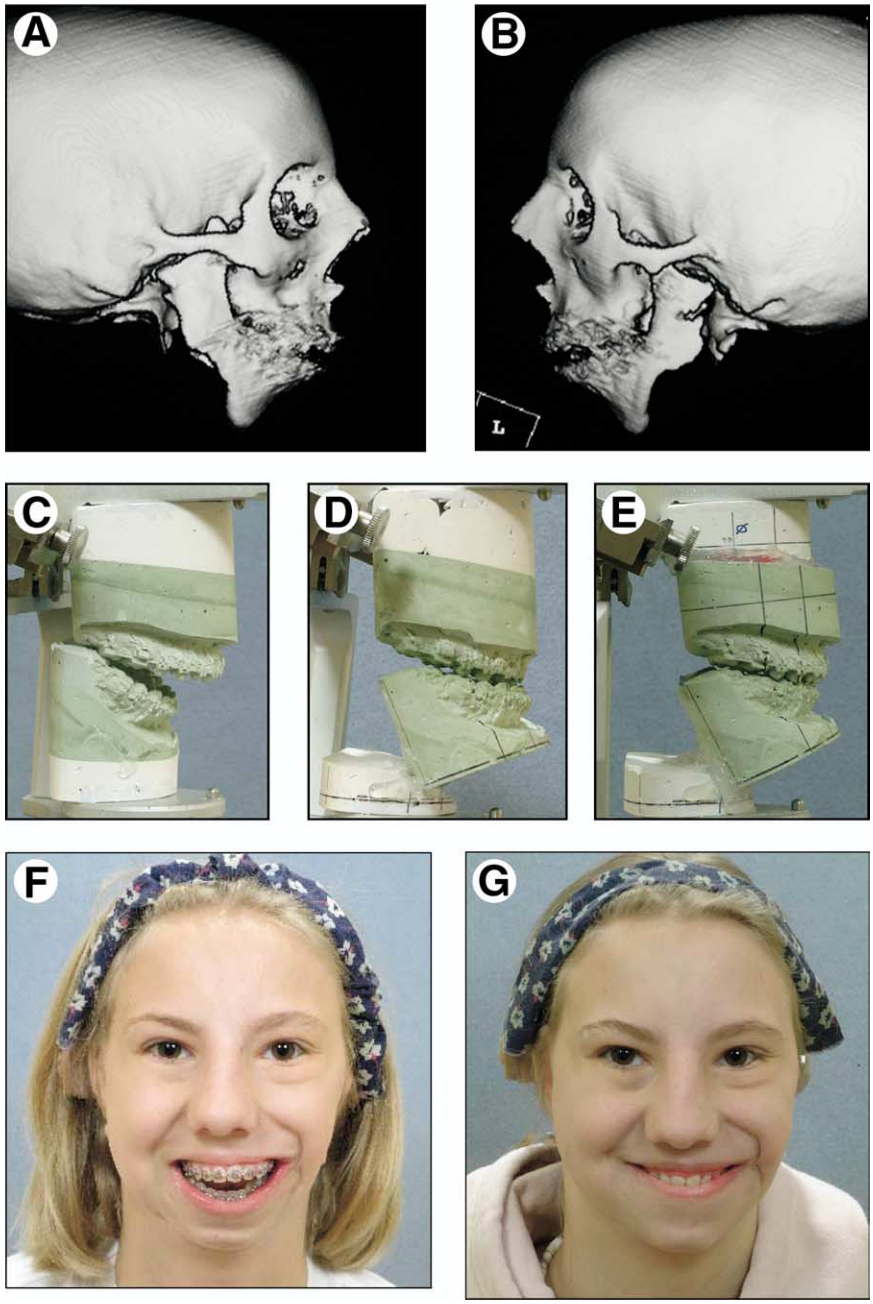

FIGURE 3. A female was born with an asymmetric bilateral form of hemifacial microsomia. At 16 years of age, she underwent a maxillary Le Fort I osteotomy, bilateral coronoidectomies, bilateral sagittal ramus osteotomies with autogenous iliac corticocancellous interpositional bone grafts, and an oblique osteotomy of the chin. *A, B,* Lateral craniofacial CT scan views before reconstruction. *C–E,* Articulated dental models demonstrating stages of reverse model surgery planning. *F, G,* Frontal smile views before and after reconstruction. **(Figure 3 continued on next page.)**

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cence and was eventually referred to the senior author at 14 years of age. At age 16, after completion of orthodontic preparation, she underwent a maxillary Le Fort I osteotomy with 3-dimensional repositioning (cant correction, occlusal plane adjustment, midline correction, vertical and horizontal adjustments), sagittal split osteotomy of the left ramus, reconstruction of the right condyle–ascending ramus with an autogenous costochondral graft, and a genioplasty (horizontal advancement) (Fig 1). The described modified model surgery planned technique was used.

Patient 2

Another patient was born with a bilateral asymmetric form of hemifacial microsomia manifested by mod-

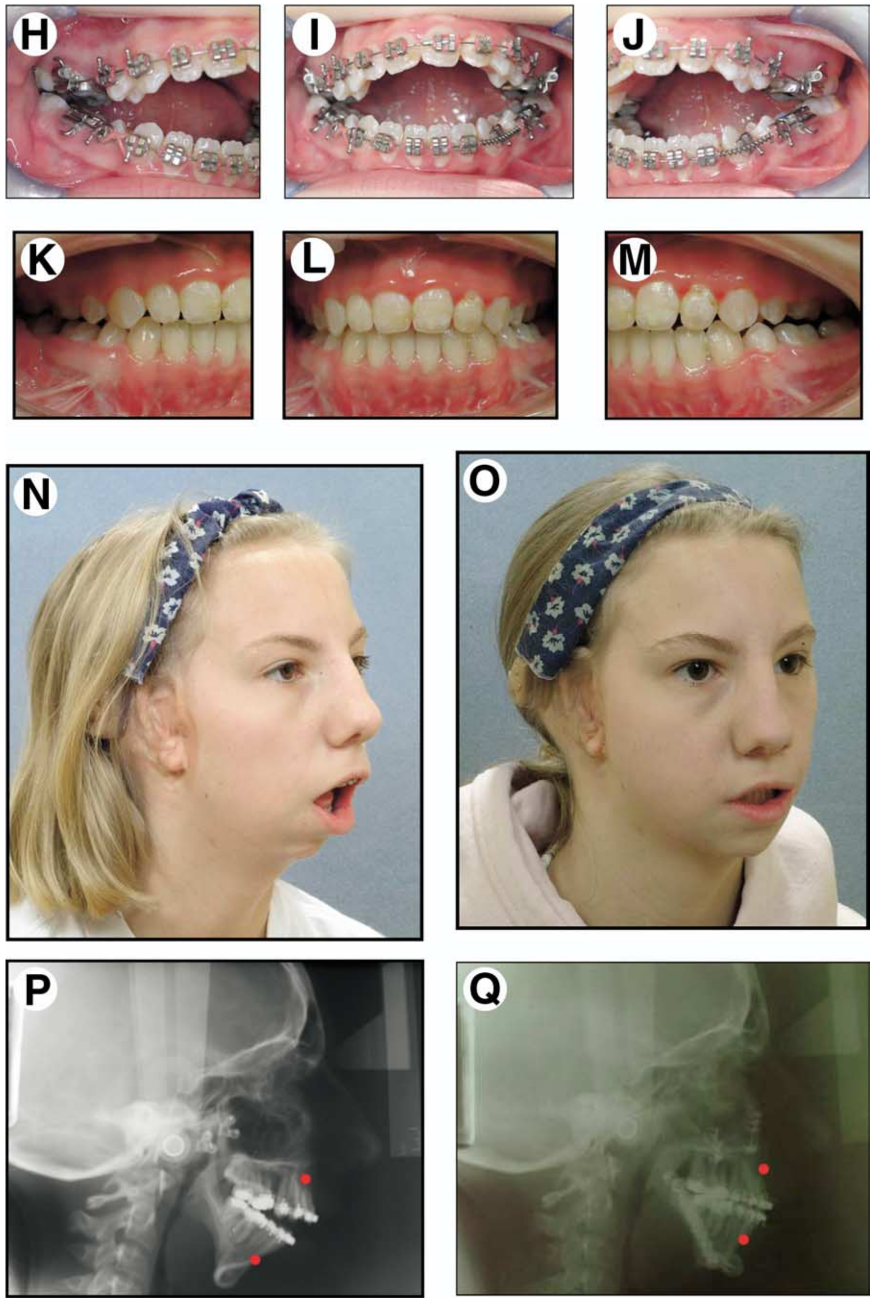

FIGURE 3 (cont'd). *H–M*, Occlusal views before and after reconstruction. *N, O*, Oblique facial views before and after reconstruction. *P, Q*, Lateral cephalometric radiograph views before and after reconstruction.

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erate hypoplasia of the right-sided soft tissues, displacement/deformity of the external ear, anomalous external auditory canals, and a Kaban type III mandibular malformation. Right-sided macrostomia repair was carried out early in childhood. At 15 years of age, he was referred to the senior author for maxillofacial evaluation (Fig 2). After orthodontic preparation, he underwent a maxillary Le Fort I osteotomy in 2 segments with 3-dimensional repositioning (horizontal, vertical, transverse, dental midline, occlusal plane, and cant correction), sagittal split osteotomy of the left ramus, reconstruction of the right condyle–ascending ramus mandible with autogenous costochondral graft, genioplasty, and bilateral otoplasty. The described modified model surgery planning technique was used.

Patient 3

A third patient was born with an asymmetric bilateral form of hemifacial microsomia manifested by moderate hypoplasia of the affected soft tissues—including the muscles of mastication and adnexal structures, bilateral microtia, atresia of the external auditory canals, and mild bilateral hypoplasia of the zygomas and orbits. Bilateral asymmetric Kaban type IIB mandible malformations were present. Previous surgeries included multiple external ear reconstructive procedures, including use of autogenous carved rib cartilage grafts (by another surgeon). She also underwent an attempt to open the left external auditory canal, which was aborted after facial nerve concerns (by another surgeon). Mandibular reconstruction was attempted twice (ages 7 and 11) by another surgeon using external distraction osteogenesis techniques, but with limited results. The previous procedures created intraoral and facial scarring, and a 15-mm anterior open bite malocclusion remained. At 14 years of age she was referred to the senior author for evaluation (Fig 3). After additional orthodontic preparation, she underwent a maxillary Le Fort I osteotomy, bilateral coronoidectomies, bilateral sagittal ramus osteotomies with autogenous iliac corticocancellous interpositional bone grafts, and genioplasty. The described modified model surgery planning technique was used.

Discussion

The definition of CR is controversial and frequently misstated.[6-10] In 1987, the definition of CR underwent a change in terminology from 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.[7] For model surgery planning in preparation for orthognathic surgery, defining the exact position of the condylar head during mandibular protrusion and lateral excursions is not critical. It is essential, however, to locate a mandibular position that is reproducible (without the assistance of the patient) and that can be reliably accomplished both preoperatively and intraoperatively. This position must also be transferable to the articulator in order for "model surgery" planning to be accomplished accurately. An erroneous recording of "CR" may lead to malposition of the maxilla and/or mandible during surgery.[5,11]

Hellsing and McWilliam[12] used a "subtraction" technique to assess repeatability of the CR recorded with a one-handed push-back technique. They found that the mandibular condyles can be seated in a reproducible position, well suited for the registration of CR. Campos et al[10] compared the "swallowing" technique with the "chin-point guidance" technique in upright and supine body positions. Both techniques established a physiologic CR in a reproducible manner. Interestingly, when the "chin-point guidance" method was being used, their work suggested that the upright, seated patient was more reliable than supine.[12] Simon and Nicholls[13] compared the chin-point guidance; chin-point guidance with ramus support; and bimanual manipulation techniques. They found that there were no significant differences in the ranges of mandibular positions observed. We find the chin-point guidance technique— used both preoperatively and intraoperatively by the same surgeon—to be the most reliable and convenient. This is the method we have adopted.

The effects of the material used to record CR (ie, wax) have also been considered as a potential source of introducing error.[14,15] Adrien and Schouver[15] studied mandibular model mounting errors and demonstrated that wax can create error and that the error is directly proportional to its thickness. They suggest that the wax between the distal molars should be as thin as possible. The wax should not be punctured and should retain its rigidity to avoid distorting contacts.

Model planning in preparation for orthognathic surgery involves a series of steps, each of which must be accurately completed to achieve reproducible results. Ellis[16] demonstrated how inaccuracies during model surgery could create statistically significant errors when repositioning the maxilla. Alternative approaches to the classic "maxilla first" approach to "2-jaw" orthognathic surgery have been previously described in attempts to improve the accuracy and predictability of surgical outcomes.[17-19] Although there is no scientific evidence that these or our alternative approach decrease the introduction of error, there are specific clinical situations in which utilizing alternative model surgery planning techniques are necessary. We believe that the subset of patients in which CR is difficult (or impossible) to achieve are best suited for an alternative approach. Examples include congenital anomalies (eg, Kaban type III hemifacial microsomia), trauma (status post condylar fracture or ankylosis resection), pathology (status post condylar resection), or the inability of a patient to cooperate in the office setting (inability to maintain an airway, neuropsychiatric issues, spasticity, pain). In these clinical situations, we prefer to use the modified model surgery planning technique described.

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