Model Surgery and Computer-Aided Surgical Simulation for Orthognathic Surgery

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Learning Aims

1. Traditional model surgery (TMS) remains a time-tested manner of preoperative surgical simulation (PSS).
2. Precision can only be obtained through TMS by careful attention to detail at each one of the steps.
3. Translation of a preoperative surgical simulation to the operating room remains predicated on an accurate clinical database.
4. Computer-aided surgical simulation (CASS) has greatly enhanced the accuracy and efficiency of orthognathic surgery for the correction of dentofacial deformities.
5. CASS illustrates complex skeletal corrections beyond the dental level and allows for the fabrication of custom cutting guides and patient-specific plating implants.
6. CASS provides a number of preoperative insights into the planned orthognathic procedure and is especially useful in complex asymmetries.

61.1 Introduction

Traditional model surgery (TMS) is one of the first widely used examples of preoperative surgical simulation and template fabrication used to guide surgical movements. The complex three-dimensional (3D) movements of the maxilla, mandible, and chin achieved by orthognathic surgery necessitate the significant precision that can be obtained through this process, if care is taken when performing each sequential step. Models are used throughout the course of the patient's treatment, beginning with the pretreatment planning stage, proceeding to an immediate preoperative analytical model surgery, and ultimately resulting in splint construction that is transferred intraoperatively to the orthognathic procedure. The diagnostic information gained from the pretreatment clinical facial and dental measurements, radiographic assessment, and model analysis is integrated to establish a treatment plan. The articulated anatomically mounted models can be utilized in this pretreatment planning stage. They help in the determination of the type of surgery needed and can direct the presurgical orthodontic movements and decompensations.

Presurgical records that provide the ability to surgically simulate surgery include dental impressions, a bite registration with the patient in centric relation (CR), a facebow transfer, and facial measurements made from a standardized clinical examination. Standardized clinical photos and a standardized cephalometric film are also obtained, but their analysis and use are addressed elsewhere in this text. The dental models are placed on a semi-adjustable articulator using the centric relation bite registration and facebow transfer. The treatment plan is expressed in the model surgery that simulates the proposed surgical changes. These models are used to fabricate the occlusal wafers (splints), which facilitate jaw positioning during the actual surgery.

Advances in technology are revolutionizing the preparation and performance of orthognathic surgery. Imaging and software innovations have brought fully computerized three-dimensional treatment planning, virtual dental models, virtual simulated surgery, and computer-assisted manufacturing of surgical splints or custom onlay implants. A virtual three-dimensional model of the patient can be created and interactive software can be used to provide preoperative evaluation and treatment planning as well as simulated surgery and splint fabrication. Virtual surgical planning and splint manufacturing is not always indicated for straightforward routine orthognathic cases, but these advances currently lend themselves well to the correction of complex facial asymmetry cases [1]. Outcome studies on the accuracy of virtual surgical simulation in orthognathic surgery and its cost-benefit analyses continue to be explored.

61.2 Traditional Immediate Preoperative Analytical Model Surgery

61.2.1 Presurgical Clinical Database

The clinical exam of the patient is the first and most important step in the orthognathic surgical workup. A comprehensive variety of measurements are obtained that can characterize the patient's skeletal deformity. These measurements reflect not only the position of the maxilla and mandible, but help identify the symmetry of other facial structures. The clinical measurements used to identify the three planes of space; transverse, vertical and anteroposterior can be categorized into those measured at facial frontal view, facial lateral view, and oral examination (◘ Fig. 61.1). A small millimeter ruler is used to make most linear measurements while an angle ruler can be utilized for angle measurements.

The transverse measurements include the evaluation of the midlines – relating the facial midline to the maxillary dental midline maxillary midline to the mandibular midline, as well as the chin point to the maxilla. In patients with a notable deviation of their nasal structure or in those with hemifacial asymmetries there will be added complexity in evaluating midlines. In these instances, utilizing a glabellar mark with a skin marker and holding a perpendicular plumb line from this point will help to measure facial and dental midlines. Occlusal cant is measured both at the maxillary canines and at

Orthognathic Physical Examination Database			
Transverse	**Date:**	**Date:**	**Date:**
Maxilla to face			
Mandible to maxilla			
Chin to maxilla			
Occlusal plane			
Mandibular angles			
Arch width			
Vertical			
Crown length			
Upper lip length			
Upper lip—resting			
Upper lip—speech			
Upper lip—smiling			
Open bite/overbite			
Anteroposterior			
Overjet			
Nasolabial angle			
Nasal contour			
Labiomental fold			
Chin			

Fig. 61.1 Clinical orthognathic physical exam database

the first maxillary molars. It is quantified by measuring from each orbital rim or medial canthus to the tip of the maxillary canine on the same side. The difference between the two sides defines the cant (e.g., 1.5 mm down at the left maxillary canine). While occlusal cant is often found in the maxilla with mandibular adaptation, there may be an isolated mandibular cant in rare instances. Another measurement of the asymmetry in the transverse plane is assessment of the symmetry of the left and right mandibular angles as measured from the lateral most aspect of the infraorbital rims.

The measurement of maxillary and mandibular arch-widths is accomplished through the oral exam and on study models. In areas where a tooth crossbite exists within the mouth, hand articulating the study models will reveal whether this represents a true arch-width discrepancy or is merely a reflection of the relative skeletal discrepancy manifested by the position of the mandible or maxilla. When a unilateral crossbite is observed clinically more often than not the crossbite is actually bilateral, but the mandible slides to one side upon closure to achieve better interdigitation of the teeth. The examiner should carefully manipulate the mandible to a seated condylar position and then close the teeth together to determine where the first point of contact occurs. This can be crucial in determining whether the mandible is truly asymmetrical or has deviated from a bilateral end-to-end occlusion to a unilateral full cross-bite in "centric occlusion." This assessment can also be made on carefully mounted models.

The maxillary central incisors are key to treatment planning in orthognathic surgery. Their preoperative position must be assessed when the patient is smiling, speaking, and most importantly, in repose. In addition, any additional gingival show must be noted and quantified. Open bite in the area of the central incisors must be measured preoperatively as well as the length of the upper lip. Overbite, positive or negative, should be noted pretreatment and following orthodontic decompensations. The importance of this evaluation is to detect any orthodontic closure of a pretreatment open bite that may relapse after completion of all treatment. In addition, the nasolabial angle and the labio-dental fold often help assess the soft tissue contour that accompanies the jaw relation discrepancies. One must also be mindful of the nasal contour while treatment planning upper jaw procedures. Typically, maxillary advancements or impactions widen the alar base and elevate the nasal tip. Concomitant procedures can be performed to correct significant nasal functional and esthetic concerns such as osseous recontouring, alar cinch, turbinate reduction, and septoplasty.

The position and structure of the chin play a major role in the final esthetic perspective of most patients. While model surgery may or may not reveal the final position of the chin, it will predict the final position of "B" point, which can then be used with the cephalometric analysis and prediction tracing to predict final chin position. Thus, a preoperative assessment of the chin position at baseline is important to assess the need for change.

61.2.2 Presurgical Records

61.2.2.1 Dental Impressions

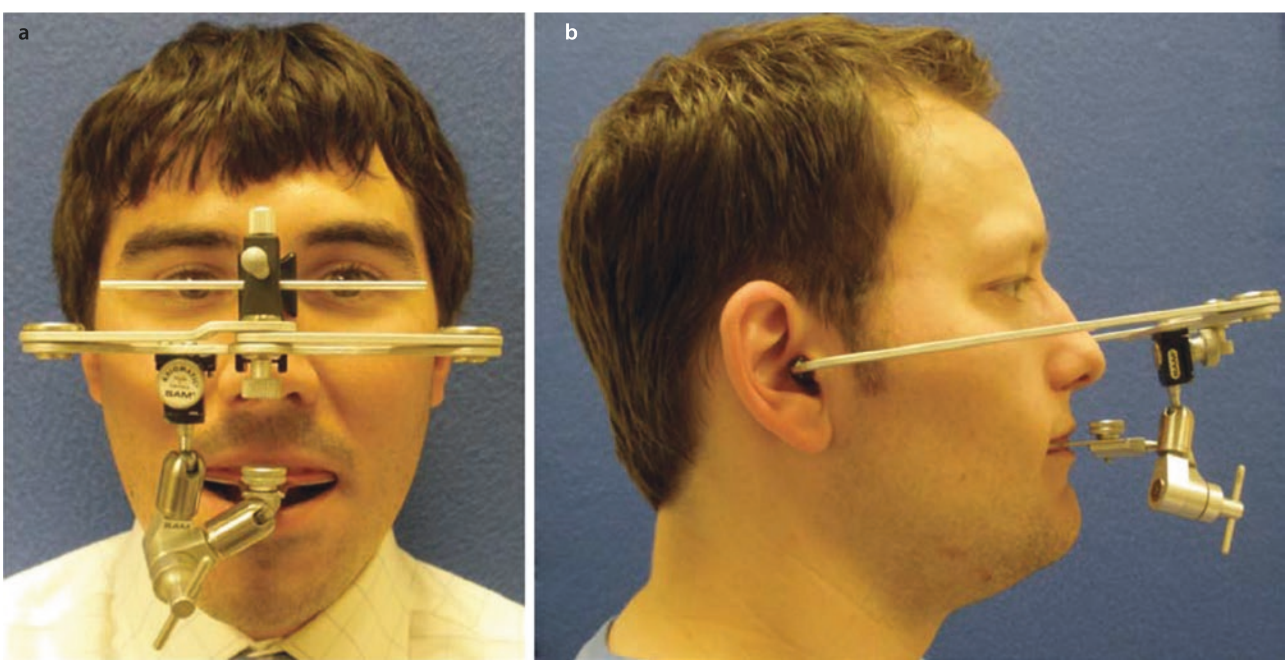
Dental impressions are obtained with alginate at the final presurgical records appointment. They must be obtained after all preoperative orthodontic tooth movement is complete and the surgical stabilizing arch wires have been in place for several weeks and are passive. Recently placed surgical arch wires cause tooth movement, which may continue to take place after the impressions are obtained. Any tooth movement that occurs after the impressions are made will lead to inaccuracies in how well the splint fits intraoperatively. The dental impressions must include the occlusal surfaces of each of the teeth and be without voids or alginate tears. The impressions are poured up using dental die stone and a dental vibrating platform for a hard and precise model. Indentations may be placed within the base of the cast in order to allow for future separation and re-indexing of the cast from its plaster mounting.

61.2.2.2 Facebow Transfer

The transfer of the maxillary cast to the articulator by using a facebow (◘ Fig. 61.2) gives a reliable estimation of the distance between the dentition and the intercondylar hinge axis. This is important when vertical movements of the maxilla and/or mandible are planned, as autorotation changes the position of the jaws in both vertical and horizontal dimensions. The more accurately the maxillary model is mounted with respect to the true hinge axis, the more accurate will be the information provided about the horizontal and vertical movements of the jaws during model surgery. Traditionally, a facebow device is used to register the three-dimensional relationship of the maxillary dental arch to the Frankfort horizontal plane (FHP) using either the patient's external auditory meatus or the condylar heads (depending on the requirements of the facebow) as the posterior reference.

It is universally accepted that the upper arm of the articulator represents Frankfort horizontal (FH). However, this assumption can introduce errors. The semi-adjustable articulator used for model surgery was originally created for use in prosthetic dentistry. Its facebow was designed to transfer the relationship of the maxilla to the terminal hinge axis of the mandible. To accomplish this, the posterior end of the facebow was aligned to the terminal hinge axis (middle of the condyle), and the anterior end was aligned to orbitale. These points defined a plane called the *axis-orbital plane (AOP)*, which is 7° off from Frankfort horizontal. Modifications have been made for surgical cases to minimize this error. Facebows equipped with an adjustable nasal rest and an infraorbital pointer provide an additional point of reference. The pointer arbitrarily lowers the anterior part of the facebow below orbitale by 6.8 mm; thereby reducing the inclination of the occlusal plane. This facebow registration is transferred to the articulator to position and mount the maxillary dental model.

There are other reasons for the inaccuracy in the traditional facebow mounting of dental models [2]. (1) the position of the patient's external auditory meatus or mandibular condyles (depending on the reference for the facebow) may be asymmetric from side to side compared with the fixed symmetric position of the facebow mounting rods on the articulator; (2) owing to anatomical variances, the patient's FHP as determined by the facebow may be significantly different than the fixed FHP of the articulator; (3) the facebow may be improperly positioned on the patient, or facebow components could shift when tightening the bolts, nuts, and/or screws during the registration procedure; (4) cranial base and jaw aberrations may be present that are not reproducible on the articulator; (5) anatomical structures may be absent (i.e., hemifacial microsomia), rendering the face-



◘ **Fig. 61.2** **a** The Student Articulator of Munich (SAM) Student Articulator of Munich (SAM facebow is used to relate the maxillary occlusal plane to the axis-orbitale plane (AOP). **b** The axis-orbitale plane (AOP) is a plane formed by the intercondylar axis of the mandible and the lowest point of the inferior orbital rim known as orbitale. This plane is approximately 7° different than true Frankfurt horizontal (FH). This often results in cases where the maxillary occlusal plane is too steep when mounted bow mounting totally arbitrary; and (6) shifting of the facebow components can occur during the mounting of the maxillary model. Despite these limitations, a carefully obtained and clinically correlated arbitrary facebow is essential to mount the models correctly without compromising the patient's surgical results.

61.2.2.3 CR Bite Registration

The mandibular dental model is then mounted with a centric relation bite registration. This registration is usually obtained with either wax or polyvinyl siloxane (PVS; Fig. 61.3). An accurate registration of the relationship between the maxilla and mandible *independent of the occlusion* must be obtained for proper mounting and model surgery to be carried out. This has historically been termed *centric relation (CR)* and a record of centric relation can be obtained in a number of manners. The definition of CR however, is controversial and frequently misstated. The definition of CR underwent a change in terminology in 1987 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. The most recent Academy of Denture Prosthetics' "Glossary of Prosthodontic Terms" (GPT) from 2005 defines CR as a maxillomandibular relation in which the condyles articulate with the thinnest avascular portion of their respective discs with the complex in the anterior-superior position against the slopes of the articular eminences [3]. It is essential 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. 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.

Fig. 61.3 Centric relation (CR) bite registration in wax and in polyvinyl siloxane (PVS)

The clinical methods to obtain a correct CR registration vary [4]. The "chin point guidance" procedure involves the patient opening wide while the interocclusal record material is applied over the occlusal surfaces of the mandibular teeth. The surgeon then gently manipulates the chin and guides the mandible closure until the mandibular incisors have encountered the material and the patient is held in this position until the material has set.

The effects of the material used to record CR (i.e., wax) have also been considered as a potential source of introducing error. The error introduced is directly proportional to its thickness and it is suggested 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.

61.3 Mounting Dental Models for Simulated Surgery

Dental articulators allow the surgeon to measure surgical moves and carry out multidimensional surgical simulation. Semi-adjustable articulators commonly used by oral and maxillofacial surgeons and orthodontists permit visualization of the dentoalveolar units, their relationship to one another, and to a limited degree, the position of these structures relative to other parts of the craniofacial skeleton. Typically, the upper member of a semi-adjustable or fully adjustable articulator is said to represent one of the cephalometric planes (i.e., FH), and the intercondylar distance is set to approximate that measurement in the average adult. The diagnostic utility of the articulator is enhanced when predictive mock surgery is carried out on mounted dental casts.

In order to ensure that the articulator is calibrated correctly, it is appropriate to periodically calibrate the instrument with a split-cast check.

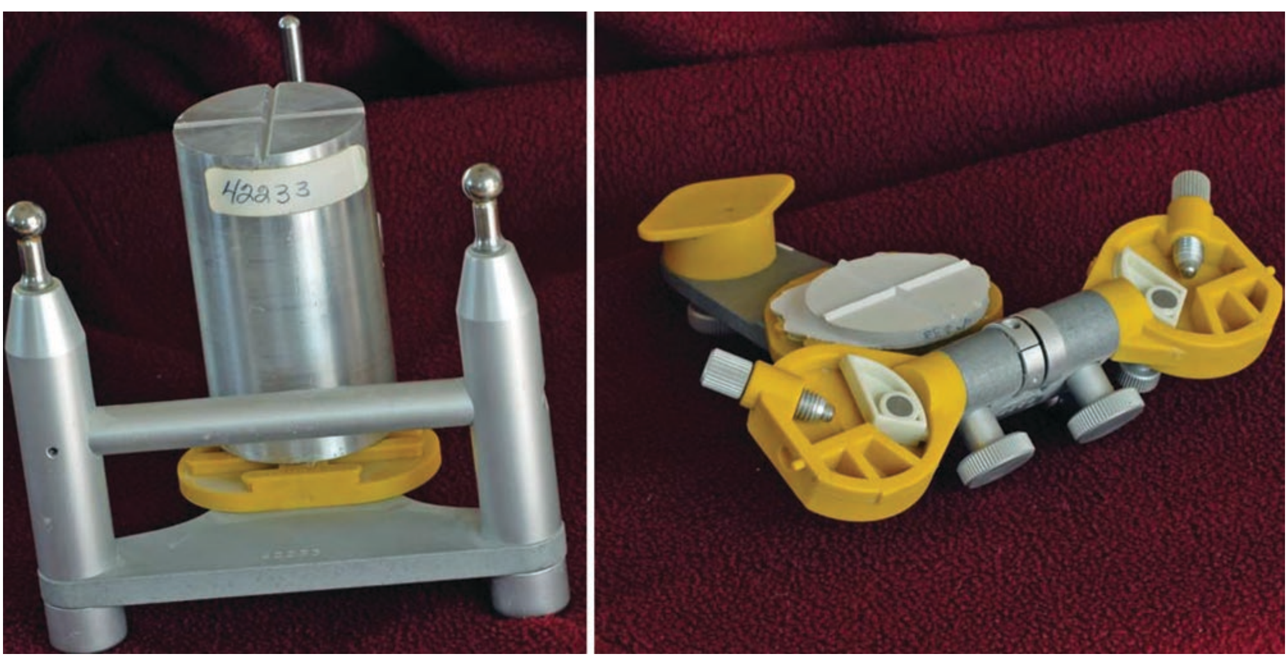
To perform the split-cast check:

1. Set the horizontal condylar inclination at 30° and the Bennett side shift at 5° (average setting) on each side.
2. The incisal pin should be at the zero mark or less.
3. Attach the metal portion of the split-cast to the lower member and attach the plaster portion of the split-cast to the upper member (◘ Fig. 61.4).
4. The two portions of the split-cast should fit together without any discrepancy (◘ Fig. 61.5).
5. If these two parts do not fit together, make sure the incisal pin is out of contact with the incisal table and check the articulator for wax or plaster debris under the split-cast or in the condylar housing area.

Mounting the maxillary cast using facebow transfer (◘ Fig. 61.6) requires that the angle between the occlusal plane of the maxillary model and the upper member of the articulator be the same as the occlusal plane angle. If the maxillary model is mounted at a different angle, the intermediate splint utilized in combined maxillary and mandibular cases will convey an aberrant position during surgery. Comparison of the maxillary plane angle (once the facebow is attached to the articulator) to patient's cephalogram may be required in the laboratory when mounting the maxillary cast. Accurate mounting of the mandibular cast using a centric relation interocclusal registration is mandatory.

The base of the mounting and the cast are best prepared for separation by application of a layer of separating media at the time of mounting. They also may be made in two separate colored stone products. For instance, the model may be poured in greenstone and the mounting may be done in white dental plaster. The base must be smooth and parallel to the base of the cast so that measuring marks can be made easily and smoothly. Trimming of maxillary cast should be parallel to the AOP. The incisal guide pin setting is recorded after mounting.

◘ **Fig. 61.5** The two portions of the split-cast should fit together without any discrepancy



◘ **Fig. 61.4** Calibration of a SAM articulator with a split-cast. The metal portion of the split-cast has been attached to the lower member and the plaster portion of the split-cast has been attached to the upper member

61.4 Marking and Measuring the Final Models and Simulating Surgery

61.4.1 Mandibular Surgery

61.4.1.1 Isolated Mandibular Surgery (Sagittal Split Osteotomy or Vertical Ramus Osteotomy Only)

Once the models have been correctly mounted, they are marked with points for measuring. When mandibular surgery alone is planned, the mandibular anterior, posterior, or rotational movements are dictated by the maxillary dentition. It is because of this that many surgeons use a simple hinge (nonadjustable) articulator to mount the final models. Although the maxillary position will remain constant throughout surgery, there are several benefits to using a semi-adjustable articulator and facebow mounting even in straightforward cases. This provides the surgeon with information regarding the distance of the surgical move at the osteotomy site and possible proximal segment positioning challenges, especially when correcting large mandibular asymmetries.

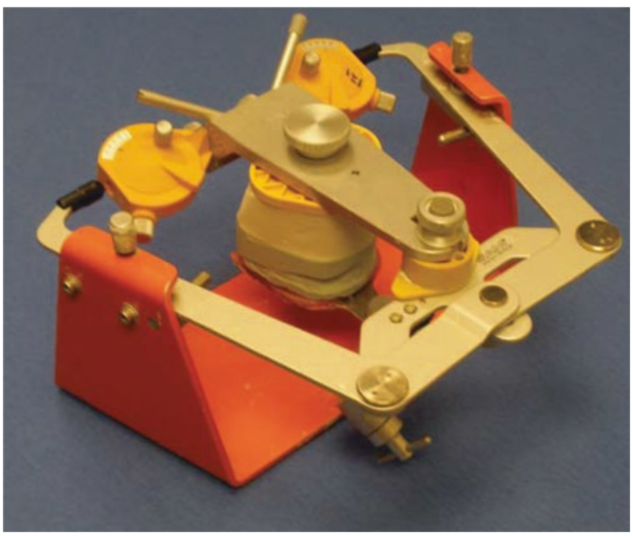


Fig. 61.6 Mounting the maxillary model on a SAM articulator using a facebow transfer

In cases of isolated mandibular surgery, representative points are made on the mandibular cast at the region of the vertical corticotomy or Dal Pont and at the mandibular incisors and genial region (Fig. 61.7). These points in the Dal Pont should be spaced as widely as possible in order to glean the most information about the move. Vertical lines are made at the posterior of the cast descending from the retromolar pad inferiorly.

There are two options to obtain the preoperative measurements now that the models are marked. One way utilizes an Erickson model platform (Great Lakes Orthodontic Products, Ltd., Tonawanda, NY), which is an orientation block on which a caliper is attached that allows for marking and measuring models to an accuracy of 0.01 mm. With the model secured on a model block the platform and caliper allow for pre-osteotomy and post-osteotomy measurements in an anterior-posterior dimension and vertical dimension (Fig. 61.8). This technique eliminates the parallax error that may be introduced by the use of the second measuring option, the freehand ruler technique measuring anterior-posterior to the articulator's pin (Fig. 61.9). Parallax error results when viewing the same object (in this case the markings on a ruler) from different places. Attempts to minimize this error include placing a straight black line on the pin platform and

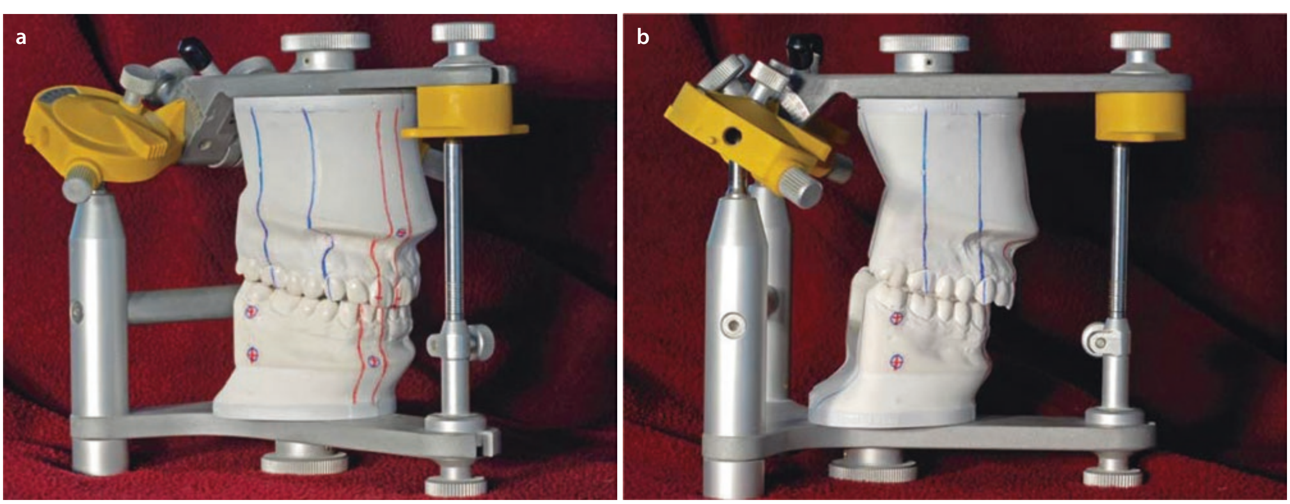


Fig. 61.7 **a**, **b** Mandibular models marked for surgery with representative points made on the mandibular cast at the region of the vertical corticotomy or Dal Pont and at the mandibular incisors and genial region

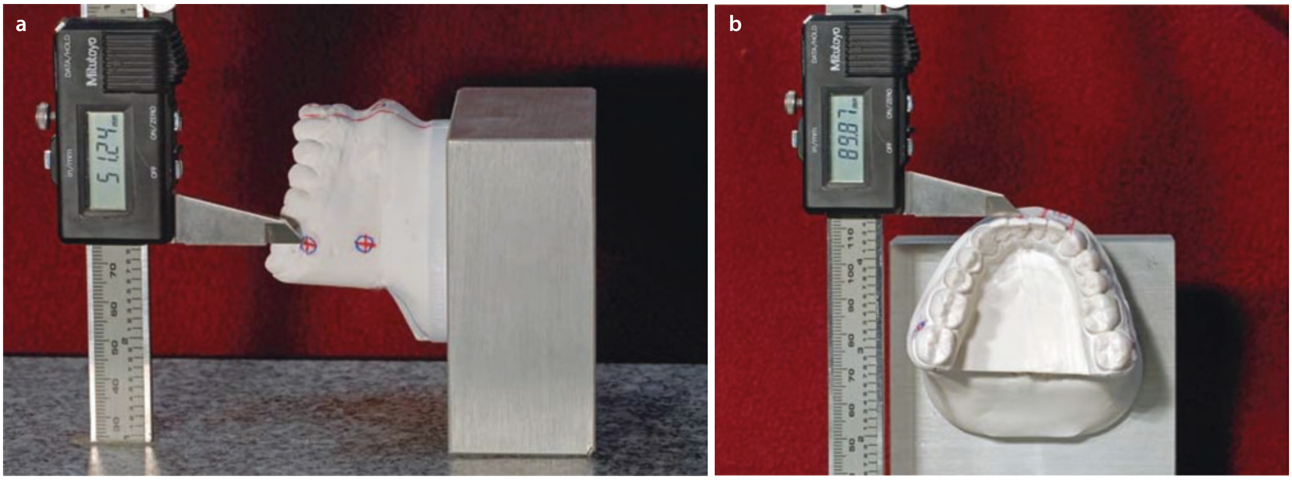


Fig. 61.8 **a**, **b** The use of a model platform with the model secured on a model block allows for pre-osteotomy and post-osteotomy measurements in an anterior-posterior dimension. Precise thin crosshatch marks are made on the mandibular cast at the region of the site of the mandibular osteotomy, central incisors, and genial region

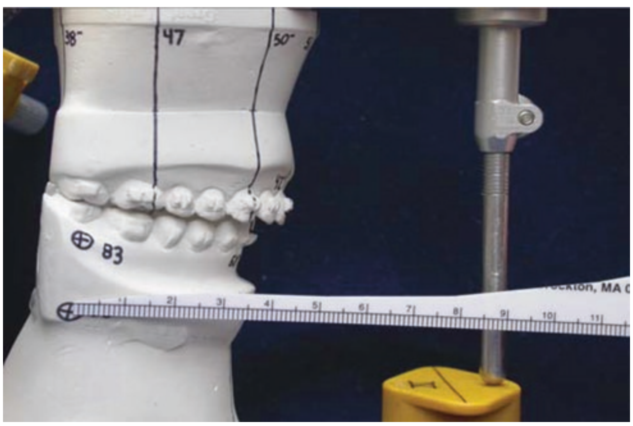


Fig. 61.9 Utilizing the freehand technique to measure anterior-posterior distance at the inferior border of the anticipated right Dal Pont osteotomy. Parallax error is introduced when viewing the same object (in this case the markings on a ruler) from different places

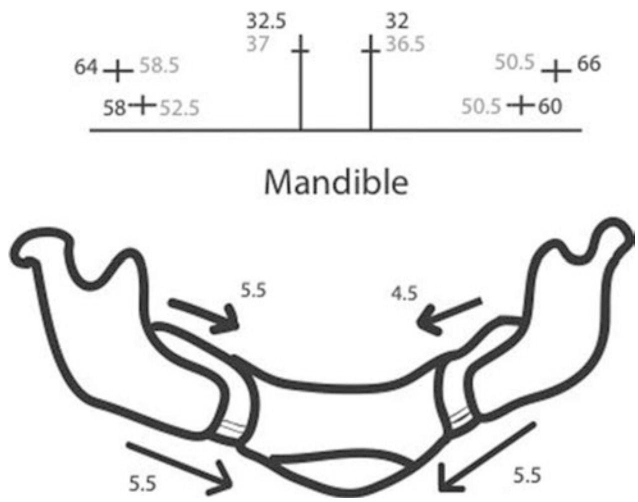


Fig. 61.10 Mandibular Road Map for an isolated mandibular BSSO planned for 5.5 mm advancement on each side. The numbers denoted in black are made prior to the surgical move while the numbers in grey are made after remounting the mandible in its prescribed final occlusion. The differences between the two numbers reflect the surgical move at that point

measuring consistently to the anterior portion of the pin while viewing from a position at which the black line becomes a point (perpendicular to the ruler). The measurements obtained are recorded onto a laboratory data sheet (orthognathic roadmap) that can be taken to the operating room for reference (Fig. 61.10).

The mandibular model can then be separated from its original cast and repositioned to the planned occlusion. Setting of bite should take into consideration the surgery that will be done (bilateral sagittal split osteotomy (BSSO) or intraoral vertical ramus osteotomy (IVRO) and should involve close communication with the patient's orthodontist. The mandibular model is secured to the maxillary with hot glue or sticky wax. The model is then remounted with plaster and a final acrylic surgical splint is fabricated. Postoperative measurements can then be obtained which will inform the surgeon of the distance the mandible is being advanced or set back (the surgical move). In patients in whom an asymmetry is being corrected, a view of the models from a posterior vantage point will help identify regions in which proximal and distal segment interferences can be anticipated (Fig. 61.11).

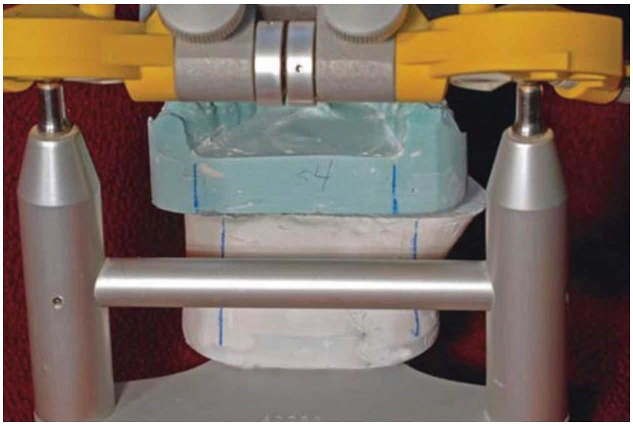


Fig. 61.11 A view of the mandibular model from a posterior vantage point after a surgical move will help identify regions in which proximal and distal segment interferences can be anticipated

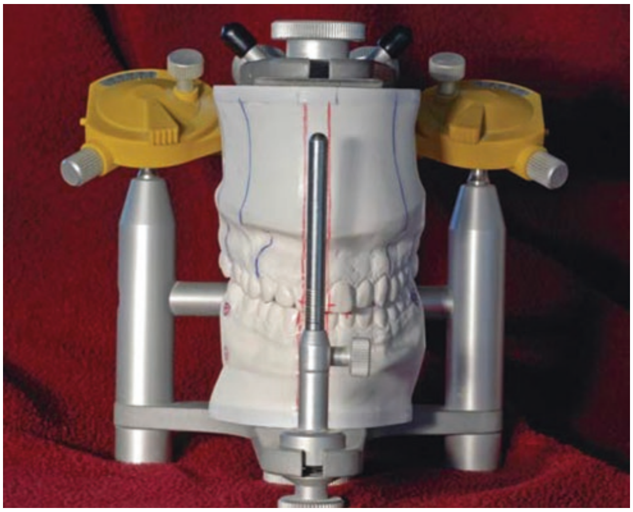


Fig. 61.12 Red vertical lines are drawn on each side of the midline, using the articulating pin as a guide. The position of these lines is entirely dependent on a correct facebow transfer and the maxillary midline should correlate to the clinical exam

61.4.2 Maxillary Surgery

61.4.2.1 Isolated Maxillary Surgery

Pretreatment model surgery is essential when contemplating maxillary surgery alone and very useful when planning two-jaw surgery. Pretreatment model surgery permits the evaluation of the maxilla and the mandible whether the mandible is autorotated without surgery or also osteotomized. If the goals of the surgery can be accomplished with a single jaw surgery, then the orthodontic preparation and patients' expectations can be influenced appropriately.

In this scenario, the mandible will serve as a template for the final position of the maxilla. A clinical example would be a single piece Le Fort I maxillary osteotomy for correction of posterior maxillary excess resulting in a skeletal class I open bite malocclusion. The models are mounted as previously discussed. A semi-adjustable articulator is strongly recommended for these cases. The advantage of using such an articulator lies in its simulation of the appropriate arc of auto-rotation of the mandible when properly mounted. When performing isolated maxillary impaction, the incisal pin will be shortened.

Marking the midline is the first step in marking models. This can be done by making lines parallel to the articulating pin on either side of it from a frontal view avoiding paralleling errors (Fig. 61.12). This step is done on both the maxilla and mandible mounted together in the presurgical occlusion. A mounted maxillary model requires measurements in the anteroposterior, vertical and transverse planes. This can be accomplished with the maxilla removed from the articulator or while on it. Where the models are measured will depend upon which of the two options is used to measure these distances: the model block or a freehand technique (Fig. 61.13). When measuring vertical distances on the model block it is necessary to "zero" the electronic caliper at the level of the mounting base prior to obtaining a measurement. The freehand technique uses a caliper for vertical measurements and a ruler for anterior/posterior measurements. Vertical measures of the maxilla are made at both the central incisors at premarked points, both of the canine cusp tips, and mesial-buccal cusp tips of the first molars. In addition, the cast should be vertically measured at both tuberosities. Anterior-posterior measurements are then recorded at the central incisors and a point representing the anterior nasal spine on the base of the cast (Fig. 61.14). Measurements obtained with the "freehand" technique are made to a point on the pin of the articulator (to which all measurements should be consistently made).

The maxillary cast is now separated from its base and is positioned in the proper occlusion with the mandibular cast. In cases of superior repositioning of the maxilla, it will be necessary to remove additional plaster from the mounting to provide clearance for the superior repositioning of the maxilla. A layer of wax or hot glue is added to the gap between the base and the model. Any anteroposterior changes are usually limited by the mandibular position. The incisal guide pin is adjusted as needed to provide the proper vertical measurement at the maxillary incisor. Shortening of the incisal guide pin height in maxillary impaction cases will allow the proper arc of autorotation of the mandible to this newly positioned maxilla. The final measurements are recorded (Fig. 61.15a, b) and the road map is prepared (Fig. 61.16). A final splint is made to this occlusion.

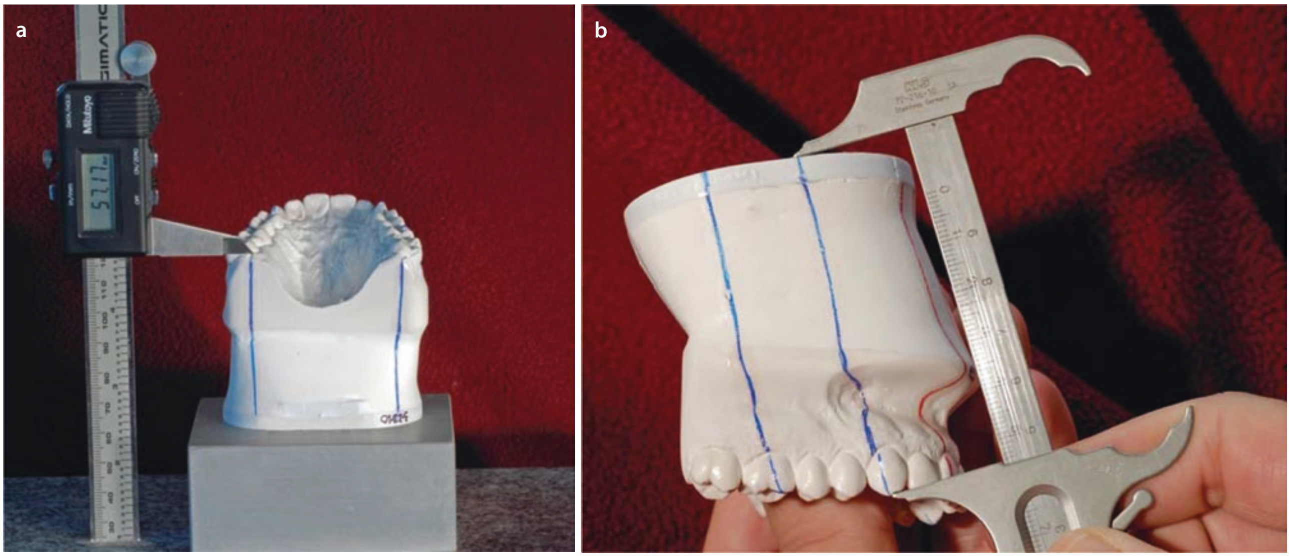


Fig. 61.13 **a**, **b** Vertical measurements may be obtained with either a model block **a** or with a hand-held caliper

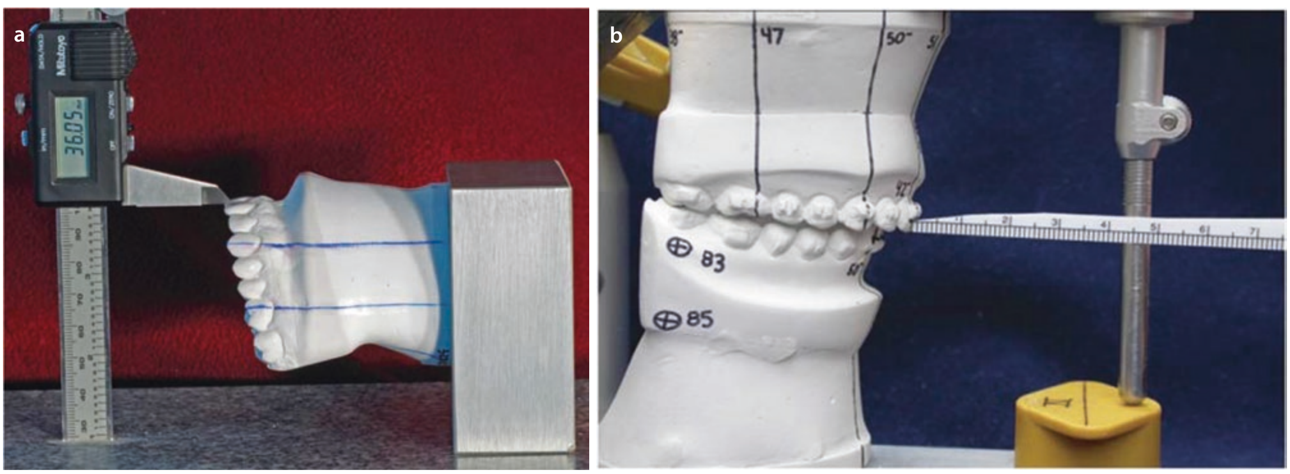


Fig. 61.14 **a**, **b** The freehand technique measuring anterior-posterior distance from a point marked on the maxillary right central incisor to the anterior of the mounting pin

61.4.2.2 Vertical Measurements in Maxillary Surgery

Despite meticulous presurgical planning and model surgery, vertical positioning in maxillary surgery will depend entirely upon intraoperative measurements unless patient-specific cutting guides and plates are utilized. How best to control the positional change of the maxilla with traditional surgery has been debated. The unfortunate use of the terms “internal” and “external” reference marks has led to confusion because internal has been used to describe an antiquated technique of scribing lines above and below the osteotomy in an attempt to measure the vertical position of the maxilla intraoperatively. The term “external” has come to mean placing a referencing device somewhere outside of the wound above the osteotomy and measuring to the mobilized maxilla, usually the central incisor brackets. But the issue is not whether the reference marks are inside or outside of the mouth or the wound, but rather that they are superior to the osteotomy and are in stable bone. The use of superior bony reference marks (SBRMs), inside or outside of the wound, has proven to be more accurate than scribing lines along the osteotomy. This makes outside of the wound reference marks unnecessary if SBRMs are placed as described below. The technique presented here provides four SBRMs in two bilateral locations. Measurement is made from the SBRM to the gingival crest rather than orthodontic

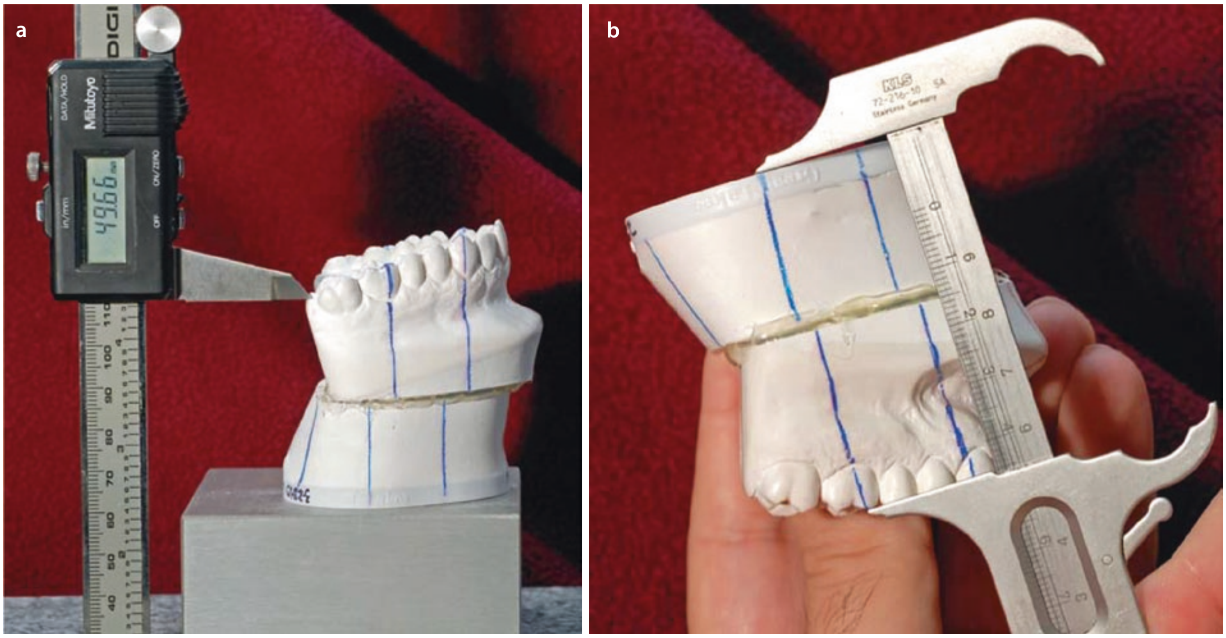


Fig. 61.15 **a**, **b** Final measurements are made at the left and right maxillary incisor, canine, and first molar teeth, as well as at the tuberosity and anterior nasal spine region. These new measurements reflect the change in vertical positioning

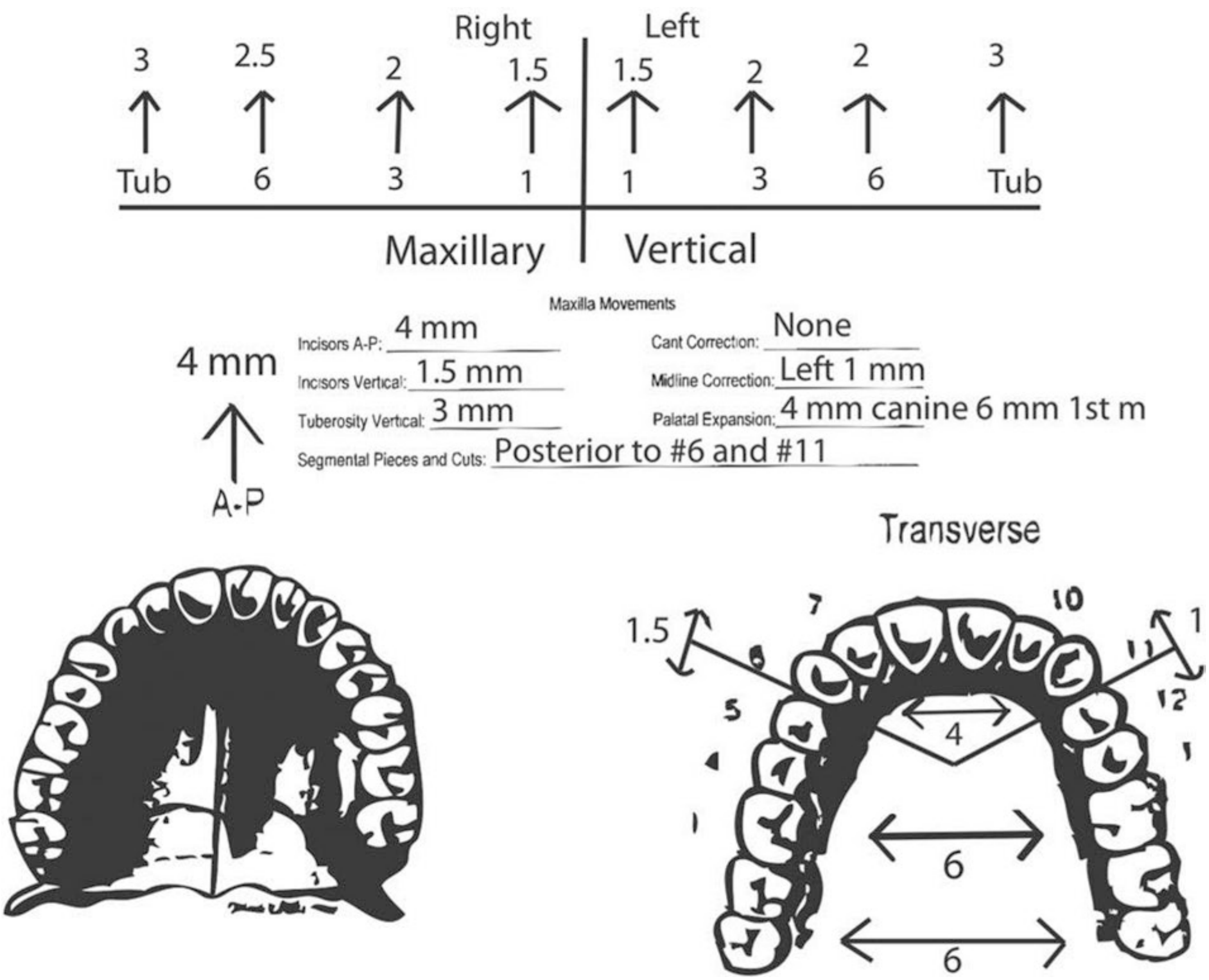


Fig. 61.16 Maxillary orthognathic roadmap denoting planned maxillary movements

brackets which can be loosened resulting in the loss of that measuring point.

Method 1: Utilizing Four Superior Bony Reference Marks (SBRMs) for Point-to-Point Intraoperative Measurements This method simultaneously employs two different manners of measuring. Preoperatively, the Erickson model block is used for pure horizontal or vertical measurements whereas bilateral "point to point" measurements are made with a Boley gauge or calipers that correlate to intraoperative measurements. Premovement measurements at the canine and molar areas bilaterally are repeated post-movement, in a point-to-point fashion, using a Boley gauge to measure vertical change.

Intraoperatively, the model surgery measurements are replicated. Superior Bony Reference Marks (SBRMs) are made bilaterally on the maxilla. These are made well above the planned osteotomy line in the piriform and buttress regions above the canine and molar. The *difference* in the two measurement sets from the models is utilized intraoperatively, in a point-to-point fashion, with a caliper, obtaining the same *difference* in the preoperative and postoperative measurements on the maxilla. This point-to-point measurement transferred from the models to the surgical measurements eliminates errors encountered as a result of AP movement.

This method does not require a reference marker outside of the surgical wound and gives bilateral information regarding the three-dimensional maxillary movement. The steps necessary for this technique at the time of model surgery are as follows:

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1. Mark a stable point on the models above the canine and 1st molar teeth bilaterally—total of 4 stable points (Fig. 61.17, points *A* and *P*).
2. Mark a corresponding point on the canine and molar teeth bilaterally. The incisal edge is usually used. It is not important that this point be the same as used at surgery so long as it is stable from before model surgical positioning until after (Fig. 61.17, points *B* and *C*).
3. Measure and record the distances from stable point to the tooth point for each of the four pairs (Fig. 61.17).
4. Measure anterior maxilla from Frankfort horizontal (FH) to upper incisor using either the model block or the freehand technique (Fig. 61.18).
5. Perform model surgery to desired 3D position (Fig. 61.19).
6. Remeasure all five distances and record the difference between pre- and post-model surgeries (Fig. 61.20).

Note: The *differences* between the pre and post-model surgery measurements at the piriform rims and the first molars are the important values to have at the time of surgery, not the absolute values (Fig. 61.21). The FH to upper incisor measurement is to place the model at the desired vertical and is not needed at surgery.

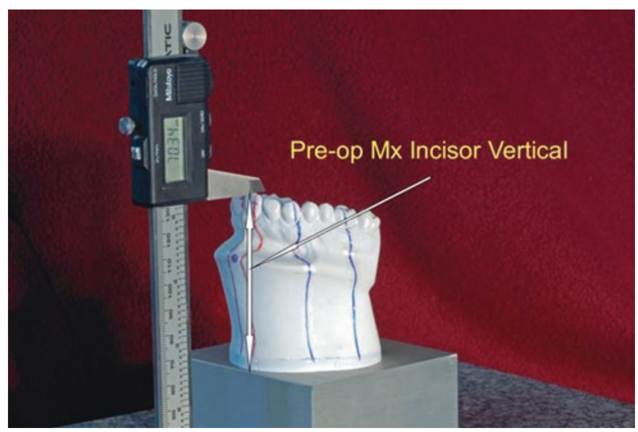

Fig. 61.18 Measurement of preoperative maxillary vertical at the right central incisor with a model block

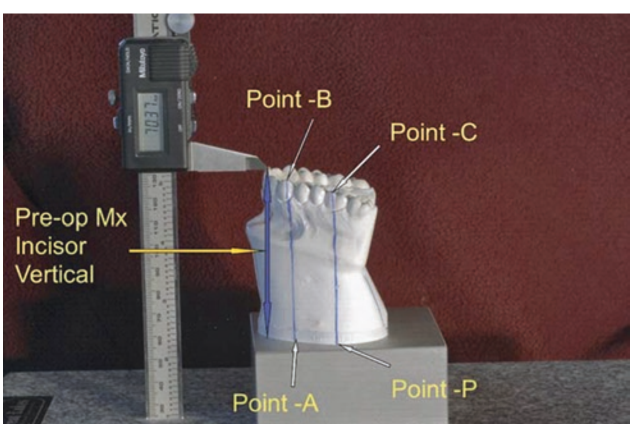

Fig. 61.17 Measurement of preoperative maxillary vertical at right canine and mesial buccal cusp tip of right first molar with a model block

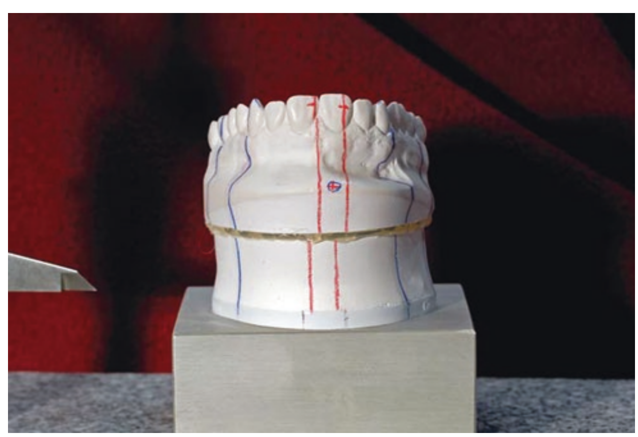

Fig. 61.19 Cut and repositioned maxillary model placed onto the model block for postoperative measurement

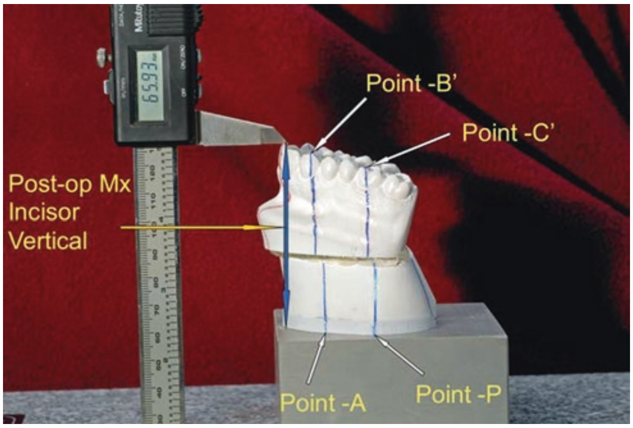

Fig. 61.20 Postoperative vertical measurements are obtained in the same fashion as was done before cutting and repositioning the maxilla. Here the new vertical measurements are obtained at the right canine and mesial buccal cusp tip of right first molar with a model block. The differences between the pre- and postoperative numbers should reflect the treatment plan

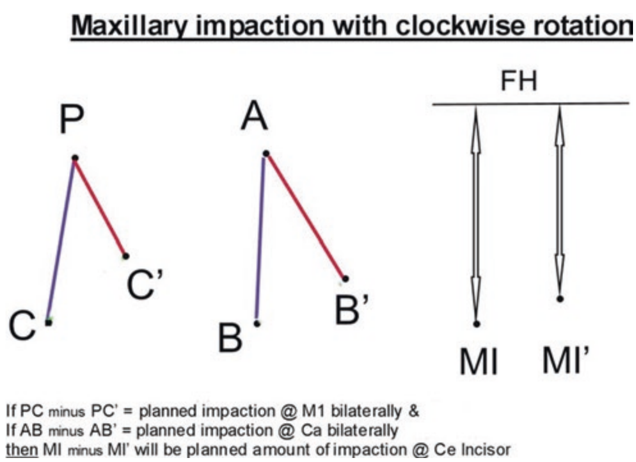

Fig. 61.21 The differences between the pre- and post-model surgery measurements are the important values to have at the time of surgery

The steps completed for this technique at the time of surgery are as follows:

A. Place SBRMs by drilling small holes in the piriform rims and zygomatic buttresses bilaterally well above the planned osteotomy (Fig. 61.22a).
B. Measure and record the distance from these holes (SBRMs) to the gingival crest of the canines and 1st molars bilaterally. Again, it is *not* important that this point on the teeth be the same as the model surgery so long as it is a stable reproducible point (Fig. 61.22b).
C. After mobilization the maxilla is positioned so that the 4 *differences* measured at model surgery match those differences measured intraoperatively (Fig. 61.23).

If the maxilla is positioned according to this method the anterior maxillary vertical will be as planned. No SBRM outside of the wound is needed and the canine and molar vertical positions will also be as planned (Fig. 61.21).

Method 2: Utilizing One Midline Superior Bony Reverence Mark outside of the wound This external reference point method provides a single measurement to assess proper vertical positioning of the maxilla and the anterior maxillary teeth. All other movements (AP and transverse) are provided from the model surgery and prefabricated splints. After anesthetic induction and patient positioning and prep are completed, the face is widely draped to allow for visualization of the nose. A 0.062 Kirschner pin (K-wire) is place at nasion approximately 8 mm in depth, and a measurement is obtained from the fixed wire to the maxillary central incisor orthodontic bracket prior to maxillary mobilization with a Boley gauge or Perkins device. Measurements are then repeated after the osteotomy and positioning of the maxilla until the planned

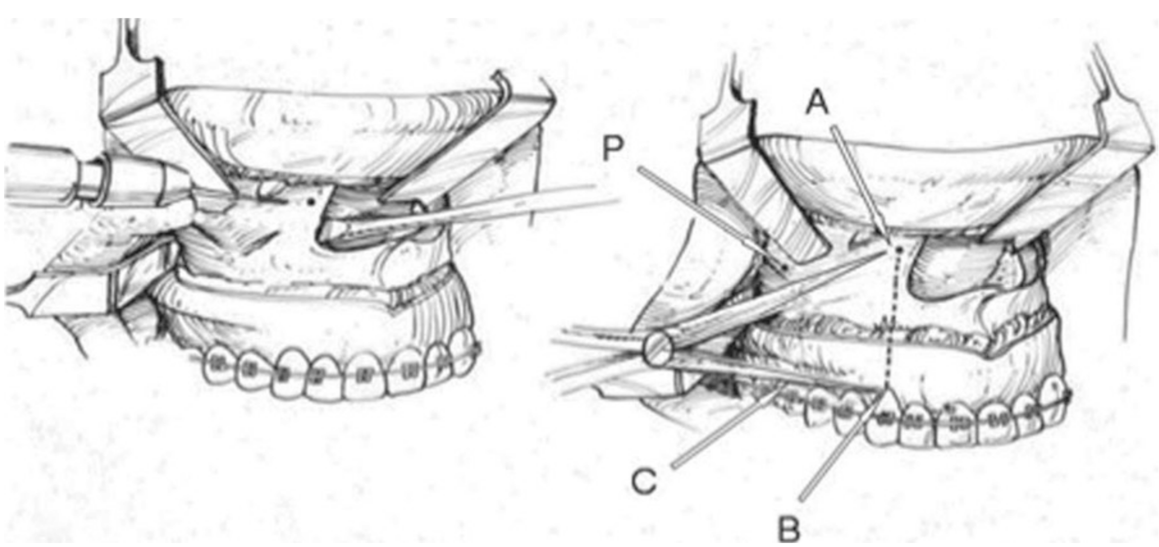

Fig. 61.22 Depicts intraoperative placement of superior bony reference marks (SBRM) by drilling small holes in the piriform rims and zygomatic buttresses bilaterally well above the planned osteotomy with a 703 straight fissure bur

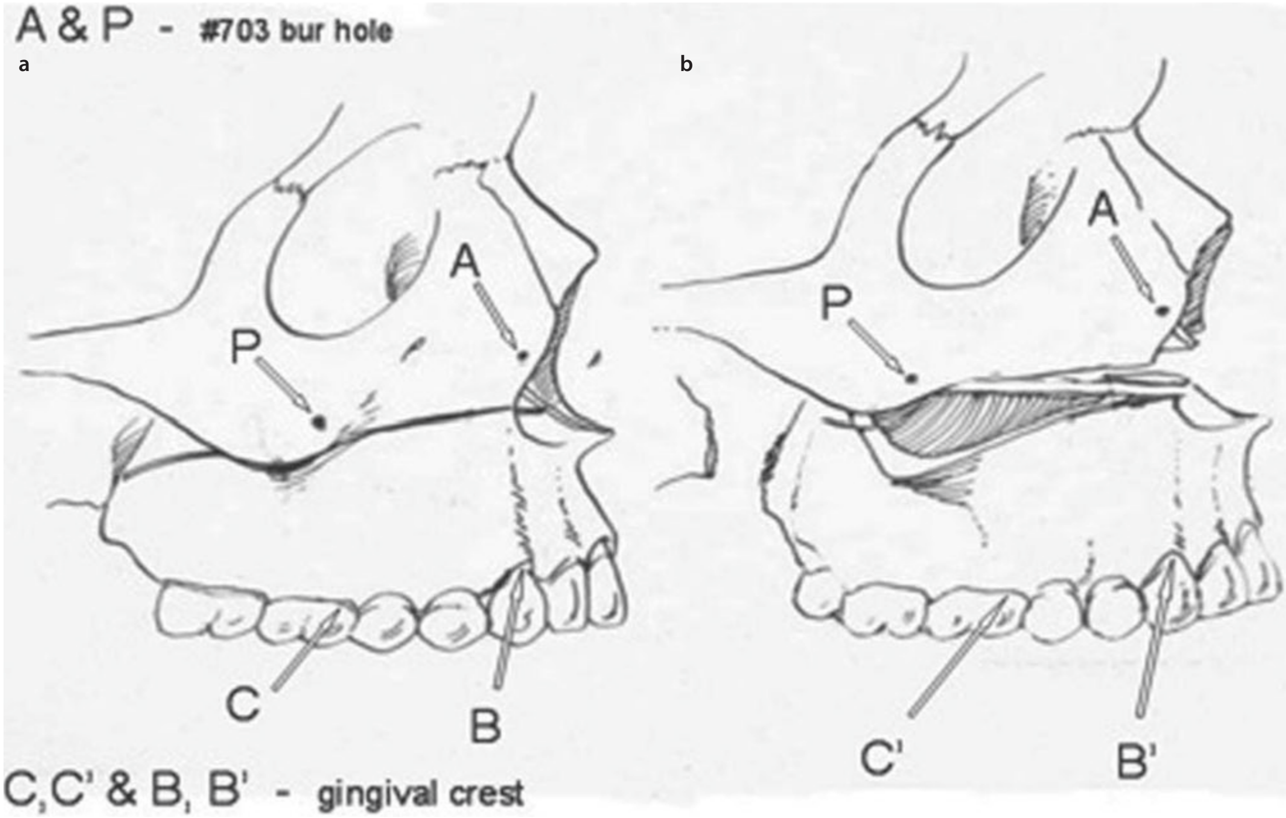

Fig. 61.23 **a**, **b** After mobilization, the maxilla is positioned so that the four *differences* measured at model surgery match those differences measured intraoperatively

change in vertical is achieved. The use of external reference points is also an accurate and predictable technique to measure and confirm maxillary position.

Key Points

- Vertical positioning of the maxilla is planned preoperatively and set intraoperatively.
- The vertical position must be measured in order to identify changes after osteotomy if not utilizing patient-specific cutting guides and plates.

61.4.2.3 Segmental Maxillary Surgery

When performing model surgery for a segmental maxillary procedure, differences begin with the obtaining of casts. It may be desirable to have more than one maxillary cast to test the planned segmentalization to determine if the surgical cast should, in fact, be sectioned in a particular manner. Periapical radiographs should be made of the interdental osteotomy sites.

Marking and measuring of the surgical cast also has some variation (Fig. 61.24). The casts are marked and measured as any other maxillary cast plus some additional markings and measurements. Vertical lines should be drawn on both sides of the planned interdental osteotomy. As segmentalization is often done on either side of the canine, some of these lines will already be present, but a line at the tooth on the opposite side of the interdental osteotomy must also be placed. Additionally, horizontal lines across the posterior of the cast between the vertical tuberosity lines and also between the vertical lines at the interdental cuts. These lines are used for points of measurement and also to aid in appreciation of any tipping of the models or vertical changes in these areas.

Transverse measurements are made with a Boley gauge at the intersection of the vertical and horizontal lines at the backside of the model, at the mesiobuccal cusps of the first molar, and at the canine. If there is an interdental cut behind the canine this measurement should be made at the premolar. Additional measurements are made at the cusps of the teeth on either side of the interdental osteotomy and at the roots (The intersection of the vertical and horizontal lines at the interdental cut). Knowing the measurement at the cusp and root of the teeth is important to ensure that the planned

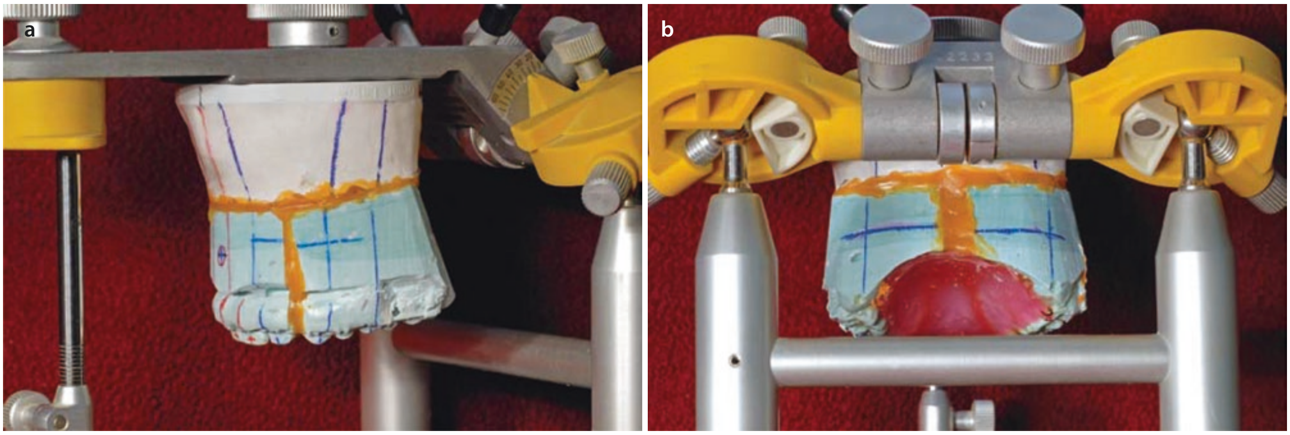

Fig. 61.24 **a**, **b** Additional markings placed on the maxillary cast for segmental surgery. Vertical lines should be drawn on both sides of the planned interdental osteotomy. As segmentalization is often done on either side of the canine, some of these lines will already be present, but a line at the tooth on the opposite side of the interdental osteotomy must also be placed. Additionally, horizontal lines across the posterior of the cast between the vertical tuberosity lines and also between the vertical lines at the interdental cuts. These lines are used for points of measurement and also to aid in appreciation of any tipping of the model of vertical changes in these areas

surgery will not impinge upon the tooth roots. Even with separation at the cusps, the roots could converge with certain tipping movements.

After all the marking and measuring are completed, the maxillary cast is sectioned in the areas of the interdental osteotomy. This is done with the thinnest diamond disk available, and in the area closest to the teeth is best done by just scoring the cast with a #15 blade and breaking this last bit of the cast along the score (after sectioning the remainder of the cast). This will prevent any removal of stone in areas of the teeth and creating an unrealistic simulation of the surgery. Once the cast is sectioned, the next step is the establishment of the maxillary arch form.

The proper maxillary arch form is the set on the mandible. Feasibility of the planned movements is determined by comparing the post-movement measurements to the pre-sectioning measurements described above. Once the maxillary arch form is set, the remainder of maxillary moves can be done in the fashion as they would be for a non-segmental surgery.

In a single jaw case, the final interocclusal splint with a trans-palatal strap (which is sufficiently relieved so as not to impinge on the palatal mucosa and blood supply) is fabricated (Fig. 61.25). Alternatively, a palatal style splint can be fabricated, without occlusal coverage and a separate interocclusal splint can be fabricated to position the remainder of the maxillary movements. In a two-jaw orthognathic case, which involves segmental maxillary surgery, the final splint must be made first in this manner. It must be trimmed and polished to completion. Since this splint will be wired into place on the maxilla and left, post-surgically, for a period of time, the intermediate splint is made as a "piggy-back" splint or a "splint within a splint." That is the upper surface will articulate with the final splint in the final maxillary position, and the lower surface will articulate to the uncut maxilla. The highly polished final maxillary splint must be adequately lubricated to prevent curing to the intermediate splint.

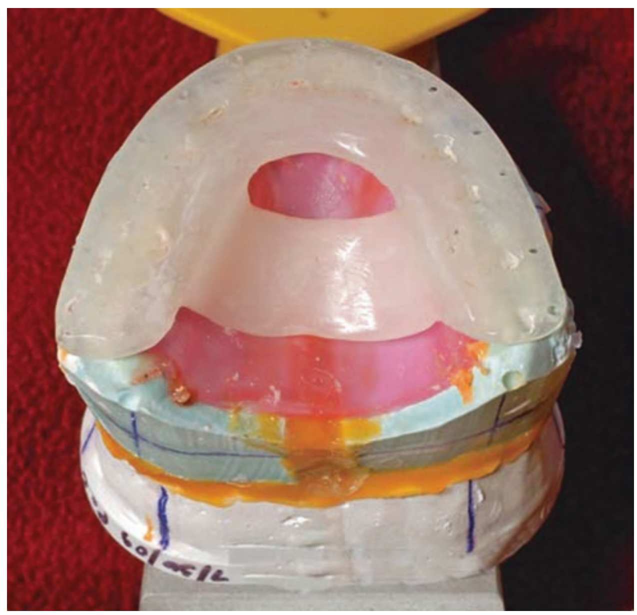

Fig. 61.25 Final interocclusal splint with a trans-palatal strap, fabricated over a layer of wax to provide relief and not impinge on the palatal mucosa and blood supply once inserted and secured. Holes are made in the flange to allow for the splint to be secured to the orthodontic brackets

61.4.2.4 Combined Maxillary and Mandibular Surgery

Examination and orthognathic workup of a patient will often reveal a skeletal deformity in both the maxilla and mandible. If the maxilla is the first jaw to be mobilized in combined surgery, the following steps are then carried out in the model surgery.

The models are articulated as per the previously described standard mounting technique utilizing a face-bow transfer and centric relation registration. The articulator's pin is not changed at all during the case. The previously described vertical and horizontal measurements are made on the casts and recorded on the models and plaster as well as on the laboratory data sheet (orthognathic roadmap).

The maxillary cast is then separated from the base. The base of the cast is trimmed sufficiently to accommodate impaction, advancement, cant correction, or rotation. The new position of the maxilla must be considered in all three planes of space. The movement is correlated to the clinical database and photos to place the maxillary midline in concordance with the facial midline. Any cant correction is achieved by correcting vertical measurements that may be unequal at first. For instance, if on clinical exam, the maxillary left canine is 2 mm lower than the right canine, this is leveled in the final position of the cast. Relating the clinical database and cephalometric prediction tracing, the maxilla is then moved in an anteroposterior dimension to the prescribed position. The vertical position of the maxilla is also prescribed by the clinical orthognathic database.

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A number of methods can be used to hold the maxillary cast in this new position while making the movements and verifying through measurements. Three small balls of white dental wax can be used during the 'move and measure' phase followed by placing yellow sticky wax in between the model and base to secure the maxilla to the base more securely in that position once the correct position is obtained. Some clinicians use dental plaster while others utilize a glue gun for the same purpose.

Caution must be exercised while making multidimensional movements to constantly reevaluate the measurements in all planes and also ensure that the heels of the cast are not kicked off in one direction that would be difficult to replicate during surgery. This is especially possible while attempting to correct the midline. As the anterior part of the cast moves to one side or another, it is easy for the heels to move in the opposite direction (sometimes in a manner that will be difficult to accommodate at the time of surgery). This can be avoided by placing the fulcrum of rotation as anterior as possible.

With the maxilla secured in its desired position, it will provide the surgeon its orientation to the unoperated mandible. Following the placement of maxilla in its new prescribed position; the mandibular cast is separated from its base, placed into the planned occlusion and a new base is created for it, preferably in a stone of a different color as opposed to the original mounting. This will be the final position of the mandible. Ideally, occlusal adjustments that are needed are performed before impressions are taken, however, if this was unanticipated these adjustments are now accomplished on the casts and marked with a red pencil in order to facilitate replication at the beginning of surgery.

A final splint is fabricated first in this position. Once that splint is complete, the mandibular model can be repositioned onto the initial base and the intermediate splint is constructed. Postsurgical measurements are then obtained and recorded on the road map for surgery.

Sequence of Bimaxillary Orthognathic Surgery

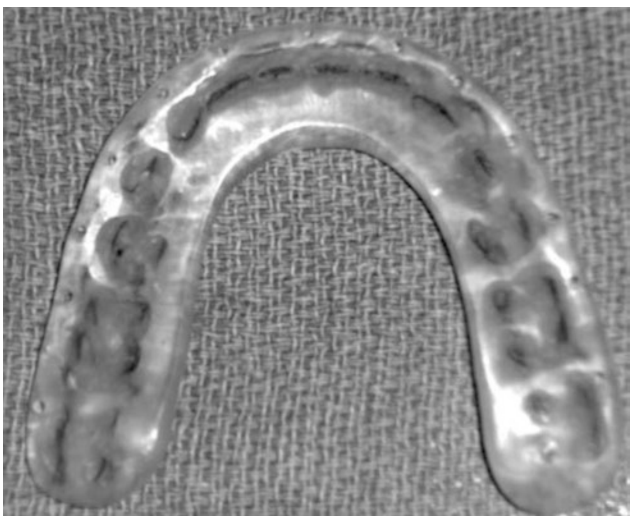
The model surgery for bimaxillary surgery will depend upon which sequence the surgeon will perform the osteotomies in the operation. The model surgery will then be performed in the same sequence to allow for correct intermediate splints to be fabricated. The majority of surgeons prefer to operate on the maxilla first, fixate it against the unoperated mandible using an intermediate splint, and then move the mandible to occlude with this new maxillary position for the final maxilla-mandibular relation. Specific situations in which this sequence may be altered and the mandible operated on first include cases in which there will be counterclockwise rotation of the maxillomandibular complex and a large (temporary intraoperative) anterior open bite created if the maxilla is moved first [5]. Other times, the mandible may be operated first purely as a matter of surgeon preference.

Splint Fabrication

Most surgical splints are made with cold cure acrylic material. An ideal splint must be thin yet strong and be devoid of interferences, air bubbles, and imperfections (▪ Fig. 61.26). Most clinicians prefer coverage of the splint to include at least the first molar tooth. However, this may allow extrusion of the second molars prior to splint removal therefore coverage of all teeth in the arch is recommended.

The steps involved in splint fabrication begin with the application of separating media on the casts. A self-cure acrylic form is created and pressed between articulated casts. It is then cured in a pressure cooker and trimmed. Marks may be made with a pencil at the regions of the cusp tip indentations to prevent excessive trimming. Once the splint has been trimmed to be sufficiently thin it is then polished and small holes are made in the flange to allow for passing wires for assisting in intraoperative maxilla-mandibular fixation.

While performing bimaxillary procedures that involve a segmental maxilla, the intermediate splint is a composite splint. This splint is constructed to fit over the final splint that remains attached to the maxilla (◘ Fig. 61.27). In segmental maxillary surgery, the final splint is often created with an additional palatal strap to prevent collapse of segments in the immediate postoperative phase. This splint is often left in place for several weeks to allow support for the segments. In cases that do not involve segmentalization, a splint fabricated from polyvinylsiloxane (PVS) may be used for both the intermediate and final splint (◘ Fig. 61.28). When segmental maxillary surgery is performed, the final splint must be a rigid acrylic or composite splint, but the intermediate "piggy-back" splint may still be PVS. A PVS splint requires much less time and material to create and offers similar results (◘ Fig. 61.29).

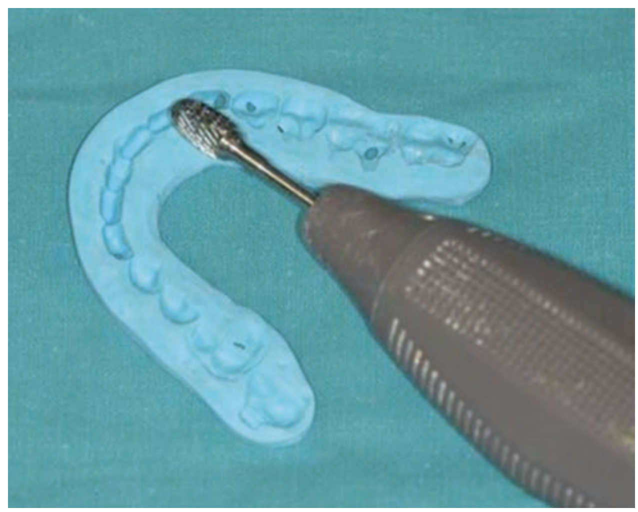


◘ **Fig. 61.26** A final occlusal splint for an orthognathic surgical procedure that does not require a segmentalized maxilla. The regions that will accommodate the incisal tips of the teeth are marked with pencil to facilitate trimming. Holes are placed between the teeth within the flange of the splint for wires to be passed

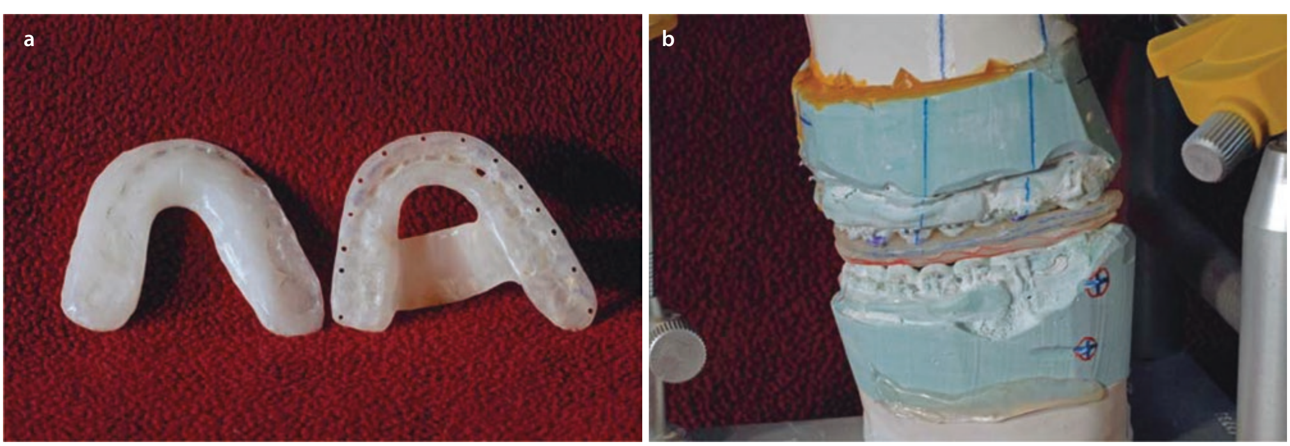
61.5 Three-Dimensional Virtual Model Surgical Simulation

61.5.1 Introduction

Traditional model surgical (TMS) planning provided oral and maxillofacial surgeons with the ability to meticulously plan and perform orthognathic surgical procedures. However, limitations and opportunities for the introduction of error through traditional model planning remain. The stone models are three-dimensional (3D) representations of the dentoalveolar structure, but cannot reflect the maxillofacial bony anatomy. Error can be introduced through an inaccurate facebow trans-



◘ **Fig. 61.27** Polyvinylsiloxane intermediate splint trimmed, final occlusal splint surface



◘ **Fig. 61.28** **a** Intermediate and final splint. **b** Intermediate splint (Red) and final splint (Blue) interdigitation on mounted casts

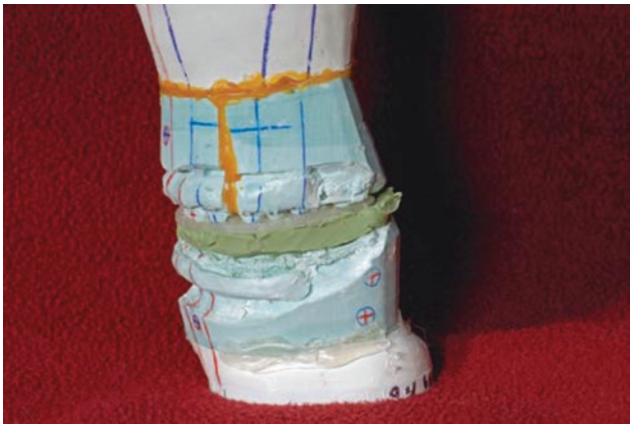


Fig. 61.29 Intermediate splint fabricated with PVS and interdigitation to the acrylic final splint for this segmental bimaxillary case

fer, bite registration, mounting, or in obtaining model measurements. The entire process, even in experienced surgeons, is time- and labor-intensive. It also involves assimilating multiple unrelated data sets (such as the cephalometric film and clinical photos), which are two-dimensional representations. The uses of a cephalometric radiograph analysis and cephalometric prediction tracings provides some level of simulation and prediction, but are extremely limited because they are two-dimensional representations.

Advances in three-dimensional (3D) medical imaging and virtual surgical simulation software for orthognathic surgery have enabled a major breakthrough and allowed unprecedented virtual diagnosis, treatment planning, and evaluation of treatment outcomes of maxillofacial deformities. Virtual simulation allows for inclusion of the bony anatomy into the treatment plan, not solely relying on the position of the teeth and allows the surgeon to be able to perform the following:

- To analyze three-dimensional anatomical discrepancies in pitch, roll, and yaw
- To analyze how occlusal movements affect surrounding bony anatomy
- To utilize simulated postoperative soft tissue and bony predictions for patient education and surgical resident teaching purposes
- To investigate multiple surgical approaches for the same patient
- To digitally create intermediate and final orthognathic splints using CAD/CAM technology
- To reduce surgeon planning time, especially for complex cases

61.5.2 History

Xia and Gateno are the first groups who have computer-aided surgical simulation (CASS) for use in the treatment planning of complex cranio-maxillofacial deformities. The first step of the CASS process is to create a composite skull model. This is accomplished with a bite jig that is used to relate the upper and lower dental casts to each other and to support a set of fiducial markers. Fiducial markers are selected points on an image that are used as a frame of reference in locating objects or in positioning (registering) images containing the same markers. After the bite jig is created, a CT of the patient's craniofacial skeleton is obtained with the patient biting on the same bite jig. Scanning the stone dental models with a laser surface scanner then creates digital dental models. The markers are then used to register (superimpose) the digital dental models on to the 3D CT skull model. The result is a computerized composite skull model with an accurate rendition of the bone and the teeth.

The second step of the CASS is to quantify the deformity with cephalometric analyses and virtual anthropometric measurements. The third step in the process is to simulate the surgery on the computer by moving the bony segments to the desired position. Using this software, the maxilla and mandible can be repositioned in all three planes of space. Hence, deformities of yaw, pitch, and roll can be accurately corrected in a virtual environment. The final step is to transfer the virtual plan to the operating room through surgical splints and templates that are created using a specialized computer-aided design and computer-aided modeling (CAD/CAM) techniques.

A number of CAD/CAM programs are currently commercially available for applications in craniofacial surgery and orthognathic surgery.

61.5.3 Sequence of Data Acquisition Prior to Computer-Assisted 3D Surgical Simulation (CASS)

1. The patient is clinically physically examined in the same fashion as one would for carrying out a traditional analytic model surgery, and the same orthognathic database measurements are obtained and analyzed.
2. With the patient in an adjusted natural head position (ANHP), photos of the patient in repose and anima-

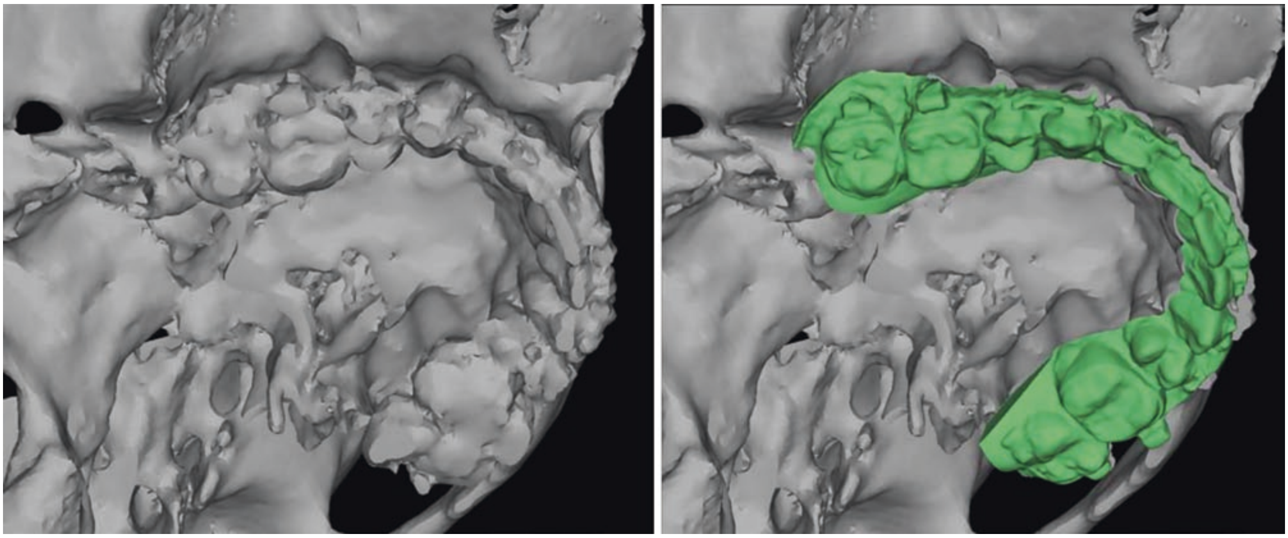


Fig. 61.30 For an accurate occlusal surface, high-resolution laser scans of the patient are obtained and integrated into the CT/CBCT scan using fiducial marker registration

tion (smiling) are acquired from the frontal, left and right profile, and left and right oblique views.

3. CT technology currently lacks the ability to capture the teeth and their occlusal surfaces with high accuracy. To produce accurate CAD/CAM splints, it is necessary to replace inaccurate occlusal surfaces from CT or CBCT scans with either a high-resolution laser scan or CT scan of the patient (Fig. 61.30). Digital intraoral scans are obtained of the maxillary and mandibular arches. If one does not have an intraoral scanner, alginate impressions may be obtained. If traditional models are acquired, they will need to be shipped to the CASS engineering company where they can scan the models (similar to how the patient would be scanned in office).[1]
4. A CBCT image of the patient biting in centric relation is obtained. Many CBCT machines offer options where strictly the maxilla or mandible, both jaws, or the entire patient's skull can be imaged. Ideally, the entire skull is captured. If the clinic does not have a CBCT machine, medical-grade CT is also an alternative option. The most important component to the imaging process is that the patient bites into CR during image capture (Fig. 61.31).

61.5.4 Computer-Assisted 3D Surgical Simulation Session

Once all data has been adequately collected, the computer-assisted 3D surgical simulation (CASS) session is scheduled between the surgeon and the BE. The software engineer then creates digital dental models by scanning the stone casts with a laser surface scanner. The digital dental casts are integrated into the digital CT skull using a best-fit model (Fig. 61.32). This software offers the possibility of planning surgical procedures in multiplanar and three-dimensional views. Therefore, segmentation, measurement, repositioning, and importing tools are incorporated. All planning steps are based on virtual segmentation procedures, which are necessary for performing repositioning. By using predefined Le Fort I and sagittal (or vertical ramus) osteotomy lines, the upper (Fig. 61.33) and lower jaws (Fig. 61.34) can be segmented and virtually moved in all three planes of space. A surgical plan is outlined and executed during a web conference with a software engineer. Oftentimes, a representative from the plating system company will also be included in the planning session to assist in making the process streamlined. The surgeon must have access to a desktop or laptop computer from which the planning can be viewed. With all parties accounted for, the session may begin. The following are a series of steps to make the CASS session most efficient:

1 The surgeon has the option of printing the digital models and setting the final occlusion if he/she chooses. If so, the models will need to be shipped to the CASS engineering company similar to traditional model acquisition. If the orthodontic set-up is ideal, or if a single-piece Lefort I is planned, the CASS BEs can set the final occlusion during the planning session under the direction of the surgeon. The CASS BEs have digitally segmented the maxilla and set the occlusion during the planning session, and we have also segmented the maxilla and shipped the maxilla and mandible in final occlusion to the BEs prior to the planning session. The same has been true for single-piece Lefort surgeries; we have had the CASS BEs set the occlusion and we have set and shipped occlusion to the BEs prior to the planning session. In both scenarios, surgical success has been achieved.

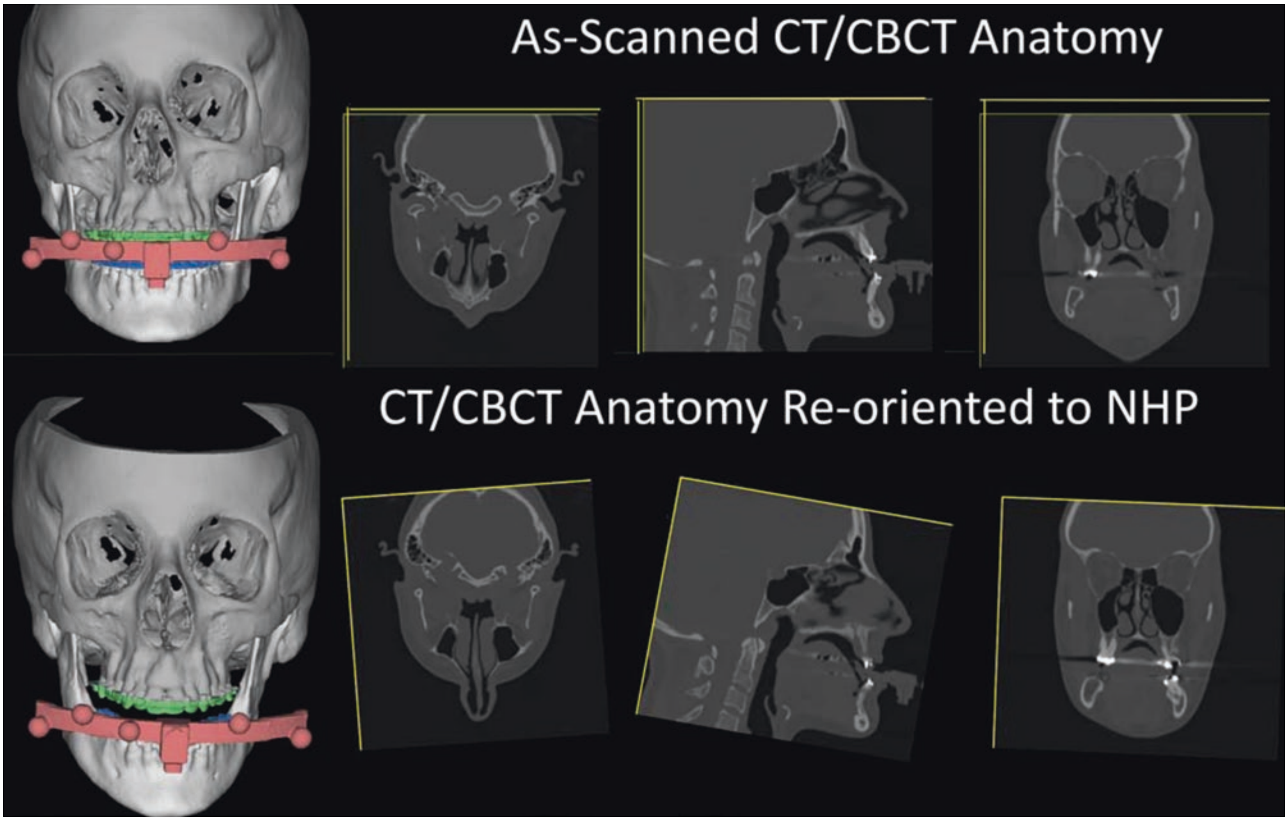


Fig. 61.31 The patient is CT/CBCT scanned in centric relation wearing a facebow device and neutral head posture (NHP) is clinically recorded by the surgeon using a gyroscope device. These orientation measurements are applied to the CT/CBCT scan to reorient the patient's digital data into the proper NHP

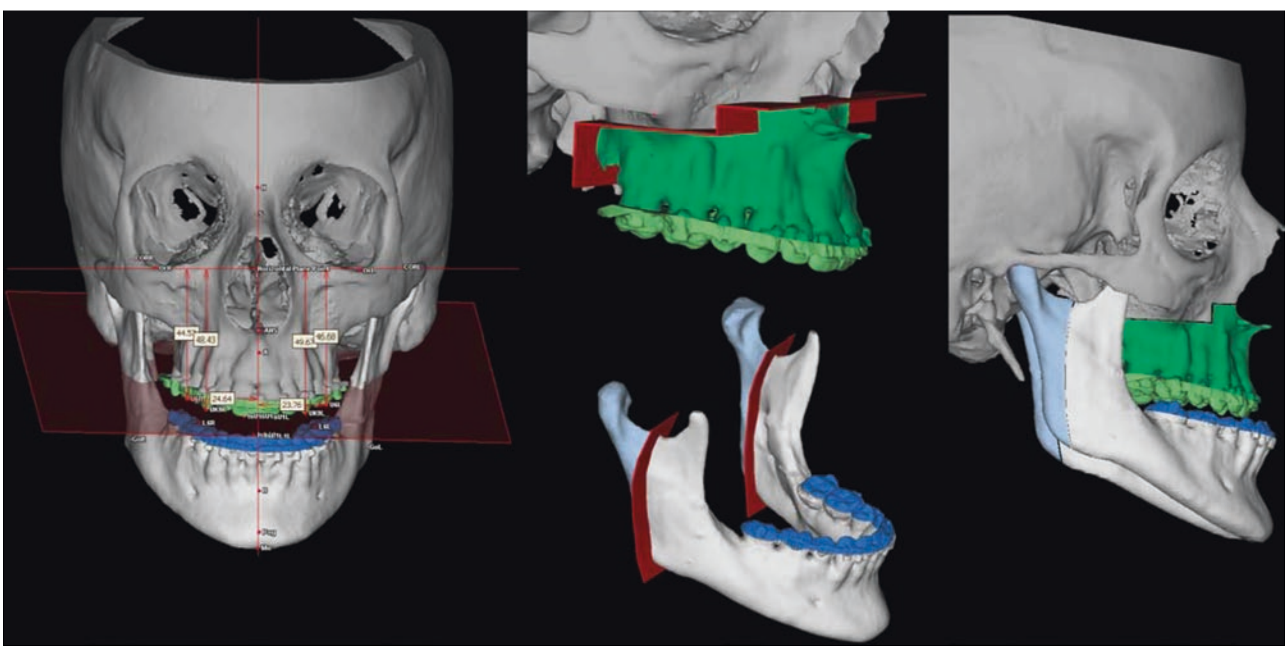
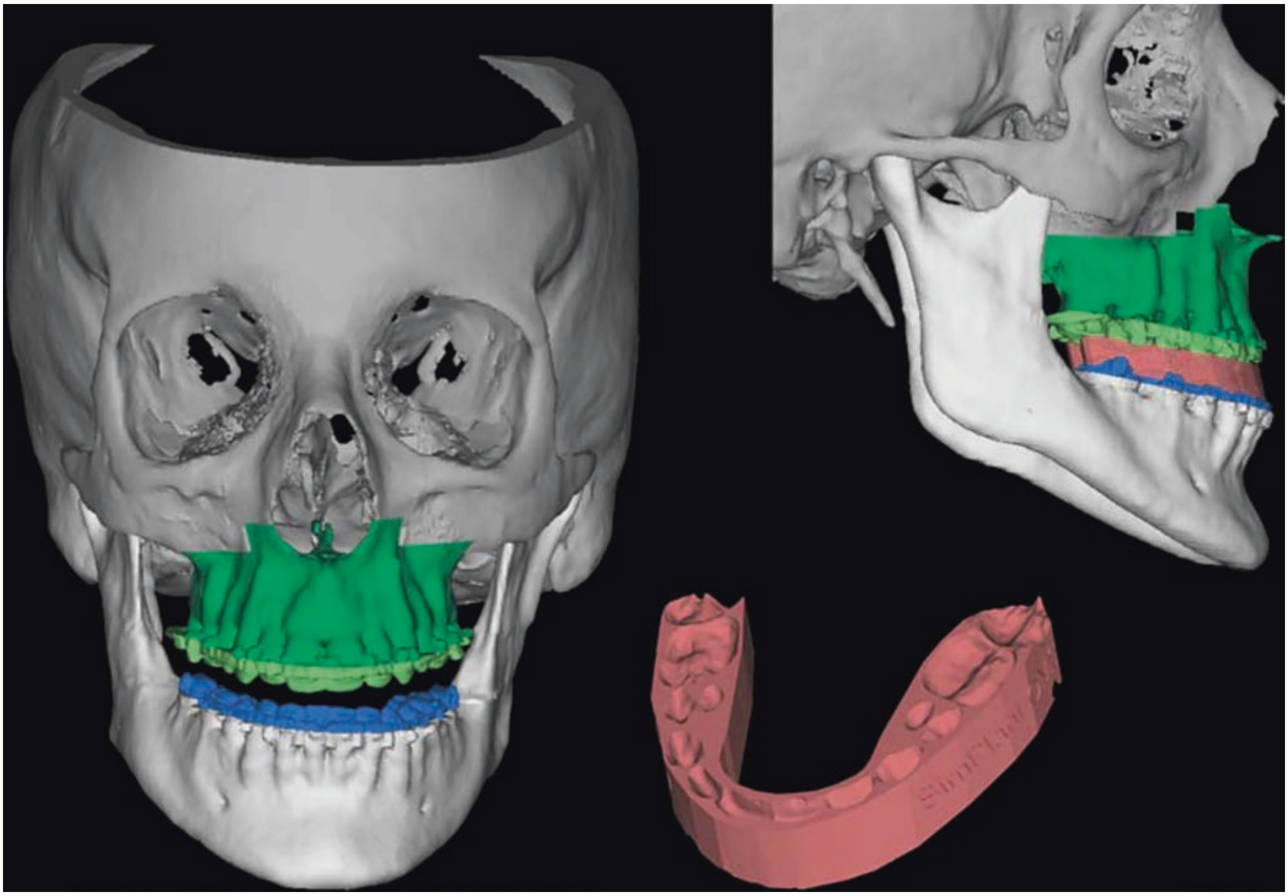
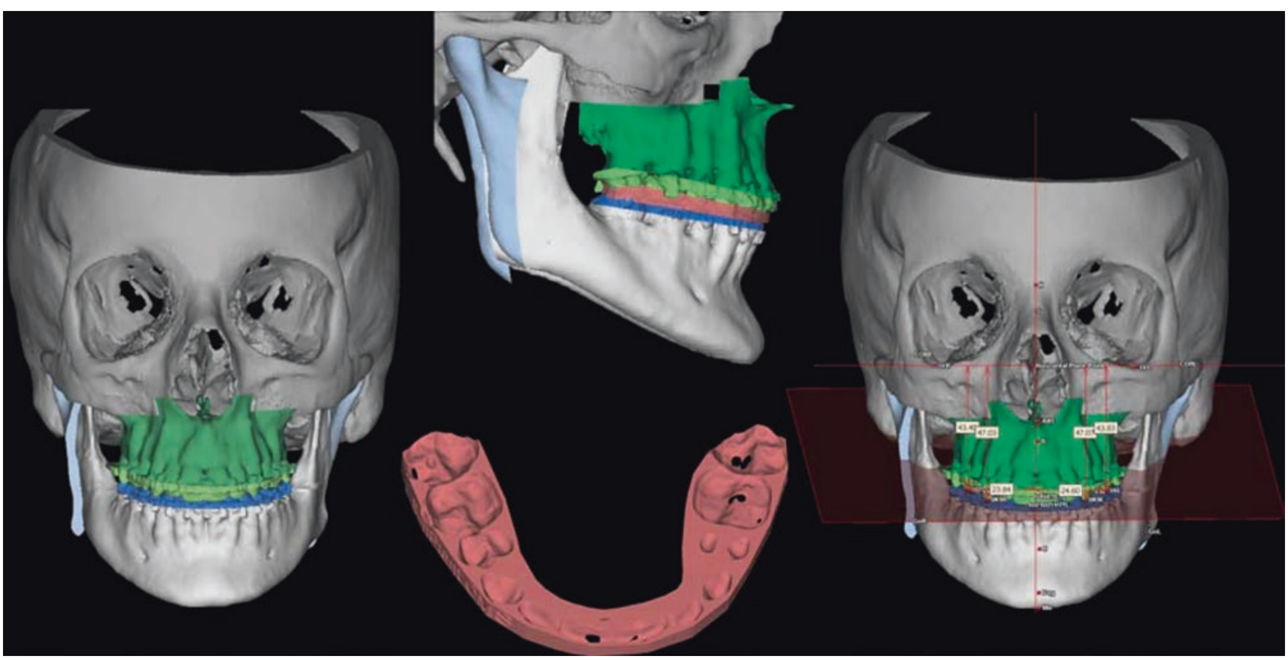


Fig. 61.32 The patient's asymmetry is quantified using digital bony landmarks and measurements to orthogonal reference planes. Digital osteotomies are performed on both the upper and lower jaws



■ **Fig. 61.33** The maxilla is moved to its final position and a CAD/CAM intermediate splint is designed from the digital plan



■ **Fig. 61.34** The mandible is moved into final occlusion and a final position CAD/CAM splint is designed from the digital plan. The simulated final position of the bony anatomy can be assessed using digital cephalometric analyses

1. Orient the 3D data for the patient's head position. We like to complete this step by having the BE position the head based upon clinical measurements and photos we recorded of the patient while in adjusted natural head position. For example, we adjust the pitch by having the BE drop a plum line from glabella; the BEs have the ability to bring the soft tissue into focus (as it is captured during CT imaging). Then from the glabella vertical line, the BE will rotate the skull in a clockwise or counterclockwise fashion until the facial of the maxillary central incisor is the same distance to glabella vertical on the computer, as recorded clinically. This can also be accomplished utilizing the preoperative gyroscope Euler angle readings (Fig. 61.31).
2. Orientation (cont.). Correct the roll orientation of the skull. One can complete this step by asking the BE to adjust the head until the heights of the maxillary canines are the same as we noted clinically. For example, if clinically the left maxillary canine is 2 mm down in comparison to the right maxillary canine (as would be consistent with a downward cant in the left maxilla), we ask the BE to "roll" the skull until there is a vertical discrepancy of 2 mm down on the left canine in comparison to the right.
3. Orientation (cont.). Set the facial midline orientation. Again, this is completed based upon the clinical findings. If the maxillary midline is 3 mm right, the BE can move the maxilla 3 mm in the yaw orientation to replicate the patient's preoperative position. A bodily movement is also possible. The clinical findings dictate the virtual changes.
4. The maxillary and mandibular osteotomies are performed and movements are made with the patient's composite CT scan in the previously defined NHP. Deformities of yaw, pitch, and roll can be virtually corrected and accurately assessed using precise angular and linear digital measurements. Any inaccuracies in the virtual plan can then be corrected based on the virtual image analysis.
5. The maxilla is repositioned to the new position. The move may be confirmed by having the BE measure the horizontal and vertical changes at the incisor tip from the original position to the new position. At this time, the occlusal plane angle may also be adjusted. The BE will have an existing plan angle based upon the difference in heights from the maxillary central incisor to the cusp tip of the first maxillary molar. The degree of inclination can be rotated based upon the surgeon's preference. We generally aim for a 7–8° inclination as it allows for easier 2nd molar clearance when the patient bites into maximum interception.
6. Once the maxilla has been positioned, the mandible is moved to fit the maxilla. If the surgeon has submitted casts with the final occlusion to the CASS engineering company, the BE will set the mandible to the maxilla, and the occlusion will match the submitted models. However, if the occlusion is going to be set virtually, the BE will set the digital models in a best-fit position virtually. Regardless of the decision, once the occlusion is set, the BE will be able to assess the occlusion virtually, and will notify the surgeon if any occlusal adjustment is necessary. As an aside, once the final CASS plan is mailed from the engineering company to the surgeon, a map with occlusal adjustment needs will also be present.
7. A decision must be relayed to the BE regarding which jaw will be operated on first in bimaxillary surgery to ensure that the appropriate intermediate splints are fabricated.
8. If a genioplasty is warranted, it will be cut and positioned after the maxilla and mandible are in their final position. Another advantage to CASS, unlike traditional model surgery, is that a cutting guide can be fabricated to guide the genioplasty osteotomy.
9. Once all skeletal movements are complete the BE will fabricate intermediate and final splints. The option for custom plates and additional cutting guides is also discussed. But if the surgeon voices no further needs, this will complete the CASS planning session.

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61.6 Other Virtual Surgery Customizations

61.6.1 Custom Plates and Cutting Guides

Over the past decade, the development of 3D printed models and patient-specific guides has improved surgical planning. 3D technology has also improved the precision with the transfer of the surgical plan to the execution of the procedure in the operating room. There is evidence that more consistent surgical results can be obtained from the implementation of 3D technology. An additional benefit of CASS is the opportunity for a custom cutting guide and custom plate fabrication. Traditionally, during Lefort I osteotomy the surgeon has to freehand the osteotomy along the anterior maxilla, envisioning the anticipated position of the hardware for fixation. As the osteotomy is completed the surgeon constantly thinks about cutting high enough that root tips are not be injured, but also low enough so that the soft tissue dissection is not excessive. With custom cutting guides, the guesswork is eliminated. During the CASS planning session, all vital structures are identified and the cut is planned away from those structures. In addition to the planned osteotomy, predicted holes and custom plates can be planned. The added benefit to this is that now the new position of the maxilla can be moved precisely to its planned position, and the custom plates will automatically place the maxilla is in the correct position three-dimensionally. Many surgeons currently using custom cutting guides and custom fabricated plates are able to position the maxilla without intermittent periods of intermaxillary fixation (IMF), as the plates have removed all guesswork from the surgery. They save time in the operating room, and as a result of time saved operating room costs are lowered as well. Furthermore, in some of the more challenging craniomaxillofacial patients with minimal bone and minimal space for the osteotomy, custom cutting guides are ideal. The guides can provide precision and efficiency while performing the osteotomy that cannot be duplicated freehand. Simply put, custom cutting guides enable the surgeon to determine the optimal orientation of osteotomy cuts and better predict the skeletal maxilla/mandible relationship following surgery [6].

61.6.2 Limitations of CASS

With the advent of new technology, there are often frustrations associated with the learning curve, the process of implementing new protocols to match the change in workflow, and the physical transition from using the old technology to using the new technology. Virtual surgical planning has improved surgical efficiency and precision. However, a limitation to this technology is that production of 3D surgical models and/or splints requires a third-party source, leading to increased preoperative costs to the surgeon and/or patient. There is also a prolonged assembly time (on average 2–3 weeks) for splint fabrication and shipping [7]. Another limitation is that CASS does not provide the opportunity to study the mounted casts, nor does it allow for articulated models to be present in the operating room. Many surgeons who were trained on model surgery prefer to have articulated models present in the OR, and for several justifiable reasons. Those who subscribe to using CASS forego this opportunity.

Another limitation of CASS is that if the surgeon using CASS opts to forego printing the digitally scanned models, there is no opportunity for hand articulation, or coupling of the arches preoperatively. A significant amount of information may be gained from hand articulation. Assessing the decompensation of the dentition, placing the models together to assess for the ideal position of the anticipated maximum inter-cuspation, assessing whether or not there is an inter-arch discrepancy and need for segmentation of the maxilla, are just a few of the pieces of information once can find while hand articulating. If, while using CASS the surgeon solely sends the non-articulated scans to the BE, such an information-gathering opportunity is lost.

CASS is paramount to modern orthognathic surgery. The complex movement of the maxilla, mandible, and chin, and the precision with which these moves must be completed is greatly enhanced with CASS. Software innovations have streamlined the treatment planning process.

Conclusion

Traditional model surgery was one of the first forms of preoperative surgical simulation. For decades, it has allowed meticulous planning of the majority of the movements made during orthognathic surgery. Traditional model surgery allowed this planning to occur in a preoperative, low-stakes setting, with the ability to try different movements in search of the best combination, without risk to the patient. It also eliminated the majority of decisions from being made intraoperatively, where perception can be skewed by patient positioning, edema, and anesthesia equipment (such as a nasoendotracheal tube). Little has changed, in many years, with the positioning of mandibular and maxillary osteotomies themselves in orthognathic surgery, yet major advances have been made over the last two decades related to the planning of these osteotomies. Planning has gone from three-dimensional planning (traditional model surgery), which was still based much on two-dimensional input and information (cephalometrics, photographs) to true three-dimensional planning using computer-aided surgical simulation with three-dimensional information based on CT/CBCT data. This transition has helped increase the precision and accuracy of the presurgical simulation. This increased accuracy and has also led to greater ability to detect and correct certain discrepancies, such as yaw. These planning processes and the CAD/CAM process of splint fabrication have also improved the quality of life of the orthognathic surgeon, by significantly decreasing the time required to plan and prepare for these cases.

The natural evolution of the CAD/CAM technology has led to the development of patient-specific surgical cutting guides and patient-specific fixation which will continue to further enhance our ability to provide state-of-the-art, precise, and accurate orthognathic surgery with excellent results.

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