Maxillary Orthognathic Surgery

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History
Orthognathic surgery of the maxilla was first described in 1859 by von Langenbeck for the removal of nasopharyngeal polyps. The first American report of a maxillary osteotomy was by Cheever in 1867 for the treatment of complete nasal obstruction secondary to recurrent epistaxis for which a right hemimaxillary down-fracture was used. Over the next 70 years numerous authors described osteotomy techniques that mobilized the entire maxilla for the treatment of pathologic processes.

In 1901 Le Fort published his classic description of the natural planes of maxillary fracture. In 1927 Wassmund first described the Le Fort I osteotomy for the correction of midface deformities. However, total mobilization of the maxilla with immediate repositioning was not performed until 1934 by Ashhausen. Separation of the pterygomaxillary junction was advocated by Schuchardt in 1942. Moore and Ward in 1949 recommended horizontal transection of the pterygoid plates for advancement. Willmar reported on over 40 cases treated this way and of severe bleeding in most, thereby abandoning this procedure in favor of separation at the pterygomaxillary junction. Most of these techniques simply mobilized the maxilla to one degree or another, and then placed orthopedic forces on it to achieve the desired repositioning—a sort of unintentional distraction osteogenesis. These methods were associated with high levels of relapse.

In 1965 Obwegeser suggested complete mobilization of the maxilla so that repositioning could be accomplished without tension. This proved to be a major advance in stabilization, as documented by Hegemann and Willmar. de Haller, and Perko, respectively.

Anterior segmentalization of the maxilla was also addressed in the early descriptions, including those by Wassmund, by Cohn-Stock, and by Spanier. Again, complete mobilization of the maxilla with vascular compromise was avoided, and multiple segments contributed to poor stability. Cupar, Kole, and Wanderer, respectively, reported more direct surgical access to these procedures with improved mobilization and maintenance of blood supply. Posterior segmentalization of the maxilla was used by Schuchardt but it had limited stability also owing to incomplete mobilization. Kuiper improved on this technique by completely mobilizing the osteotomized segment prior to repositioning. Logically, anterior and posterior segmental osteotomies were combined to accomplish total maxillary alveolar osteotomy for repositioning and segmental manipulation simultaneously.

Sever al forms of total maxillary osteotomies were described by Cupar, Converse and Shapiro, and Kole, respectively. Willmar further established the stability of the Le Fort I osteotomy, and Bell and colleagues documented the overall superiority of the total down-fracture Le Fort I osteotomy for segmental and one-piece maxillary osteotomy. Bone grafting to enhance stabilization was advocated by Cupar, Gillies and Rowe, and Obwegeser, respectively, who first advocated grafting in the pterygomaxillary fissure. Interestingly, Willmar did not find a difference in stability with and without bone grafting in nonlefted cases.

Early descriptions of the rigid fixation of maxillary osteotomies were published by Michelet and colleagues in 1973, Horster in 1980, Drommer and Lahr in 1981, and Layk and Ward-Booth in 1985. Since that time, many methods have been advocated for the rigid fixation of maxillary osteotomies. These have included bone plates, metallic mesh, pins, the rigid adjustable pin (RAP) system, and resorbable fixation. Since these landmark papers, volumes have been written regarding a wide variety of technical factors, many of which reflect operator preference.

Basic Principles
Maxillary deformities may manifest in any of the three planes of space: sagittal, axial, and coronal. Patients displaying abnormal
facial anatomy often exhibit elements of maxillary and mandibular deformities. Therefore, the clinician must recognize and be prepared to treat maxillary and midface deformities. Subjectively, patients with maxillary deformities often describe their problem in terms of the relative mandibular appearance. Patient expectations clearly demonstrate the importance of the chin in patient satisfaction. This perceptual preoccupation with apparent mandibular excess or deficiency in the absence of a significant absolute mandibular abnormality may necessitate extensive consultation and guidance from the surgeon to assist the patient in recognition of the contribution made by the midface and maxilla to overall facial appearance. Similarly, the patient may relate the importance of nasal prominence or deficiency in describing his or her chief complaint.

Scrutiny of physical characteristics, model surgery, and cephalometric analysis with prediction tracings will assist in obtaining a satisfactory treatment plan. These important diagnostic and treatment planning modalities are discussed extensively elsewhere in the text; however, model surgery is the most valuable tool in preparing for orthognathic correction of skeletal facial deformities. While model surgery is essential for immediate preoperative surgical simulation and splint construction, it may be even more important in early treatment planning. Prior to any orthodontic or surgical treatment, model surgery is the best method to determine the postoperative position of the mandible as well as the maxilla. No cephalometric prediction (computer generated or hand drawn) or photographic manipulation can reveal all of the three-dimensional and occlusal information gleaned from accurate model surgery. In the pretreatment state the teeth may not fit together perfectly during this preliminary model surgery, but orthodontics can be simulated to permit an accurate projection of specific movements required of the maxilla and mandible to achieve the desired results. The model measurements made at the time of this exercise should be exactly the same as those used for the actual preoperative model surgery (see below). Pretreatment model surgery is essential when contemplating maxillary surgery alone and very useful when planning two-jaw surgery. Pretreatment model surgery permits the three-dimensional evaluation of the maxilla and the mandible, whether the mandible is autorotated without surgery or osteotomized.

**Model Surgery, Reference Marks, and Intraoperative Positioning**

The purposes of preoperative model surgery are to (1) mark the models to facilitate three-dimensional measurement of the pre- and postoperative positioning; (2) place the jaw models into the desired positions based on all of the database including three-dimensional clinical assessment (the most important), radiographic analysis, model studies and patient desires; (3) evaluate the feasibility of the planned surgical moves using the measurements and make necessary adjustments; (4) determine the vertical change that will be achieved at the time of surgery in such a way that it can be accurately duplicated intraoperatively; and (5) construct the surgical splint(s).

The following method has been used successfully for over 20 years by the senior author (RAB). The technique is based on three simple principles:

1. A measurement is made from a point above the osteotomy to a point below it at model surgery and intraoperatively. After the maxilla is moved the same superior point is used but the point on the maxilla has been moved along a predetermined plane. This creates a triangle defined by one superior point and two inferior points (pre- and postoperatively). This triangle can be measured accurately on models and on the patient at surgery.
2. Central incisor vertical measurements can be made directly on the models.
3. If the measurements made on the models and at surgery have the same pre- and postoperative differences, the incisor vertical will be correct.

Centric relation mounted models are marked to record all possible surgical movements anteriorly and posteriorly (Figure 57-1). For the purpose of illustration Figure 57-1A and B demonstrate the measurements that are necessary for intraoperative control of the vertical position of the maxilla. The vertical measurements at the maxillary canines and first molars are the critical ones for use intraoperatively (see Figure 57-1C). The bilateral vertical measurements must be made from stable points on the top of the mounting ring, not just anywhere along the mounting ring (points A and F) to cusp tips. Gingival cuffs will be used intraoperatively (Figure 57-2) on the canines (point B) and first molars (point C). The maxillary model is then moved to the desired position, including vertical. The measurement of the vertical position of the incisor is made by placing the Boley gauge flat on the top of the mounting ring (parallel to the Frankfort horizontal) to the tip of the incisor (see Figure 57-1D). This vertical measurement of the maxillary central incisor is constantly controlled while the maxilla is positioned in all other planes of space (see Figure 57-2A). After the maxillary model has been fixed in the proper position, an imaginary triangle is created by points A, B, and B' and by points P, C, and C'. The lines A-B and P-C are the preoperative vertical values and the lines A-B' and P-C' are the hypotenuses of the triangles and the postoperative vertical values (see Figure 57-2B). The differences between lines A-B and A-B' and lines P-C and P-C' are the important values. The absolute numbers are not.
Intraoperatively marks are made above the proposed osteotomy sites in the piriform rims and the first molar/buttress areas (points A and P) (see Figure 57-2C). Measurements are made from point A to the gingival cuff of the canine (point B) and from point P to the first molar (point C). The gingival cuffs are used because the cusps will be hidden under the splint and the brackets may come loose during surgery. During maxillary positioning, lines A–B' and P–C' can be measured until the difference between lines A–B and A–B' and lines P–C and P–C' are as predicted by the models (see Figures 57-2D and E). When this is accomplished the anterior vertical changes of the central incisors will be as they were on the models, so that no direct measurement of incisors is necessary. Usually the maxilla is repositioned anteroposteriorly and sometimes mediolaterally as it is moving vertically. This method of measurement is especially important when large anteroposterior or mediolateral moves are included.

Our experience and that of others has shown that external reference marks add nothing to the accuracy of vertical maxillary positioning if the internal reference method is as outlined above. 56, 57

Surgical Anatomy

Osseous Structures

The body of the maxilla contains the maxillary sinus in its entirety, except rarely when the apex extends into the zygomatic bone. 39 The anterior surface of the maxilla is the anterolateral wall of the sinus. The infraorbital foramen is located at variable distances below the inferior orbital rim. Continuing inferiorly is the
canine fossa lateral to the canine tooth. The anterior alveolar process of each maxilla surrounds the piriform aperture, and they unite in the midline to form the anterior nasal spine. This bony spine is the most anterior and inferior attachment for the mobile anterior cartilaginous nasal septum. An elevated sharp crest at the junction of the anterior and nasal surfaces of the maxilla, which forms the nasal floor, inclines this structure superiority at the aperture. The body of the maxilla and its frontal process form the superolateral boundary of the piriform aperture as a thin edge of bone (Figure 57-3).

In the midline the nasal crest of the maxilla articulates with the septal or quadrangular cartilage and vomer. The septal cartilage rests in a central groove, which extends posterior to the anterior nasal spine. This articulation is flexible but strengthened by the perichondrium-periosteum continuity and interposed connective tissue. In the midline at the junction of the maxilla and the premaxilla is the incisive fossa, which typically presents the openings of four canals through which the nasopalatine arteries and nerves are conducted.

The palate is formed by the palatine process of the two maxillae and the horizontal lamina of the palatine bones. The transverse suture between the maxilla and palatine bones lies roughly 1 cm anterior to the posterior margin of the hard palate. At its lateral extent the suture widens into the greater palatine foramen, which is approximately 1 cm posteromedial to the second molar (Figure 57-4).
The greater palatine canal is formed similarly between the perpendicular laminae of the palatine and maxillary bones, which form the inferior lateral nasal wall. The inferior nasal concha also articulates with the maxillary and palatine components of the lateral nasal wall.

Posterolaterally the maxillary tuberosity is behind the third molar. Above this tuberosity the posterior superior alveolar foramina may be observed through which the nerves and vessels emerge. The pyramidal process of the palatine bone unites the two pterygoid plates of the sphenoid bone with each other and to the maxilla. The pterygomaxillary junction, formed by the palatine bone, ends superiorly in the pterygomaxillary fissure leading into the pterygopalatine fossa. The foramen rotundum enters the posterior wall of the pterygopalatine fossa and the pterygoid or vidian canal. Medially the sphenopalatine foramen leads to the lateral nasal cavity posterior to the middle nasal concha of the ethmoid bone. Anteriorly the infraorbital and zygomatic nerves and infraorbital vessels run in the infraorbital canal, and inferiorly the descending palatine artery and greater palatine nerves course within the greater palatine canal.

**Vascular Structures**

Although numerous texts describe the anatomy of the intact maxilla, several aspects of maxillary blood flow remain in doubt following maxillary osteotomy.

The Le Fort I maxillary osteotomy had been performed for over 100 years before Bell first identified the exact nature of blood vessels in the osteotomized maxilla, which provided information regarding the viability to the pedicled maxilla. It was obvious that even though the direct blood supply to the maxillary teeth and periodontium was interrupted, collateral circulation existed to perfuse the dental pulp and surrounding structures (Figures 57-5 and 57-6). This same circulation was also responsible for the survival of the rest of the maxilla; however, the exact nature of the various factors affecting maxillary perfusion is still not well documented or understood. Bell's studies revealed that saving the descending palatine arteries made little difference, indicating that a collateral vasculature existed, probably from the soft palate, which was adequate for maxillary perfusion. The down-fractured maxilla has a rich blood supply via the ascending pharyngeal artery and the ascending palatine branch of the facial artery.

Bell also verified the revascularization of anterior maxillary osteotomies using the microangiographic technique. Brusati and Bottoli performed revascularization studies similar to those of Bell and found quite different results. They found the tunneling technique to be superior in maintaining the blood supply, especially to the pulpal tissues, when compared with the labial pedicled anterior maxillary procedures. This was just the opposite from the findings of Bell. A possible explanation for this discrepancy is that Bell used monkeys whereas Brusati and Bottoli used dogs, which they claimed possess a more similar maxillary vasculature to that of the human. The clinical significance of these differences is not clear to this day.

Revascularization does not necessarily represent blood flow, and therefore Nelson and colleagues used a radioactive microsphere technique to evaluate maxillary blood flow. Unfortunately several variables were present in this study that made interpretation difficult. In none of the above-mentioned studies were the maxillae moved to a new position, which may represent the largest insult to the blood supply at the time of actual maxillary osteotomy. Additionally, in Nelson's study, severance of the descending palatine vessels was inadvertent and no ligation was performed. This allowed bleeding to occur through the lacerated vessels and prevented a pressure head...
from developing to maintain distal flow to the anterior maxilla. Also there were large differences in the preoperative microsphere values between animals such that postoperative comparisons were impossible. In other studies involving anterior maxillary osteotomies, Nelson and colleagues found no significant differences among three different techniques that were similar to the ones described by Brusati and Bottoli, plus a third procedure using only a palatal pedicle. Although no statistical difference was seen, the palatal flap seemed to be slightly superior to the others. Again the same problems existed with this study as before, rendering conclusions impossible.

**Soft Tissue Envelope of the Maxilla**

The midfacial superficial fascia or subcutaneous tissue contains a variable amount of adipose tissue with the muscles of facial expression in its deep layer. This is tightly bound to bone except adjacent to the buccal fat pad and in the lower eyelids. Hollinshead divided the mimetic or facial muscles into five chief groups concerning the mouth, nose, orbit, ear, and scalp. Of concern to the present discussion are the muscles of the mouth and nose, which are innervated at their posterior inferior aspect by the facial nerve. They insert into the skin and most arise from periosteum of the facial skeleton.

The upper oral group of muscles radiates from their insertions near the corner of the labial commissure. From a horizontal to vertical orientation and inferior to superior the risorius, zygomaticus major and minor, and the levators (levator labii superioris alaeque nasi) insert and blend with the skin and orbicularis oris. The risorius does not arise from bone but originates from the superficial fascia over the parotid gland. The risorius, zygomaticus major, and zygomaticus minor elevate and retract the corner of the mouth and upper lip laterally. The superficial levator muscles and a third deeper one, the levator anguli oris, elevate the lateral upper lip. In addition the levator labii superioris alaeque nasi attaches to the skin and greater alar cartilage of the nose, thus lifting the ala and widening the nares.

The orbicularis oris is composed of many multidirectional fiber groups that blend with other surrounding facial muscles, encircle the mouth, originate from periosteum covering the roots of the canine teeth, insert laterally at the corner of the mouth, and pass at right angles to the encircling sphincter fillers connecting skin to labial mucosa. This diverse muscle draws the lips together, purses the lips, presses the lips against the teeth, and pulls the corners of the lips inward.

The buccinator arises from the mandible and maxilla and the pterygomandibular raphe, by which it is separated from the superior pharyngeal constrictor. The fibers pass forward and slightly inferiorly to blend with the orbicularis oris and attach to the mucosa and skin of the labial region. The buccinator flattens the cheek against the teeth.

Both Litthauer and Nairn place emphasis on the modiolus, which is the point at the lateral aspect and just superior to the corner of the mouth where muscles of the oral group of the mimetic muscles converge. The orbicularis oris and buccinator joined at the modiolus form a continuous muscular sheet on either side of the midline. The zygomaticus major, levator anguli oris, and depressor anguli oris (as a group referred to as “modiolar stays”) immobilize the modiolus in any position. Additionally the marginal and peripheral parts of the orbicularis oris muscle are distinguished. The peripheral aspect of the muscle lies parallel with the inner labial mucosal surface, and the marginal part curls outward following the vermilion surface. As tension is expressed in the orbicularis oris, the marginal aspect of the muscle is thought to straighten and decrease vermilion exposure, thereby pulling the upper and lower lips toward each other and against the dentition.

The nasal group of facial muscles dilates and compresses the nares. The nasalis arises from the maxilla lateral and inferior to the ala. The transverse portion unites with the contralateral muscle over the dorsum of the nose. The alar part inserts into the greater alar cartilage. Thus, the two parts compress and dilate the nasal apertures respectively. The depressor septi muscle lies beneath the orbicularis oris and attaches to the base of the columella and posterior ala. Its action narrows the nares. The posterior and anterior dilator muscles are intrinsic muscles of the nose that course from the alar cartilages to the margin of the pads. The nasal mucoperiosteum is firmly fixed to the elevated periform rim above the floor of the nose, to the lateral margin of the nasal aperture and the anterior nasal spine. The premaxillary wings that flare laterally from the anterior midline nasal crest provide an irregular attachment of the mucoperiosteum along the inferolateral nasal floor.

The palate is covered by mucosa firmly adherent to the periosteum and containing mucous minor salivary glands. The mucosa is thin in the central palate and
thickens toward the alveolar process. The palate is a transverse elevation at the posterior border of the horizontal plate of the palatine bone that gives attachment to the tensor veli palatini muscle. The larger lateral pterygoid plate is the origin of the inferior head of the lateral and the medial pterygoid muscles. A small part of the medial pterygoid also arises from the maxillary tuberosity. The tensor veli palatini muscle curves around the hamulus, which is the inferior end of the medial pterygoid plate. From the hamulus the tensor muscle of the palate enters the soft palatal tissues. The tensor aponeurosis is an adherent connec
tive tissue sheath continuous with the periosteum, which covers the posterior hard palate attaching laterally to the submucosal layer of the pharynx and the ten
sor veli palatini tendon.

**Surgical Techniques**

**Soft Tissue Incision and Surgical Exposure of the Maxilla**

Exposure of the anterior, lateral, and pterygomaxillary regions is most commonly achieved by incising horizontally through the buccolabial mucoperiosteum above the attached gingival margin at the level of the maxillary teeth apices (Figure 57-7A). The vestibular incision courses from the first molar to the contralateral first molar (Figure 57-7B). The parotid papilla is identified and retracted supero-
laterally during completion of the incision posteriorly. The incision can be made with electrocautery or steel as there have been no studies performed that show a difference between the two. After initial penetration of the mucosa the natural tendency to cut more superiorly with deeper penetration must be avoided. This is particu-
larly important in the incisor area, as this would carry one into the nasal cavity.

The superior tissues are reflected subperiosteally, first at the piriiform aperture margins (Figure 57-7C). Progressively more superior exposure lateral to the nasal aperture will expose the infraorbital nerve exiting from its foramen. Posterior reflection proceeding from the delineated infraorbital foramen reveals the zygomatico-
maxillary suture, zygomatic buttress, and the most anterior aspect of the zygomatic arch. Inferiorly, with subperiosteal tunneling, the lateral aspect of the maxillary tuberosity and its junction with palatine bone and pterygoid plates of the sphenoid bone are identified. Care should be taken to direct this subperiosteal dissection inferi-
orly, toward the maxillary junction, as it is carried back toward the pterygo-
maxillary fissure, to avoid vascular structures. Meticulous maintenance of the subperiosteal plane of dissection will prevent troublesome exposure of buccal fat pad tissue, which impairs visualization and retraction of soft tissue during subsequent osteocraphic surgery. A retractor with a curvilinear end is placed in the pterygomaxillary junction to facilitate exposure. Attention should be paid to the placement of this retractor, as it too can be responsible for periosteal rents and exposure of the buccal fat.

**Tissues inferior to the horizontal incision are elevated minimally. In areas of interdental ostotomies for segmentalization of the maxillary arch the inferior attached gingiva and periosteum are elevated conservatively, with a Woodson elevator, while retraction laterally is provided by skin hooks (Figure 57-8A). Since the alveolar osteotomy will be accomplished with thin osteotomes, osseous exposure requirements at the alveolar crest level are minimal.**

When intersegmental movement will be great and may result in tearing of the gingival papilla, an alternative approach to the interdental region may be used. Additionally a wider exposure of alveolar bone is frequently needed when an osteotomy is to be performed in an edentulous or extraction space. In these situations a vertical mucosal incision at the line angle, one-tooth distant from the osteotomy site (Figure 57-8B), will facilitate wider exposure for osseous procedures. This incision should be used only when an anterior labial pedicle is maintained to maximize the labial vascular pedicle during multise-
gmental ostectomy.
For one-, two-, and most routine three-piece maxillary osteotomies, a circumvestibular incision with minimal interdental exposure is preferred. For three-piece maxillary osteotomies that involve exceptionally wide expansion or extreme changes at the interdental site, four-piece maxillary osteotomies, and osteotomies in some cleft patients, soft tissue incisions can be modified from second molar to first premolar to maintain an anterior labial pedicle (Figure 57-9). A midline vertical incision is placed to gain access to the midline of the maxilla.

Once the labial incisions are completed, the nasal mucoperiosteum is elevated to complete soft tissue exposure of the osseous surgical site (see Figure 57-7C). Initial establishment of a subperiosteal dissection plane is imperative for completion of nasal tissue dissection without disruption of mucoperiosteal integrity. Because the nasal cavity is more voluminous inside the piriform rim than at the piriform aperture, the elevator should be held at an oblique angle to the surrounding maxillary bone adjacent to the nasal aperture. While maintaining the elevator tip against bone, the mucoperiosteum is reflected from the nasal floor, lateral nasal wall, and nasal crest of the maxilla. The dissection should continue superiorly for a centimeter up the vertical nasal walls to prevent tearing during osteotomy or down-fracture of the maxilla, particularly at the superior reflections of the nasal floor medially and laterally. The anteroposterior depth of this soft tissue dissection is approximately 15 to 20 mm. The remaining posterior soft tissue is reflected more precisely after initial down-fracture of the maxilla.

**Osseous Surgery**

After recording the reference measurements as outlined earlier (see Figure 57-2), the osteotomy is performed. The design of the osteotomy will depend on the maxillary movement desired. Regardless of the design of the osteotomy the measurement marks are used as illustrated in Figure 57-2. Initially the basic horizontal osteotomy will be discussed and then alterations will be described for specific situations. Segmentation of the maxilla may be necessary in certain cases. Specifics of this procedure will be discussed at the end of the basic horizontal technique. The lateral maxillary osteotomy (Figure 57-10) is started at the greatest convexity of the zygomatic buttress because that is the easiest starting surface for the reciprocating saw. It is advanced anteriorly through the lateral piriform rim below the inferior turbinate while the nasal mucoperiosteum is retracted and protected using a periosteal elevator. For the basic maxillary osteotomy this horizontal osteotomy is parallel to the maxillary arch wire approximately coincident with the cut performed previously during model surgery. After the anterior osteotomy is completed, it is continued posteriorly by tapering inferiorly toward the pterygomaxillary junction. A thin reciprocating saw blade and copious irrigation are used for this osseous cut. The most posterior centimeter or so of the lateral wall can be cut with the same saw, but from inside out (Figure 57-11).

Next a nasal septal osteotomy is directed slightly downward and posterior (Figure 57-12) beginning just above the anterior nasal spine while the anterior nasal mucoperiosteum is retracted. Proceeding posteriorly the osteotomy is carefully maintained in the midline. The tendency toward superior deviation while separating the cartilaginous and vomerine septum from the nasal crest of the maxilla...
necessitates maintenance of a slight downward inclination of the septal osteotomy. The lateral nasal wall is severed using a thin osteotome directed posteriorly while medial retraction of the nasal mucoperiosteum is accomplished with a periosteal elevator. The osteotome is gently malleted posteriorly for a distance of approximately 20 mm to avoid premature injury to the descending palatine neurovascular bundle that resides in the lateral posterior nasal wall.

After the above osteotomies have been performed, the pterygoid plates are separated from the maxillary tuberosity (Figure 57-13) using a small sharp curved osteotome. This instrument is preferred over the traditional thick pterygomaxillary osteotome because the thin cutting edge limits fracture and promotes precise division of this bony junction.33 The tip of the osteotome is directed as anteriorly, inferiorly, and medially as the tunneled baccal soft tissue allows. A finger placed palatal and posterior to the maxillary tuberosity will facilitate early verification of the complete separation of bone while avoiding trauma to the palatal vascular pedicle. The authors prefer to have this instrument sharpened before each case.

Downward pressure is placed on the anterior maxilla using the sharp hooks of a Senn retractor to facilitate initial downward fracture of the maxilla (Figure 57-14). If moderate pressure does not result in mobilization of the inferior segment, the completeness of the above osteotomies must be suspect. The cement spattula osteotome is used to ensure complete bony severance of the anterior lateral nasal wall and zygomaticomaxillary portions of the osteotomy. The curved osteotome is again placed into the pterygomaxillary junction, malleted gently, and then torqued to mobilize the maxilla. If no significant movement is detected, then the osteotome may be stepped slightly superiorly, directed anteriorly, and malleted until the separation is complete.

When mobility occurs the nasal mucoperiosteum is elevated progressively more posteriorly until the posterior edge of the hard palate is encountered (see Figure 57-14). Portions of the pterygoid plates or perpendicular process of the palatine bone that resist fracture may be completely separated from the maxilla using an osteotome under direct visualization (Figure 57-15). The descending palatine neurovascular bundle is isolated, ligated, and divided.

Significant movement of the posterior maxilla can cause tensile forces on the descending palatine neurovascular components. Superior repositioning forces on the maxilla may also compress the exposed vessels and nerve between the inferior and superior osseous segments. Severe postoperative bleeding after Le Fort I maxillary osteotomy has been reported.34-37 Attempts to preserve the neurovascular bundle may increase this possibility. Ligation and division of this structure has been shown to have no deleterious influence on perfusion or neurosensory function.38,39 The bone of the perpendicular plate of the palatine bone surrounding the neurovascular bundle is
carefully removed using a Woodson elevator, burs, and rongeurs, and the neurovascular bundle is ligated and divided (see Figure 57-15). After down-fracture, complete mobilization of the maxilla is the next objective. A J stripper normally used for periosteal elevation in sagittal osteotomies engages the posterior border of the midline nasal floor at the posterior nasal spine (Figure 57-16), and anterolateral pressure is exerted to progressively increase mobility of the maxilla. The goal of these maneuvers is to move the maxilla into the approximate final position with only gentle digital pressure. After mobilization from the cranial base is completed, a reassessment of the surgical move is considered. Based on the movement planned any possible bony interferences posterior to the second molar must be removed before application of maxillomandibular fixation (MMF). When all possible interferences posterior to the second molar have been removed, the maxilla is wired to the mandible with the occlusal split interposed.

We prefer to have the patient completely paralyzed during the period of maxillary positioning. Condylar positioning while rotating the maxilla and mandible is paramount to success. The physiologic position of the condyles is thought to be a superanterior orientation relative to the glenoid fossae against the posterior slopes of the articular eminences, with the disk interposed between the condyle and the fossa. The surgeon must position the condyles of the maxillomandibular complex in this upright and forward direction prior to autorotation (Figure 57-17). The importance of this stage of the surgery cannot be overstated. The most likely points of unrecognized bony interferences are in the areas of the pterygoid plates, the maxillary tuberosities, and the perpendicular plate of the palatine bone. It is quite possible to rotate the maxillomandibular complex inappropriately while being unaware of a premature pivot point in these posterior bony areas (Figure 57-18A). This will result in Class II open bite discrepancy once the patient is released from MMF. If a significant period of MMF or training elastics is used postoperatively, this discrepancy may not become apparent for weeks or months (Figure 57-18B). Once these posterior interferences have been removed, the surgeon continues to rotate the entire complex around the temporomandibular joints until the appropriate vertical relationship is achieved as described above. The cartilaginous sep-
tum and vomer as well as the nasal crest of the maxilla are reduced in height equal to the planned movement of the maxilla. This may entail a submucous resection of the cartilaginous nasal septum to prevent buckling of the septum from pressure as the maxilla is repositioned. A groove can be fashioned in the midline of the nasal floor to accommodate the recontoured septum.

A portion of the inferior edge of the cartilaginous septum should be removed. The tendency is to remove too little because of the irregular inferior contact between septum and maxilla. Even if the maxilla is inferiorly positioned, buckling of the septum may occur because the cartilaginous septum extends anterior and inferior to the anterior nasal spine and therefore can be buckled as the maxilla moves forward even if there is some downward movement (Figure 57-19). All of the maxillary positioning has been predetermined by the model surgery and splint construction, except for the vertical. As the maxilla is rotated upward around the condyles, bone is only removed at the point of contact, not a full wedge (Figure 57-20). This facilitates ideal bone-to-bone contact and avoids large gaps in between. Once the desired vertical relationship has been achieved based on the measurements described above, the maxilla should be fixed in position with internal rigid fixation. Sequentially eliminating only interfering osseous structures ensures optimal bone contact. This method is preferred over a wedge osteotomy. Maxillomandibular fixation is removed and the mandible is rotated into the splint while held to the maxilla. If the occlusion is correct, the splint is removed and not left in place postoperatively.

Variations in the above basic osteotomy design may enhance osseous contact, facilitate bone graft placement, or aid fixation device application, and result in improved stability of the superiorly, inferiorly, or anteriorly repositioned maxilla. These variations will be described below as they apply to specific maxillary movements. To prevent septal deviation despite adequate bone and cartilage removal, it is often desirable to suture the nasal septum to the anterior nasal spine. This is done by drilling a hole through the anterior nasal spine and passing a 1-0 polyglycolic acid suture through the septum and anterior nasal spine before tying it in a knot. This also helps to prevent deviation of the septum back to its previous position.
suture through the hole and then through the cartilaginous septum (Figure 57-21). This will also prevent postoperative displacement of the septum during extubation or in the Post-anesthesia Care Unit.

**Segmentalization**

A wide range of permutations may be undertaken if segmentalization is needed. Three-piece maxillary osteotomy is perhaps the most common. The decisions regarding which of the many options will be used are made by pre-treatment and preoperative model surgery. The need for extractions is also determined at this stage. If no extractions are necessary, interdental osteotomies can be safely made between parallel roots of the canines and laterals or canines and premolars. If extractions are decided on by the coordinated efforts of orthodontist and surgeon, they may be done early in treatment or during the osteotomy. A complete discussion of the indications and considerations that influence these decisions is covered elsewhere in this book. However, if there are no specific orthodontic reasons to extract teeth, it has been our experience that it is rarely necessary to extract just for the purpose of surgery. The most common need for segmentalization is to widen the maxilla and adjust the angulations of the posterior maxillary segments. If the anterior six maxillary teeth fit well with the lower anterior teeth, the interdental osteotomy is performed between the canine and premolar teeth. This places the potential for a periodontal defect at the interdental osteotomy site more posteriorly in the mouth. But if the canines need to be widened along with the posterior segments, the interdental osteotomy is placed between canine and lateral incisor teeth. We prefer to make this osteotomy with a thin cement spatula osteotome while palpating palatally. The standard circumvestibular incision can be made with conservative tunneling from the incision interiorly to the alveolar crest on the buccal surface of the maxilla. The osteotomy is malleted until palpated under the palatal mucosa (see Figure 57-8A). With care the osteotomy can be carried superiorly to the level of the horizontal maxillary osteotomy and medially to the horizontal surface of the palate. This should be done before any of the other maxillary osteotomies are done because the maxilla must be stable at the time of malleting. If teeth are to be extracted at the time of osteotomy, an alternative to tunneling is to lay a flap into the gingival sulcus for better access (see Figure 57-8B). However, if this is done, it is recommended that an anterior pedicle be retained for blood supply (see Figure 57-9).

Segmentalization using this or any other technique is more difficult when significantly altered osteotomy designs are used, such as high Le Fort I, II, or III. When the Z osteotomies (see below) are used, interdental segmentalization between canines and laterals is feasible, but more difficult if attempted between canines and premolars.
Following the down-fracture and full mobilization of the maxilla, the remainder of the segmentalization can be performed. The palatal soft tissue is very thin in the midline and the bone is very thick, but the opposite is true 6 to 8 mm lateral to the midline. For that reason two parasagittal osteotomies are made along the floor of the nose using a bur with a rounded tip, such as a Steiger bur (Figure 57-22). The parasagittal cuts are joined with the interdental ones to free the three dental/ossal segments and one midpalatal bony fragment. In two-piece osteotomies the two parasagittal cuts are joined with the interdental cut between the central incisors at the incisive canal.

The orthodontic arch wire is cut at the interdental osteotomy sites, and the segments are mobilized appropriately. The segments are wired to the preformed surgical splint. If bone grafting is needed on the palate it must be done before the maxilla is positioned and stabilized vertically. Interdental and buccal bone grafting can be done just before closure of the soft tissue wounds. Following splint fixation the orthodontic arch wire can be luted back together with quick curing acrylic if necessary. This avoids the time-consuming practice of tying in a preformed surgical arch wire.

If two-piece maxillary osteotomy is to be performed in the midline, we still prefer to use two parasagittal osteotomies that are brought together at the incisive canal. The interdental osteotomy is also performed with a cement spatula osteotome before the other osteotomies. Four-piece maxillary osteotomy is practically never indicated with a competent orthodontic setup. If it is attempted, a tunneling technique is recommended in which an anterior pedicle of mucoperiosteum is retained to assist in the perfusion of the anterior segments.

The length of time that the splint is left in place depends on the amount and type of movements made by the various segments. The range of time the splint is left in place would be 3 weeks for smaller movements and up to 8 weeks for greater expansion. The patient is returned to the orthodontist immediately after removal of the splint for fabrication of the appropriate retention and resumption of orthodontic treatment.

Finally, if large interdental bone removal is necessary to close large extraction spaces, access may be needed on the palate, especially in the midline. In this case we prefer to retain an anterior or labial mucoperiosteal pedicle with a small midline vertical incision to access the anterior nasal spine (Figures 57-23 and 57-24). This allows for a midline palatal incision and conservative circumdental incisions to access the palatal bone removal.
Superior Repositioning

Lateral maxillary wedge ostectomy prior to maxillary repositioning often leaves large gaps between the bony interfaces as the maxilla is moved superiority. Shifting, tilting, or advancing the maxilla may reduce bone-to-bone contact. Sequential removal of osseous contacts avoids this. Therefore, only one horizontal ostectomy is made and no bone is removed until MMF is established and vertical repositioning is begun.

With MMF in place the maxilla and mandible are moved through the arc of rotation as dictated by the seated mandibular condyle (see Figures 57-17 and 57-18). The areas of bone contact can now be seen as the maxilla is positioned superiorly. Just enough bone is removed at the contact points to permit the superior repositioning planned. In many cases this will result in the formation of slots or grooves in the zygomatic buttress wall or elsewhere along the maxillary wall (see Figure 57-20). One must be careful that the grooves do not inhibit the free rotational movement of the maxillo-mandibular complex. This technique is particularly valuable when the maxilla is being shifted laterally or torqued in a transverse direction, which makes prediction of an ostectomy difficult. The maxilla is rigidly fixed and the MMF removed, the mandible anterotated into occlusion, and correct maxillary position confirmed.

Anterior Repositioning

The traditional Le Fort I ostectomy is inclined inferiorly from anterior to posterior in order to avoid the relatively large maxillary cuspid tooth root and placement of the cut inferior to the lateral extent of the zygomatic buttress. The resultant inclined plane may be problematic if this does not coincide with the desired movements.

A variety of straight, stepped, and Z osteotomies can be designed to accommodate the planned moves (Figures 57-25–57-28). If grafting (Figure 57-29) is desirable, the steps or Z osteotomies provide much better grafting sites than the pterygomaxillary fissure.

Inferior Repositioning

Inferior repositioning of the maxilla offers a special challenge in orthognathic surgery because there is a great relapse tendency. Various mechanisms have been advocated for stabilization and fixation of the maxilla after inferior repositioning. There have been a variety of techniques used to stabilize the inferiorly positioned maxilla, including suspension wires, interosseous wires, bone plates, Steinmann pins, Wessberg pins, and RAPs.

Stabilization of the inferiorly repositioned maxilla may not require bone grafting from a distant site if a series of slanted Z or step osteotomies are used (see Figure 57-25). The angulations of the osteotomies are planned so that the maxilla will slide down the incline plane of the cuts, maintaining bone contact as it is repositioned anteriorly and inferiorly. Depending on the inclination of the anterior versus posterior osteotomies, the maxilla may be positioned more anteriorly or more inferiorly (see Figures 57-26–57-28).

Most surgeons prefer to use bone grafts and rigid fixation to stabilize the maxilla that has been inferiorly repositioned and has no bone-to-bone contact. Grafts can be secured with bone screws or plates if sufficient bone is available or with wire (see Figure 57-29). Candidates for inferior maxillary repositioning often have paper-thin maxillary bone. Internal rigid fixation with interosseous metal plates is the stabilization method of choice; however, occasionally insufficient bone is available adjacent to the osteotomy sites. In these cases the RAP system can be a crucial alternative (Figure 57-30). The application of this system has been described elsewhere.

Posterior Repositioning

Posterior repositioning of the maxilla must be approached cautiously due to resultant loss of upper labial and paranasal osseous support for the overlying soft tissue. If the osteotomy is carried through the pterygoid junction, bone must be removed either from the pterygoid plates (with great caution) or the canine fossa. An alternative is to direct the osteotomy through the maxillary
tuberosity just posterior to the second molar. This will leave tuberosity bone attached to the pterygoid plates, which can be more safely removed. Dangers of the technique include damage to the greater palatine artery distal to its anastomosis with the lesser palatine.

Maxillary horizontal excess may also be addressed by anterior maxillary osteotomy when extractions are indicated or edentulous sites are present. These techniques are discussed in detail later in this chapter.

**Stable Fixation for Maxillary Osteotomies**

Rigid internal fixation with bone plates and screws has become the standard for maxillary stabilization. Although this technique has eliminated many of the early postoperative stability concerns, the technique is less forgiving than wire fixation. Therefore, intraoperative positioning is even more important. A wide variety of plating systems and sizes are available. Each surgeon will discover his or her preference, but 2.0 mm four-hole plates are used in most cases. These will require a little more effort for adaptation than lighter ones, but with practice can be used just as accurately and with more stability. When used, these plates virtually eliminate postoperative plate fracture or mobility.

**Specific Procedures**

**Total Maxillary Alveolar Osteotomy**

The total maxillary alveolar osteotomy was designed to avoid some of the problems seen with the Le Fort I down-fracture technique; however, it did not fare any better. Purported advantages including improved nasal airway, improved stability due to better bony contact, improved ability to widen the maxilla, and better maxillary perfusion have not been realized. In several thousand maxillary osteotomies over the past 20 years, we have not found a need for this procedure.

**Anterior Maxillary Osteotomy**

Numerous techniques have been used to accomplish the anterior maxillary osteotomy. The three major techniques involve the use of one of three vascular pedicles: labial (Figure 57-32), palatal (Figure 57-33), and a combination of these with vertical incisions in both (Figure 57-34). All of these can be successful, and when done properly have few complications; however, what scant literature exists would indicate that the palatal pedicle provides the best vascularity.

Anterior maxillary osteotomies are generally used to treat horizontal maxillary excess when the posterior occlusion is correct or correctable by mandibular surgery. Commonly, anterior maxillary osteotomy with premolar extractions is used for bimaxillary protrusion in which both the anterior maxilla and the anterior mandible are to be retracted.
These procedures are also used for correction of anterior open bite. Occasionally anterior maxillary osteotomy may be coupled with mandibular advancement and anterior mandibular segmental surgery in patients with a severe curve of Spee.

Sequencing the work-up when both jaws are involved requires imagination, because the surgical procedures need to be done systematically so that the surgeon never loses orientation. There are two possible scenarios: (1) the posterior occlusion is not going to be changed because the posterior maxillary and mandibular teeth need not be moved, or (2) mandibular surgery will be performed thereby correcting the posterior occlusion. This crucial difference because if the posterior occlusion is not going to be changed by surgery, then the models must be mounted in centric occlusion, not centric relation. If the posterior occlusion will be altered by mandibular surgery, then a new centric relation will be established by the surgery and model surgery can be done as usual. In the first case the maxillary anterior model is cut and repositioned to the best relationship against the uncult mandible in centric occlusion and the remaining maxillary dentition, and then a splint is constructed.

If mandibular surgery is to be done, two mandibular models are mounted, one mandibular model is cut, and the other is left intact to preserve the intermediate phase. The anterior maxilla and the mandible are cut and repositioned together to the final position and a final splint is made. The cut maxilla can then be articulated with the uncult mandible to establish the intermediate position and a second (intermediate) splint is made. The final splint will be wired to the maxilla for a postoperative period so there must be a separate intermediate splint that articulates with the final splint and the mandibular teeth.

Particularly in segmental surgery the model surgery should simulate the actual surgery to provide a clear understanding of the three-dimensional movements necessary to the proper performance of the surgical procedure. Measurement marks should be made at the level of the interproximal spaces and the root tips. Marks should also be made on the palate at the root tips and the maxillary midline. If widening is to occur, transpalatal marks should also be used. The use of intermediate splints in segmental cases is a little different from their use in total arch cases. Since the posterior maxilla is not mobilized, the anterior maxillary positioning is more difficult and can be deceiving. For example, the anterior maxilla can fit into the splint and appear ideal until the mandible is rotated into occlusion. If the mandible does not arc into the ideal occlusion, it is possible that the anterior maxilla is tipped superiorly or inferiorly and must be adjusted. For this reason the mandible should not be wired into MMF but left free to rotate into the maxilla. After surgery, if the mandible is held into intermaxillary fixation during the fixation process for the anterior maxilla, it is possible to pull the condyles out of the fossae.

**Figure 57.28** An alternative method for advancement is to create a step (A) in the buccal and place a bone graft (B) in the step after repositioning.

**Figure 57.29** A, A single hole is placed in the middle of the bone graft and a loop of 26 gauge stainless steel wire is placed through the hole from inside out. The two ends are divided, with one placed through the superior maxillary bone wall and the other through the inferior maxillary segment. Finally one end is passed through the loop and twisted to the other, much like an Ivy loop. B, Bone graft shown in place.
with a resultant malocclusion. Therefore, the splint must be ligated to the posterior maxilla first, and the anterior maxilla is then brought into the splint and ligated. If the mandible rotates into the desired occlusion, then the maxilla can be considered to be in the correct place and fixed accordingly. If mandibular surgery is required, it can be initiated at this time.

The choice of surgical technique is made on the basis of access and the areas that will be most difficult to visualize intraoperatively. For example, in cases of open bite in which no teeth are to be extracted, the anterior segment will be rotated clockwise downward after interdental osteotomies. Access to the interdental area, the midline of the palate, and the anterior nasal spine is not as critical as it is with other surgical movements. This procedure can be done with a circumvestibular incision or with bilateral horizontal incisions in the canine-molar regions and a vertical incision in the midline between the central incisors. On the other hand, if first premolars are to be extracted or have already been, and the anterior maxilla is to be retracted several millimeters, access to the midpalatal area is essential. The Wunder team, in which the palatal soft tissue is elevated posteriorly, gives great access to the palatal bony tissue, but care must be taken to preserve the labial soft tissue pedicle. However, if superior repositioning is required, the access to the junction of the anterior nasal spine and the nasal septum is poor. A vertical incision can be made over the anterior nasal spine, but since this labial flap represents the total blood supply to the anterior maxilla, it is not recommended.

Our choice of procedures for most anterior maxillary osteotomies is a hybrid (see Figure 57-34). The labial incisions are made laterally as per Wunder with a vertical midline incision to permit access to the anterior nasal spine-nasal septum. However, in place of a full palatal flap, circumventricular incisions are made around the necks of the teeth on either side of the interdental osteotomies and a midline incision is made over the midpalatal suture with a small anterior Y if necessary. The Y should be anterior to the interdental bone cut and be as conservative as possible.

Fixation of anterior maxillary osteotomies is as varied as the surgical techniques. Orthodontic arch wires and cast splints represent two of the extremes.
in techniques used for fixation. Orthodontic appliances, if they are in place, are the handiest to use at least for part of the fixation. However, supplemental fixation may be desirable. An occusal splint, with skeletal wire in the anterior nasal spine, is helpful in such cases, especially if tension on the free segment is expected. Small plates and screws can be carefully used to fixate the segment. Arch bars have been used and in certain cases may be appropriate, but a lower level of precision can be expected.

The most important guideline is that, at the time of surgery, the anterior maxilla must be mobile enough so that it does not require any significant pressure to move it into the desired position. Fixation can then be instituted by one of the many methods that will hold the segment in the proper position throughout the healing period. Maxillomandibular fixation is almost never required.

**Posterior Maxillary Osteotomy**

The posterior maxillary osteotomy and its modifications are rarely indicated today. If open bite or transverse expansion is needed, the Le Fort I downfracture is much easier, quicker, and more predictable. Posterior maxillary osteotomy is usually indicated as a preprosthetic procedure to correct hypereruption of a posterior maxillary dentoalveolar segment. Meticulous model surgery is essential to visualizing the three-dimensional movements and in anticipating osseous interference of the segment. Periapical radiographs are useful for evaluating planned interdental and supra-apical osteotomy sites. Once again the models should be mounted in centric occlusion, not centric relation, unless the mandible is also going to be operated on.

Outpatient anesthesia can be used for isolated posterior segmental procedures. A high palatal vault permits palatal osteotomy transantrally beneath the nasal floor. The soft tissue incision is made horizontally in the maxillary buccal vestibule from the anticipated anterior interdental osteotomy site to the second molar (Figure 57-36). Maxiosteosal dissection beneath the superior aspect of the incision exposes the lateral maxilla. The pterygomaxillary region is exposed and soft tissue retracted in a tunneling dissection. At the anterior interdental osteotomy site, conservative tunneling of the periosteum exposes the full vertical extent of the dentoalveolus. After retraction of the soft tissue with skin hooks and right-angle retractors, the buccal interdental osteotomy can be outlined with a small fissure bur in a rotary handpiece or can be directly completed with a thin cement spaltula osteotome.

A horizontal osteotomy is made approximately 5 mm above the roots of the teeth and connected with the anterior interdental cut (see Figure 57-36). The vertical interdental osteotomy should be completed first so that the segment is not mobile while using interdental osteotomes. The palatal osteotomy is accomplished with a small sharp curved osteotome directed at the juncture of the vertical alveolus and horizontal palatal shelf. The surgeon places a finger in the palatal mucosa to detect complete osseous sectioning while minimizing palatal mucosal trauma (Figure 57-37A and B). In cases with high palatal vaults the transantral cut is completed along the entire anteroposterior extent of the planned palatal osteotomy (see Figure 57-37B), except in the area of the descending palatal neurovascular bundle. Next the pterygomaxillary junction is separated with a chisel using a technique similar to that for a total maxillary osteotomy. Patients with low flat palatal vaults are more easily osteotomized through the nasal floor (Figure 57-37C).

The posterior dentoalveolar segment is down-fractured using digital pressure. Anticipated osseous interference may be

![Figure 57-34](image1)

*Figure 57-34.* A combination of labial and palatal pedicles can be used for an anterior maxillary osteotomy without extractions.

![Figure 57-35](image2)

*Figure 57-35.* Anterior maxillary osteotomy with first premolars extracted corrects maxillary excess, bimaxillary protrusion, and anterior open bite.

![Figure 57-36](image3)

*Figure 57-36.* Posterior maxillary osteotomy. Horizontal vestibular incision with tunneling access to the interdental papilla. The dashed line marks horizontal and interdental osteotomies.
removed using a bar or rongeur. Previously inaccessibile medial and posterior walls of the mobile segment are addressed following mobilization and displacement of the posterior segment. Bone removal at the perpendicular plate of the palatine bone and mobilization should continue until the segment can be repositioned with minimal digital force (Figure 57-3B).

Final contouring is accomplished while holding the splint on the stable portion of the maxilla. The mandible is rotated into its dictated occluding position to ensure that no distortion of the splint has occurred. A slightly thicker splint and transpalatal acrylic or wire reinforcement will add rigidity to prevent inadvertent distortion of the posterior extension of the splint. The segment is ligated to the splint.

The repositioned posterior maxillary segment may be fixed with intersosseous wire, suspension wire, stable pin fixation, or bone plates. Osseous grafts are rarely required but may be obtained from local regional sites. Additional stability is attained by luting the orthodontic arch wire back together with quick curing acrylic or by placing a rectangular arch wire across the interdental osteotomy site. Intermaxillary fixation is not required.

If the posterior segment is to be repositioned laterally or medially to any extent, added access is necessary. A midline palatal incision may be made and the palatal tissue reflected laterally (Figure 57-3B). Careful dissection ensures the integrity of the greater palatine vasculature. This approach gives access to the sinus and nasal cavity. If the palatal vault is high, the osteotomy is usually carried through the sinus (see Figure 57-3B). If the alveolus is short and the palatal vault shallow, the osteotomy usually crosses the medial sinus wall and passes through the floor of the nose (see Figure 57-3C).

**Surgically Assisted Rapid Palatal Expansion: History**

The concept of correcting maxillary transverse arch discrepancies originated in the United States in 1860 by Angell, who reported it in *Dental Cosmos*. Angell described a widening of the maxillary dental arch by opening the midpalatal suture. The concept fell into disuse by American practitioners by the early 1900s. Haas re-introduced the concept in 1961 with rapid palatal expansion (RPE, also referred to as rapid maxillary expansion), appliances that effectively correct arch width discrepancies. In growing children nonsurgical RPE results in opening of the midpalatal suture, but stability has been questioned. Timms and Moss, Haas, and Issacson and Ingram have shown orthodontic RPE to result in alveolar bending, periodontal membrane compression, lateral tooth displacement, and tooth extrusion. For those reasons Haas believed that overexpansion was very important. Even

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**Figure 57-37** A, Transpalatal osteotomy is made at the junction of the horizontal palate and vertical alveolar process. B, Approach for deep vaulted palates. C, Approach for flat shallow palates.
Reported results vary with technique and the timing of placement of an active orthopedic expansion device, but all note the expansion to be more stable than orthodontic RPE alone.

The role of surgery with RPE is to release the areas of resistance in the maxilla before RPE. Whether RPE will be done alone or in conjunction with surgery will depend on the patient's age and the condition of the midpalatal suture, but not the maxillomandibular relation. Lines found surgically assisted rapid palatal expansion (SARPE) to be extremely valuable in young patients (growing children) exhibiting maxillary collapse, maxillary retrusion, and pseudo-Class III malocclusions. SARPE is distraction osteogenesis of the maxilla in a transverse plane. The benefits of its use are gradual callous distraction that allows the soft tissues to accommodate and greater long-term stability.

When maxillary expansion and total maxillary osteotomy are needed, two treatment regimens are possible SARPE as a first stage followed by a one-piece maxillary osteotomy at a later date or multiple-piece maxillary osteotomy in the normal orthognathic sequence. The four factors that must be considered when determining which method is preferred are arch length discrepancy, arch morphology, vertical dimension, and ectopic eruption of posterior teeth.

Arch Length Discrepancy In cases of arch length deficiency, a SARPE increases arch circumference sufficiently, especially in the anterior, to permit alignment of crowded teeth and avoid extraction of premolars or excessive tipping of incisors. SARPE is also beneficial when minimal changes in the sagittal dimension are necessary because of the nasolabial angle and lip-to-tooth considerations.

Arch Morphology The majority of cases of transverse deficiency characteristically exhibit a narrow tapering arch form with the discrepancy pronounced in the canine region. To achieve a functional occlusion, the intercanine width must be increased and the anterior segment flattened for a normal elliptical arch morphology. If nonextraction orthodontic therapy is desired, a SARPE is the treatment of choice. A three- or four-piece segmental maxillary surgical procedure may be less ideal, particularly because of potential periodontal problems and possible vascular compromise.

If the discrepancy is minimal and extraction of the first premolars is desired, a three-piece segmental maxillary procedure is indicated, but only after the canines are orthodontically moved posteriorly to provide an increased width. The inherent problem is relapse of the buccally displaced canines. This procedure is indicated if there is no transverse discrepancy in the canine region but significant constriction in the premolar-molar region.

Vertical Dimension The vertical dimension is of particular concern in patients who exhibit anterior open bites. Segmental orthodontics is suggested, with no attempt to level the arch, using a three- or four-piece maxillary procedure to level the arch and at the same time correct the bilateral absolute transverse maxillary deficiency.

Ectopic Eruption of One or Two Posterior Teeth If ectopic eruption is serious enough that it cannot be treated with orthodontic therapy, a segmental osteotomy with expansion may be done.

The stability of SARPE has been reported. In one reported study on long-term stability of SARPE, the surgical results remained stable with only 6.4 to 7.5% relapse in the canine, premolar, and molar regions.

Surgically Assisted Rapid Palatal Expansion: Surgical Technique Bilateral mucoperiosteal incisions are made from the piriform rims to zygomatic
buckles (Figure 57-40A). Bilateral osteotomies are then made from the piriform rims to low in the pterygomaxillary junction (see Figure 57-40A). A simple anteroposterior osteotomy from the piriform rim to the pterygomaxillary junction is suggested for SARPE. More complicated designs appear to be advantageous in two-dimensional drawings, but in fact are meaningless when applied to three-dimensional geometric structures such as the maxilla. The theory put forth by Betts and colleagues shows a sloped cut from the piriform to the buttress. The supposition is that as the maxilla is expanded, it will “ride down” this slope. This concept appears valid in a two-dimensional drawing; however, three-dimensionally, if the osteotomy is made flat from lateral to medial, as expansion occurs, then the bone at the piriform slides laterally over the flat surface lateral to it and the bone of the buttress slides laterally over the flat surface lateral to it. Therefore, if the lateral maxillary wall saw cuts are made straight in perpendicular to the midsagittal plane from lateral to medial, then the angulation of the cut from anterior to posterior does not affect the vertical position of the segments as they are expanded. This can be easily demonstrated on a dry skull.

Osteotomies are made of the anterior 1.5 cm of the lateral nasal wall because this is the thickest portion of the anterior nasal wall. Separation of the hemimaxillae is performed by driving a spatula osteotome between the central incisors parallel to the palate for approximately 1 to 1.5 cm (Figure 57-40B-D). The expansion device is turned until separation is noted between the central incisors teeth (Figure 57-41). Both segments are mobilized by prying until equal mobility is seen bilaterally. Mobilization is continued until approximately 1.5 to 2.0 mm is opened between central incisors.

Some authors recommend a subtotal Le Fort I osteotomy with a horizontal osteotomy, vertical midline osteotomy, and pterygoid and septal separation. Shetty and colleagues demonstrated, with a photoelastic model, that the midpalatal and pterygomaxillary articulations were the primary anatomic sites of resistance to expansion forces. The article by Shetty and colleagues in 1994 report performing only incomplete cuts of the lateral maxillary wall, from second bicuspid to second molar. It is unclear whether these findings would be as significant with complete cuts from the piriform to the pterygomaxillary fissure. Need for separation of the pterygomaxillary junction is therefore a point of debate. However, since our results have
shown minimal relapse without pterygomaxillary disjunction, we do not perform this maneuver in most cases.

If two sources of potential hemorrhage (manipulation of the pterygomaxillary junction and separation of the nasal septum from the nasal crest of the maxilla) are avoided, this procedure can be done as an office-based procedure, on an outpatient basis, and under intravenous sedation. Steroids are routinely used but antibiotics are not necessary. A 5-day post-operative rest period is observed, after which the expansion appliance is turned according to specific instructions until the desired expansion is achieved.

Unilateral SARPE can be achieved by completing a vertical interdental osteotomy between the appropriate teeth and connecting that with a horizontal osteotomy extending posteriorly to the pterygomaxillary junction. If the entire hemimaxilla is to be mobilized, it is performed in the same way as described for a bilateral case, only unilaterally. If a widening of only the posterior part of the hemimaxilla is desired, the interdental osteotomy must be completed all the way to the midline suture (Figure 57-42). The segment is mobilized (Figure 57-43A) and expanded in the same manner as the bilateral procedure (Figure 57-43B).

**Zygomatic Osteotomy**

In patients with severe midface deficiency it may be favorable to enhance the prominence.
of the zygomas. Also, esthetically, high cheekbones have always been popular, and with a growing public awareness of surgical capabilities an increasing demand has surfaced for procedures to enhance this area. Numerous methods have been developed to augment the malar eminences, most involving grafts or implants. Autologous grafts are disappointing because of resorption and the need for a donor site. Allogeneic transplants such as lyophilized cartilage have been used with some success but are prone to migration. Presently our choice for malar augmentation is with alloplastic implants (porous polyethylene).

However, when alloplasts are contraindicated, the zygomatic osteotomy may be useful. The zygomatic osteotomy is approached through an intraoral incision. A reciprocating saw is used to make a parasagittal osteotomy through the zygoma just adjacent to the root of the structure (Figure 57-44A and B). This is done as close to the lateral orbital rim as possible. The zygoma is out fractured gently so that an interpositional material can be placed to hold it in position. The interpositional material can be stabilized in any traditional method, since it is not difficult to fix this area. This technique does not give anterior projection unless the interpositional material is fashioned to project forward (Figure 57-44C).

**Modified Le Fort Osteotomies**

Osteotomies that extend the traditional Le Fort I have been called by many names including modified Le Fort I, II, III; high Le Fort I; and pyramidal, middle, intermediary, quadrangular, and maxillary-malar-intraorbital osteotomies (Figure 57-45A–C). We have used them all and have described them previously. This group of osteotomies is severely limited regarding expansion, and rotational and torquing movements. Therefore, with the success of porous polyethylene implants to the malar, infraorbital, lateral orbital, and parasatal regions, we rarely see a need for these more invasive osteotomies (Figure 57-46A–C).