Paparella: Volume IV: Plastic and Reconstructive Surgery and Interrelated Disciplines

Section 1: Plastic and Reconstructive Surgery

Chapter 17: Orthognathic Surgery

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Orthognathic surgery is that aspect of maxillofacial surgery dealing with the surgical correction of malocclusion and its attendant facial deformities. Orthognathic surgery addresses those patients whose malocclusion represents a malrelationship of the basal bone of the jaws, a malalignment that cannot be corrected by conventional orthodontic treatment alone. Close cooperation with an orthodontist is necessary in virtually all orthognathic cases.

The orthognathic surgeon must carefully evaluate the patient from both an occlusal and an aesthetic standpoint and integrate these considerations into the final treatment plan. This type of surgery is primarily of a functional nature, ie, the correction of malocclusion, but the aesthetic ramifications of these mandibular and midface osteotomies must be carefully planned and incorporated in the treatment plan.

The first surgical correction of a mandibular deformity was probably performed by Simon Hullihen in Wheeling, West Virginia in 1849. Martin Wassmund, of Germany, is generally credited with having performed the first complete maxillary osteotomy to correct an occlusal deformity in 1927. Orthognathic surgery slowly evolved in Europe during the first half of this century and was reintroduced to the USA by Hugo Obwegeser at his landmark lecture on this topic at Walter Reed Army Hospital in 1966. Since then, an exponential increase in the orthognathic surgical literature and in the volume of this type of surgery has occurred on both sides of the Atlantic.

Paul Tessier of Paris integrated orthognathic surgery with surgery of the anterior cranial fossa and orbital region to tailor combined craniofacial osteotomies for patients with hypertelorism and deformities resulting from the syndromes of Crouzon and Apert.

Patient Evaluation

History and Physical Examination

The workup for orthognathic surgery begins with history taking and physical examination. In addition to the general history, significant information to be elicited includes previous facial trauma, previous orthodontic treatment, or temporomandibular joint (TMJ) problems. Environmental allergies and nasal airway complaints should be discussed, because the nasal airway may be affected by surgery. The surgeon should also evaluate the patient's psychological status and motivation for undergoing this surgery, as one would for a cosmetic operation.

Physical examination focuses on the oral examination and must include a dental and facial aesthetic evaluation. The Angle classification of the occlusion is determined and the dentition is evaluated in terms of the periodontal status and possible need for restorative dentistry, endodontics, or periodontal therapy before orthodontic banding. A measurement of the amount of maxillary central incisor exposed under the upper lip at rest is of critical importance in planning maxillary surgery. A careful evaluation of the midline of the upper and lower lips, the midpoint of the chin, and the dental midlines should be performed and any asymmetries noted and measured. Vertical facial thirds should be evaluated and disproportions recorded. The fullness of the submental region should be evaluated, since mandibular setback procedures may accentuate this fullness. Nasal aesthetics are an important part of this evaluation, and adjunctive rhinoplasty may be included in the overall treatment plan.

Dental impressions are taken so that the resulting plaster models of the patient's teeth may be evaluated, mounted on an articulator, and used for subsequent model surgery. In cases involving osteotomy of the maxilla, a face-bow transfer is necessary to orient the dental models properly to the intercondylar axis of the articulator. A wax bite registration is obtained, reflecting the patient's centric occlusion.

Radiographic Evaluation

Basic radiographic evaluation of a candidate for orthognathic surgery should include a panorex and a cephalometric radiograph. The panorex allows evaluation of the morphology of the TMJs and provides information on the status of the teeth and their alveolar bone support. This film also screens the patient for occult intraosseous jaw pathology.

The cephalometric radiograph is a true lateral projection of the head taken in a standard position with the teeth together and the facial musculature at rest. The cephalometer engages the patient's head with ear rods that extend slightly into the external auditory canals. The patient is then positioned so that the Frankfort horizontal line is parallel to the floor. A tracing is made of this radiograph, and key points such as the sella turcica, the frontonasal suture, and the angle of the mandible, are identified. The angles subtended by the lines connecting these key points can be compared with normal values, aiding the surgeon in arriving at the correct diagnosis of the deformity. In addition to bony landmarks, various soft tissue landmarks can be identified on the cephalometric tracing and can be used to evaluate facial proportions. A variety of analyses are described for evaluation of cephalometric radiographs. An excellent review of this topic is provided by Zide and colleagues. Figure demonstrates the basics of a cephalometric tracing of a patient with a normal profile.

Analysis of a cephalometric tracing is intended to aid the surgeon and orthodontist in their clinical evaluation, but the surgical treatment plan should be primarily dictated by clinical findings. The surgical-orthodontic team should "treat the patient" and not specifically attempt to "treat the numbers" of a cephalometric tracing.

Types of Deformities

Jaw malrelations may occur in the anteroposterior, vertical, or transverse planes or may involve any combination of these three spatial axes.

Anteroposterior

This subgroup of horizontal jaw malrelationships involves two basic problems. The first is that of the class Ii malocclusion and class II facial profile, which indicates a relative deficiency of the mandible and is characterized by a weak-appearing chin. This deformity is most commonly due to an abnormally posterior position of the mandible and may include an absolute microgenia; it has been termed the "Andy Gump" deformity. Cephalometric analysis of an isolated mandibular deficiency would demonstrate an SNB value less than the normal 77 to 80 degrees. It is much less common for this deformity to be caused by an overprojected maxilla with a relatively normal mandible. In this situation, cephalometric analysis would demonstrate an SNA greater than 77 to 80 degrees with SNB in the normal range. In the more common situation of an isolated mandibular deficiency, correction by mandibular advancement, possibly with adjunctive advancement genioplasty, is indicated.

The second horizontal malrelationship is that of the class III malocclusion and prognathic facial profile. This may be due to a horizontal excess of the mandible, a horizontal deficiency of the maxilla, or both. In most class III cases the problem is due to a mandibular excess, and analysis of the cephalometric tracing shows a normal SNA with SNB greater than 77 degrees. In this situation, mandibular osteotomy with posterior repositioning is indicated. Less frequently, the mandible is normal, but cephalometric and clinical evaluation reveal a maxillary deficiency. Maxillary osteotomy with advancement is indicated in this situation. If the advancement exceeds 7 mm in a cleft palate patient or 10 mm in a non-cleft case, stabilization of the advancement with bone grafts at the pterygoid plate region and lateral maxillary walls is advisable. Overcorrection of the maxillary deficiency is also recommended.

Severe class III cases with the markedly prognathic "lantern jaw" appearance are frequently associated with combined maxillary deficiency and mandibular excess. These patients require simultaneous maxillary advancement and mandibular recession to correct the occlusal and aesthetic deformity properly.

Vertical

The most common vertical problem in the maxilla is that of vertical maxillary excess, which has been termed the "long-face" syndrome. Characteristic of this deformity include excessive exposure of the maxillary central incisors with the lips at rest, a "gummy" smile, and a receding chin. The vertical excess of the maxilla lowers the occlusal plane, and with the teeth in centric occlusion, the mandible assumes a position that is autorotated inferiorly and posteriorly from the normal, creating a weak-chin appearance. A class II malocclusion is frequently associated with this deformity, and anterior open bite may be present. When this deformity occurs with adenotonsillar enlargement, it is termed "adenoid facies". Cephalometric analysis of "long-face" patients generally demonstrates a normal SNA, indicating that the anteroposterior position of the maxilla is not disturbed. SNB may be less than normal, reflecting the inferior and posterior rotation of the mandible. The mandibular plane angle (MPA) is characteristically greater than the normal 35 degrees, demonstrating that the maxillary deformity has produced an inferior and posterior rotation of the mandible about the intercondylar axis.

The "long-face" syndrome may include an anterior open bite, apertognathia. This type of malocclusion entails a lack of contact of the anterior teeth when the molars are in normal occlusion. Patients with anterior open bite must use their canine and premolar teeth for the incising function best suited to the central and lateral incisors.

The least common deformity seen in the vertical plane is the "short-face" syndrome in which a decreased vertical height of the maxilla creates a "bulldog" appearance with the maxillary incisor teeth completely covered by the upper lip. Patients with this deformity reveal their maxillary incisors only on the most forced smile. The occlusal plane is abnormally high in these individuals, and the resultant superior and anterior autorotation of the mandible gives a pseudoprognathic appearance to the face. Cephalometric analysis of "short-face" patients shows a mandibular plane angle of 10 to 20 degrees, significantly less than the 35-degree normal. SNA and SNB values may vary.

Transverse

The transverse plane is less frequently involved in malocclusions requiring orthognathic surgery; however, the simple crossbite is a frequent problem treated by conventional orthodontic therapy. Normally, the maxillary dental arch is slightly wider than the mandibular arch, allowing the maxillary posterior teeth to overlap their mandibular counterparts by half a tooth's width. Any deviation from this relationship constitutes a crossbite, which may be classified as either buccal or lingual.

The best example of a transverse problem that generally requires orthognathic surgical correction is the maxillary collapse with decreased arch width and crossbite that occurs in cleft palate patients.

Children with a decreased transverse dimension of the maxilla that produces a unilateral or bilateral lingual crossbite can undergo orthodontic expansion of the maxilla without surgery. After the pubertal growth spurt, nonsurgical maxillary expansion is more difficult and a combined surgical-orthodontic procedure is used. Cleft palate patients require autogenous bone grafting to the cleft defect to stabilize such a maxillary expansion.

Chin Deformities

The correction of a chin deformity may be the only surgical procedure required for a given patient, or it may be adjunctive to a more major orthognathic operation. Deformities of the chin, like occlusal malrelationships, can occur in all planes; however, the most common chin deformity requiring surgical correction is microgenia. The term "microgenia" is used in contradistinction to "retrognathia", which signifies a posterior displacement of the entire jaw. Some patients exhibit both retrognathia and microgenia and require combined mandibular advancement and augmentation or advancement genioplasty.

Hyperplastic disorders of the chin are much less common and can occur in either the horizontal or vertical plane. Correction of these hyperplastic problems entails removal of a section of bone to allow appropriate repositioning of the chin point and its soft tissue attachments. A vertically hyperplastic chin requires removal of a horizontally oriented section of bone, and a horizontally hyperplastic chin entails a vertically oriented ostectomy. One should not attempt to reduce the chin prominence by merely grinding off the excessive bone, because the resulting reduction in the soft tissue projection of the chin will be unpredictable and the chin contour may appear unnatural.

A lateral displacement of the mental prominence from the mandibular dental midline frequently accompanies the deviation of the entire mandible and maxilla in conditions such as condylar hyperplasia and hemifacial microsomia, and requires adjunctive transverse genioplasty in addition to maxillary and mandibular osteotomies for restoration of facial symmetry.

Surgical Planning

Cephalometric Prediction Tracing

After analysis of the cephalometric film and correlation with clinical findings, a series of retracings is undertaken to simulate the effect of the various treatment options available. Separate acetate segments are traced for each jaw or segment and are manipulated to achieve the proper procedure or combination of procedures that will result in the best functional and aesthetic result. These prediction tracings are compared until the best treatment plan is determined.

Model Surgery

The patient's plaster dental models are placed in centric occlusion and mounted on an articulator, a hinged device that approximates the complex motions of the paired TMJs. Coordinated with the results of the prediction tracing, the dental models are repositioned to simulate the occlusal results of surgery. Once the final occlusion has been established, an acrylic splint is fabricated for use at the time of surgery.

Role of Orthodontic Therapy

Close cooperation between surgeon and orthodontist is the cornerstone of orthognathic surgery. Treatment planning entails a meeting between the orthodontist and surgeon to arrange their priorities. A significant jaw malrelationship produces compensatory malalignment of the teeth. Such a malalignment serves to bring the biting surfaces of the teeth somewhat closer together, producing a partial functional compensation for the basic malrelation of the maxilla to the mandible. These "dental compensations" must be orthodontically removed by uprighting and aligning the teeth, thereby placing them in a much better orientation with the basal bone of each jaw to best deal with future masticatory forces. To the patient, this presurgical alignment produces an apparent worsening of both the malocclusion and the deformity. The patient with significant dental compensations needs to be counseled as to the rationale of this "reverse" orthodontic therapy prior to treatment.

Orthodontic care occur in three phases: (1) presurgical preparation, (2) perioperative management, and (3) postsurgical finishing.

Presurgical Preparation. During this orthodontic phase of management, each arch is treated independently, leaving the final maxillomandibular relationship to be defined later by surgery. The arches are leveled and aligned and rotated teeth are corrected. Changes in tooth angulation and torque may also be necessary. It is during this phase that dental compensations are removed. It is not uncommon for adults to require 1 year or more of presurgical orthodontics. If dental extractions are required to alleviate crowding of the teeth, this phase may take 18 months or more.

Perioperative Management. The orthodontist assists the surgeon in surgical planning, and may participate in the model surgery and fabrication of the surgical splint used to define the postoperative occlusion. The orthodontist changes the patient to heavier arch wires with lugs or surgical hooks that can be used for intermaxillary wiring if necessary.

Postsurgical Finishing. During the postoperative period the jaws are metabolically active, and it has been the general observation of many orthodontists that orthodontic treatment tends to proceed faster after surgery. Traditionally, the postsurgical finishing period encompasses minor refinements of the new occlusion before final debanding. Some orthodontists, however, use this metabolically active period for more extensive tooth movement.

Surgical Techniques

Maxilla

The maxillary osteotomy along the lines of a LeFort I fracture was first described by von Langenbeck in 1859. Anterior segmental and posterior segmental osteotomies in which the entire maxilla is not mobilized find little current application.

The LeFort I osteotomy is performed under general nasoendotracheal anesthesia supplemented by local anesthesia with epinephrine for hemostasis. Hypotensive anesthesia techniques are often used by anesthesiologists experienced in orthognathic anesthesia. In the rare instance in which orthodontic bands are not already on the teeth, arch bars are applied at the beginning of the operation.

The incision is made in the height of the mucobuccal fold and extends from first molar to first molar. Periosteum is reflected from the anterior surface of the maxilla up to the infraorbital foramen, the piriform rim, and the zygomatic buttress areas. The subperiosteal dissection extends posteriorly along the lateral aspect of the maxilla until the pterygomaxillary junction is identified and the mucoperiosteum of the nasal floor is elevated.

A rotary bur is then used to scribe vertical reference lines on the anterior wall of the maxilla so that the amount of maxillary repositioning can be measured. A reciprocating saw is used to create a horizontal osteotomy through the piriform rim, along the anterior wall of the maxillary sinus, and through the zygomatic buttress. This osteotomy should be about 3 to 5 mm above the apex of the canine tooth. If miniplate rigid fixation is to be employed, the horizontal osteotomy can be performed at a slight higher level, allowing placement of screws into thicker bone.

If the treatment plan calls for a vertical impaction of the maxilla, calipers are used to measure the amount of bone to be removed, and a second osteotomy is performed above the first, as dictated by the measurement. The intervening bone strip is then removed.

A fine osteotome is introduced through the osteotomy in the anterior wall of each maxillary sinus and is gently malleted to extend the osteotomy horizontally across the posterior wall of each maxillary sinus. The medial wall is severed in an anteroposterior direction with the same fine osteotome. To avoid excessive bleeding at this stage, the surgeon may choose to limit the use of the osteotome to the anterior two-thirds to three-quarters of the medial antral wall, preserving the descending palatine artery. This adjacent bone can be fractured subsequently, allowing the potential preservation of the descending palatine artery in some patients. The microvascular studies of Bell and colleagues have shown that the maxilla derives adequate blood supply from the lateral soft tissue attachments alone, but preservation of the descending palatine artery is beneficial although not essential. The nasal septum is separated from the palate by the use of a U-shaped osteotome, which is introduced over the anterior nasal spine and malleted posteriorly.

The final step before mobilization of the maxilla is the separation of the pterygomaxillary junction. The tip of a curved osteotome is introduced into this area from its lateral aspect as the corner of the mouth is retracted. The index finger of the surgeon's opposite hand is then positioned on the soft palate, palpating the medial side of the pterygomaxillary junction. When malleting through this area, it is important to avoid comminuting the pterygoid plate area, because an intact pterygoid region can provide a buttress for supportive bone grafts.

The maxilla is now manually grasped and fractured inferiorly. The posteromedial wall of the maxillary sinus generally retains some intact bone, which is fractured at this stage. If possible the descending palatine vessels are preserved, but if these structures limit maxillary mobility, they may be clipped and divided. Repetitive manipulation of the maxilla by rocking and anterior distraction is then performed to gain mobility and to allow passive placement of the maxilla into its new position. Proper mobilization of the maxilla is *crucial* to success and is essential to avoid relapse.

In some cases the treatment plan calls for segmentalization of the maxilla to allow differential repositioning of the anterior and posterior maxillary segments. Such a situation would be seen in the correction of an anterior open bite in which the molar region is vertically repositioned to a greater degree than the anterior segment(s).

To perform a segmental osteotomy of the maxilla, the surgeon palpates the palatal mucosa adjacent to the site of the planned segmental osteotomy while creating that osteotomy with a rotary bur. The surgeon's tactile sense allows him to complete the osteotomy with the bur without damaging the palatal mucosa. Segmental osteotomies and ostectomies can be performed through the socket of an extracted tooth such as a first bicuspid when the treatment plan calls for contraction of the dental arch. Segmentalization is more commonly performed without extracting teeth. In this situation a rotary bur is used to divide the antral and nasal floor, and a fine osteotome is carefully malleted between the tooth roots, dividing the alveolar bone up to the crest of the ridge. Again, the surgeon's palpating finger spares the palatal mucosa and gingiva from injury. It is technically easier to perform interdental osteotomies before downfracturing the maxilla, while the maxilla is still firmly attached.

A horizontal strip of bone and cartilage is then removed from the inferior aspects of the nasal septum, somewhat exceeding the planned amount of vertical maxillary repositioning. In addition, any residual nasal crest of maxilla is removed from the floor of the nose, and the anterior nasal spine is removed if necessary.

The next step is to establish the new occlusion by wiring the mobile maxilla to the mandibular dentition. An acrylic occlusal splint may be employed to add further stability to the new occlusal relationship. It is frequently evident at this stage that further removal of bony interferences from the maxillary segments is necessary.

The mandible, with the maxilla firmly wired in place, is then manually guided posteriorly, ensuring that the condyles are gently seated in their most posterosuperior position. The mandible is rotated upward, allowing no translational movement whatsoever, and the maxilla guided into its final position. In cases of horizontal advancement, little work is necessary to remove bony interferences. Cases involving a vertical intrusion of the maxilla or segments thereof require careful removal of bone in the posterior region as well as the previously described resection of the inferior edge of the nasal septum. When there is vertical impaction of greater than approximately 6 mm, consideration should be given to reduction of the inferior turbinates and/or reduction of the nasal floor to preserve nasal airway space.

Once all interferences have been removed, the maxilla can be gently rotated into its new position. The maxilla is then fixed either by rigid miniplates at the piriform rim and zygomatic buttress areas, or by direct transosseous wiring and suspension from the inferior orbital rim. Rigid fixation with miniplates offers the advantage of early release from intermaxillary fixation.

Careful closure of the vestibular incision is critical in maintaining lip aesthetics. A small V-to-Y-plasty is performed anteriorly to preserve the projection of the lip lobule as well as the amount of vermilion show. The incision is closed in a running, locking fashion with small, equal suture bites. The nasal airway may be stented for 24 to 48 hours with nasal trumpets.

Mandible

Before the early 1970s the most common skeletal malocclusion to require surgical correction was mandibular prognathism. A variety of operations have been reported for the correction of this deformity, including osteotomy of a segment of the mandibular body and osteotomy of the mandibular ascending ramus. A blind subcondylar osteotomy using a Gigli saw introduced through percutaneous stab incisions was also popular.

The basic operation that has withstood the test of time was reported by Robinson (1956). This procedure entailed the creation of an oblique subcondylar osteotomy through an extraoral approach, and overlapping the condylar fragments laterally over the remainder of the ascending ramus as the mandible is posteriorly repositioned. Hebert and colleagues subsequently reported a transoral approach for a similar osteotomy, using the Stryker oscillating saw, and termed the intraoral vertical ramus osteotomy (IVRO).

Intraoral Vertical Ramus Osteotomy

After injection of the area with an epinephrine-containing local anesthetic, a vertical incision is made in the buccal mucosa lateral to the mandibular ascending ramus and extended into the mandibular buccal vestibule. In a subperiosteal plane the masseter is reflected off the lateral surface of the mandibular ramus, and the posterior border of the ramus is freed of soft tissue attachments. Specially designed retractors are used to engage the sigmoid notch above and the antegonial notch, and provide considerable lateral retraction of soft tissues. A smooth bulge on the lateral surface of the mandibular ramus can frequently be identified. This antilingula corresponds to the level of the mandibular foramen on the medial side of the ramus. The osteotomy should be performed posterior to this structure in order to avoid severing the inferior alveolar nerve. The osteotomy is almost vertical and extends inferiorly to a point just anterior to the mandibular angle. The cut is made with an angled oscillating saw designed for this purpose.

The condylar fragment is then reflected medially, and residual soft tissue attachments below the condylar neck are severed, preserving only some of the medial pterygoid attachment to prevent postoperative "sag" of the condyle. The condylar fragment is then overlapped onto the lateral surface of the mandibular ramus as the mandible is repositioned posteriorly.

After the second osteotomy, the teeth are wired into their new occlusion, with or without an occlusal splint. Each wound must then be rechecked to establish that the condylar fragment lies lateral to the mandibular ramus, and that each condyle head is seated posteriorly and superiorly into the glenoid fossa. The fragments are not wired. It is occasionally necessary to remove a small amount of bone from the posterior aspect of the sigmoid notch to allow the condylar fragment to approximate the lateral surface of the ramus. The wounds are closed in a routine fashion.

Rigid interosseous fixation is not practical when this osteotomy is performed transorally, and about 6 weeks of intermaxillary fixation followed by several weeks of night elastic fixation is required for proper healing.

Sagittal Split Ramus Osteotomy

The ascending ramus of the mandible is also the site of another osteotomy that can be used for either advancement or retrusion of the mandible. The sagittal split ramus osteotomy (SSRO) was reported by Trauner and Obwegeser and modified by Dal Pont, Hunsuck, Epker, and Wolford and colleagues. Like the IVRO, the SSRO is performed transorally. Its versatility allows correction of mild to moderate mandibular retrusion or prognathism and can accommodate moderate degrees of rotation at the osteotomy site. Owing to the extensive overlap of proximal and distal fragments inherent in this technique, it is amenable to rigid fixation by multiple lag screws, which can shorten or eliminate the need for intermaxillary fixation. The inferior alveolar nerve can be traumatized in the SSRO, and transient anesthesia of its distribution is not uncommon. Permanent anesthesia or paresthesia is an occasional complication of this technique; patients should be warned of this possibility.

The incision is similar to that performed for the IVRO, beginning in the buccal mucosa approximately 1 cm lateral to the middle ascending ramus, extending inferiorly into the mucobuccal vestibule, and ending adjacent to the second bicuspid. In contradistinction to the IVRO technique in which all periosteum is stripped off the lateral aspect of the ascending ramus, the lateral periosteum and masseter insertions are generally preserved in the SSRO. A lateral subperiosteal reflection is necessary only in the second molar area. The medial periosteum is reflected from the retromolar region along the anterior border of the ascending ramus, fully exposing the external oblique ridge of the mandible. With the aid of a forked retractor, the superior aspect of the wound is stretched upward until the retractors rests on the tip of the coronoid process. The sigmoid notch is then identified. With caution, this dissection is extended on the medial surface of the ramus until the mandibular foramen and inferior alveolar neurovascular bundle are identified. The medial subperiosteal dissection does not continue inferior to the mandibular foramen but does extend posteriorly to the posterior border of the ramus. The osteotomy begins with an anteroposterior cut of the medial cortex of the ascending ramus superior to the mandibular foramen. This can be performed with a long Lindemann bur or a reciprocating saw. The cut extends from medial to lateral, terminating at the inner aspect of the lateral cortical plate of the ramus.

A No. 703 bur is then inserted into the anterior aspect of this cut and used to create a vertical osteotomy through the cortex, hugging the medial side of the external oblique ridge. At the posterior aspect of the second molar, this line of osteotomy curves laterally, transecting the cortex of the external oblique ridge and obliquely extending to the inferior border of the mandible. Care must be exercised to cut cortex only and not extend into medullary bone. *The cortex of the inferior border of the mandible must be completely transected.* Access to this area can be maximized by removal of the bite block and closing the teeth together.

The osteotomy is completed with osteotomes. Beginning with fine osteotomes and progressing to larger ones, a split is developed that ideally follows the interface of the lateral cortex with the medullary bone of the mandible. In this fashion the inferior alveolar neurovascular bundle remains on the medial side of the split. The osteotomes are carefully twisted to produce a controlled fracture of the ramus, with most of the force applied at the inferior border. Frequently the path of the osteotomy courses through the inferior alveolar canal, and the neurovascular bundle becomes visible within the wound. With careful use of dental curettes the bundle can be teased out of the lateral segment if necessary, and adjacent bony prominences can be reduced.

A variety of "bad splits" can occur with this technique. A complete transverse fracture of the retromolar area can occur, mobilizing a third fragment within the wound, which usually consists of the medal ramus of the mandible, posterior to the second molar tooth. The presence of an impacted third molar tooth will weaken this part of the mandible and predispose to this type of complication. Owing to the excellent vascularity of this area, bone sequestration and nonunion are rare in this instance, and careful wiring of the fragments will produce a successful result. This potential problem can usually be eliminated by elective removal of the impacted third molar 6 months or more before the sagittal split osteotomy.

A more common type of "bad split" produces a complete horizontal fracture through the subcondylar area of the proximal fragment. Both Turvey and Behrman report a 3 per cent incidence of this complication. Completion of the sagittal split and close reapproximation of the subcondylar osteotomy site will produce successful results if the condyle remains posteriorly seated in the glenoid fossa.

After bilateral completion of the splits and rerouting of the inferior alveolar neurovascular bundles if necessary, complete mobilization of the fragments is performed. The periosteum at the posterior and inferior aspects of the split is incised and a curved Freer elevator is used to strip off residual periosteal attachments. The anterior segment is then advanced and the teeth are wired together, creating the new occlusion. If necessary, an occlusal splint is utilized. Each proximal fragment is manipulated to ensure that the condyle is gently and passively seated in its most posterior and superior position. The fragments are wired obliquely to maintain the condyle in this position. Alternatively, lag screw osteosynthesis can be performed through percutaneous puncture wounds. This technique requires additional lateral periosteal stripping but may obviate the need for intermaxillary fixation. The wounds are irrigated and closed in a routine fashion.

Anterior Mandibular Subapical Osteotomy

Some patients require inferior relocation of the anterior mandibular teeth to aid in leveling the occlusal plane. Such an anterior segmental osteotomy may be required to allow concomitant mandibular advancement, as dictated by model surgery.

A transverse anterior vestibular incision is made, and at the site of each interdental osteotomy a subperiosteal dissection is made toward the alveolar crest under the intact attached gingiva. The buccal cortex is deeply scored with a No. 701 bur and the interdental osteotomy is completed with a fine osteotome. A transverse osteotomy is then made approximately 3 to 5 mm under the apices of the anterior mandibular teeth, connecting the interdental osteotomies. A second transverse osteotomy is made below the first, corresponding to the predetermined amount of bone to be removed. After removal of bone wedge, the anterior segment is placed in its new position, bony interferences are removed, and the new occlusion is established with the occlusal splint. Transosseous wires or miniplate fixation may augment the stability of the segment. If an anterior segmental osteotomy is to be combined with an osteotomy genioplasty, an intact bridge of bone must be preserved between the mandibular halves.

Other Ramus Osteotomies

Severe mandibular deformities resulting from congenital or traumatic defects may require other procedures. A variety of osteotomies of the ascending ramus have been described, often including autogenous bone grafting to correct major malformations. These more extensive procedures are usually performed through an extraoral approach, and all of these procedures attempt to create some type of osteotomy in the ascending ramus between the mandibular condyle and the mandibular foramen.

Combined Osteotomies

Combined maxillary and mandibular osteotomies are often indicated when a significant component of the malrelationship is present in each jaw. Treatment plans that involve surgery in both jaws are becoming more frequent as diagnostic sophistication improves, and as surgeons become more reluctant to compromise the final occlusal and aesthetic result.

The technical execution of a combined maxillomandibular osteotomy requires that the surgeon retain a fixed point of reference so that the final result coincides with that of the prediction tracing and model surgery. The maxilla is repositioned first and its new relationship is checked by the use of an interim acrylic splint. This splint is made at the time of model surgery and reflects the new position of the maxilla fixed relative to the preoperative position of the mandible. Once the maxilla is firmly wired or plated in its new position by miniplates or transosseous wires, the mandibular osteotomy is performed and the teeth are wired together, using the final splint to establish the occlusion.

To avoid placing unnecessary strain on the maxillary fixation, the experienced orthognathic surgeon sequences his procedures as follows: (1) the procedure begins with the genioplasty, if indicated; (2) the saw and bur cuts of the sagittal split ramus osteotomy are completed, but the actual "split" is deferred; (3) the maxillary osteotomy is performed and the maxilla is repositioned according to the interim splint; and (4) after fixation of the maxilla the "split" of the mandible is completed and the mandible is placed into its final position, utilizing the final splint.

Complications

Significant complications of orthognathic surgery are fortunately rare. This low incidence is probably due to the excellent vascular supply of the oral structures.

Airway. Orthognathic surgery is generally performed under general nasoendotracheal anesthesia, tracheotomy being reserved for highly unusual situations. The nasal airway is frequently encroached on by maxillary osteotomy, and the oropharyngeal airway is similarly compromised by mandibular recession procedures. The further insult of intermaxillary fixation makes airway maintenance a potential problem in many orthognathic cases. The surgeon must assess the impact of the specific orthognathic surgical procedure on the patient's airway, and determine the need for observation in the intensive care unit postoperatively. The nursing staff must be familiar with the type of fixation employed and know how to release it in an emergency. Although the reported cases of death following orthognathic surgery are understandably few, it is likely that most such catastrophes are airway related.

Slough. Other than death, the most dreaded complication of orthognathic surgery is slough of a part or all of the osteotomized structure. Slough is very infrequent in the mandible but is occasionally seen in the maxilla, probably related to excessive trauma at the time of surgery. Division of the maxilla into multiple segments increases the possibility of a minor slough of gingiva, bone, or tooth. Minor alveolar sloughs can be treated by periodontal therapy, but major loss of a significant part of the upper jaw is best treated prosthetically. Hyperbaric oxygen therapy can be used to attempt early salvage of a jeopardized orthognathic case much as it can be employed to attempt salvage of a jeopardized flap, but there are no controlled studies to support this.

Relapse. Relapse is infrequent in contemporary orthognathic surgery, probably owing to appropriate matching of the procedure to the diagnosis, and appreciation for the principles of complete mobilization of fragments and condylar repositioning within the glenoid fossa.

Relapse of a dental nature is noted in patients with extensive preoperative dental compensations that have not been completely removed orthodontically. This type relapse entails migration of the teeth and alveolus over the basal bone and can occur undetected during the period of intermaxillary fixation. Proper orthodontic preparation will help avoid this problem.

Dental Complications. The loss of tooth vitality, as manifested by negative pulp testing after orthognathic surgery, is occasionally noted but is of little clinical significance. The actual devascularization of the dental pulp, with subsequent pulpal necrosis and periapical abscess formation, is exceedingly rare. In a 5-year follow-up of segmental osteotomies, 12 per cent of teeth adjacent to the osteotomies gave a negative pulp test to ethyl chloride, but only 3 per cent required endodontic treatment. Periodontal complications are also uncommon.

Infection. Infection is an uncommon complication of orthognathic surgery. In a retrospective series of 140 patients who underwent a variety of orthognathic procedures, a 1.4 per cent incidence of infection was observed. Of interest in this study is that two of the four patients who experienced an infection did so at the site of an alloplastic implant.

Orthognathic surgery is a challenging and gratifying aspect of maxillofacial surgery that involves the simultaneous surgical correction of both functional and aesthetic malrelationships of the jaws. Close cooperation with an orthodontist, accurate diagnosis, and treatment planning are essential for good results.