Chapter 108
Orthognathic Surgery Considerations in the Young Patient and Effects on Facial Growth

Larry M. Wolford and Daniel B. Rodrigues

Abstract Management of the growing patient with mandibular and/or maxillary dentofacial deformities presents a unique and challenging situation for orthodontists and surgeons. The surgical procedures required for correction of the deformity may affect the postsurgical growth and alter the dentofacial development. Facial growth may continue or be arrested postoperatively and negate the benefits of surgery performed, resulting in treatment outcomes that are less than ideal. Pediatric and adolescent patients with dentofacial deformities may require surgical treatment during active growth because of functional, esthetic, and psychosocial factors. From individual patient characteristics, the type of deformity, and the indications for early surgical intervention, it is possible to effectively treat many cases during growth. A thorough understanding of facial growth patterns and the effects of surgery on growth are essential, and each case needs to be evaluated individually. This chapter discusses the more common dentofacial deformities, the surgical techniques applicable for each, and the earliest age at which these surgeries can be performed with predictable results. There are, of course, exceptions to these general guidelines based on individual patient characteristics, hormonal or other factors affecting growth, the presenting deformity, co-existing disease, presence of TMJ pathology, other local or systemic factors, and the orthodontist's and surgeon's clinical abilities.

Abbreviations

AICR	Adolescent internal condylar resorption
AP	Anteroposterior
CT	Computed tomography
ILO	Inverted "L" osteotomy
MRI	Magnetic resonance imaging
SARPE	Surgically assisted rapid palatal expansion
SSRO	Sagittal split ramus osteotomy
TMJ	Temporomandibular joint
VRO	Vertical ramus osteotomy

L.M. Wolford (✉)
Department of Oral and Maxillofacial Surgery, Texas A & M University Health Science Center, Baylor College of Dentistry, Private Practice Baylor University Medical Center, Suite 400, Dallas, TX 75246, USA
e-mail: lwolford@swbell.net

V.R. Preedy (ed.), *Handbook of Growth and Growth Monitoring in Health and Disease*, DOI 10.1007/978-1-4419-1795-9_108,

108.1 Introduction

Management of the growing patient with mandibular and/or maxillary dentofacial deformities presents a unique and challenging problem for orthodontists and surgeons. The surgical procedures required for correction of the deformity may affect postsurgical growth and dentofacial development. Facial growth may continue or be arrested postoperatively and negate the benefits of surgery performed, resulting in treatment outcomes that are less than ideal. From individual patient characteristics, the type of deformity, and the indications for early surgical intervention, it is possible to effectively treat many cases during growth. A thorough understanding of facial growth patterns and the effects of surgery on growth are essential, and each case needs to be evaluated individually. Surgery is often undertaken with the expectation that additional treatment, including more surgery, may be required after the completion of growth. The chapter presented here is based on the available research and the senior author's clinical experience of more than 35 years in the correction of maxillary and mandibular deformities in the growing patient. Advantages and disadvantages of specific surgical techniques for correction of common jaw deformities, pertinence of age, and surgical considerations are discussed. The chapter should be viewed as a general outline that provides broad guidelines for management of these patients.

Questions often arise regarding the appropriate timing for orthognathic surgery in growing patients and the possible effects of such surgery on subsequent facial growth. Approximately 98% of facial growth is usually complete in girls by age 15 years and in boys by age 17–18 years (Broadbent et al., 1975; van der Linden, 1986). Some growing patients with dentofacial deformities exhibit proportionate growth between the maxilla and mandible, but others exhibit disproportionate growth with progressive worsening of the deformity. The surgical procedures required to correct these deformities may affect subsequent facial growth and dentofacial development. Thus, both surgical procedures and growth factors may affect the quality of the outcome.

Facial appearance is a fundamental factor in determining interpersonal relationships (Leggett, 1974; Mac Gregor, 1974). Thus, early orthognathic surgery may hold important psychosocial implications for some patients. Teenagers with significant dentofacial deformities are often perceived as being less attractive by their peers, and differences of behavior toward attractive and unattractive people have been well documented (Adams, 1982; Alley, 1988). Choosing nonsurgical compromised treatment or delaying orthognathic surgery until growth is complete could be damaging to the patient's self-image. Delaying treatment until adulthood can exacerbate problems related to pain, speech, airway, anatomy, occlusion, esthetics, temporomandibular joint (TMJ) function, masticatory function, and psychosocial factors.

This chapter discusses the more common dentofacial deformities, the surgical techniques applicable for each, and the earliest age at which these surgeries can be performed with predictable results. There are, of course, exceptions to these general guidelines based on individual patient characteristics, hormonal or other factors affecting growth, the presenting deformity, co-existing disease, presence of TMJ pathology, other local or systemic factors, and the orthodontist's and surgeon's clinical abilities. An understanding of the normal growth mechanism of the facial structures is important in determining the appropriate age for surgical intervention in the growing patient.

108.2 Normal Facial Growth Mechanisms

Two main types of bone development play an integral role in the development of the facial skeleton: intramembranous and endochondral ossification. The facial structure is a hybrid of osteogenic mechanisms: the cranial vault, upper face, midface, and majority of the mandible arise from intramembranous ossification, and the cranial base from endochondral sources. Developing bone receives genetic, chemical, and/or mechanical signals, that induce proliferation and differentiation, as well as impact the contour, shape, and volume of bone in any given area. This process is summarized by two co-existing theories: Wolff's law of mechanical stress (1870), and Moss's functional matrix theory (1960s). Bone responds to mechanical alterations induced by loading forces (Wolff), and to mechanical and paracrine communication from locoregional functional soft tissue (e.g., muscle) (Moss) (Reid, 2007).

Bones of the cranial vault and face exhibit three basic mechanisms of growth. First, intramembranous or endochondral ossification occurs. Principally, endochondral systems at the skull base (spheno-occipital posteriorly and sphenoethmoidal anteriorly), the midface (septopreshenoid and nasal septum), and at the mandibular condyle contribute to the three-dimensional expansion of the face throughout childhood into adulthood. Second, facial growth occurs through a series of sutures (synarthroses) that are strategically positioned to contribute to the three-dimensionality of the face; height, width, and projection. A third means of bone growth occurs from surface deposition and resorption, which contributes to bone volume and thickness (Reid, 2007).

Most craniofacial structures attain at least 70% of their growth potential by 4.5 years of age with completion of 91–93% of adult cranial vault height, 79–87% of the cranial base, 73–80% of the maxilla, and 66–76% of the mandible, which is the least mature component. The anteroposterior (AP) growth potential of the cranial base, maxilla, and mandible are less (i,e., have completed more of their growth) than their vertical counterparts. Males have greater growth potential than females (Buschang, 2007).

The paranasal sinus spaces, and particularly the nasal septum, have a significant role in the overall shape, contour, and form of the midface. The nasal septum is one of the key growth centers and provides the centrofacial region with the height and projection that characterizes this facial subunit (Reid, 2007).

The mandible is the last element to skeletally mature and is a keystone in the development of the facial skeleton, providing normo-occlusion and the maintenance of anteroposterior facial height (Reid, 2007).

Growth of cartilage is interstitial in nature; chondrocytes multiplication and extracellular matrix synthesis are primarily controlled by interstitial genetics and epigenetic factors. During growth of primary cartilage, the matrix effectively isolates the dividing chondrocytes from the environmental influences. Chondral growth of temporomandibular joint cartilage is distinctly different. Because secondary cartilage grows primarily by apposition, with proliferation occurring in progenitor cells that are surrounded by substantially less matrix, mechanical stimulation alters both the growth and the differentiation of condylar secondary cartilage cells (Buschang, 2007).

By the time children are 13.5 years of age, relative growth potential is markedly reduced to 5% or less for most components. The only exception is vertical mandibular growth, which retains considerable growth potential, especially for boys. Interestingly, the growth potential for ramus height for both males and females is greater than statural growth potential during the postpubertal years. This limits the ability of hand–wrist radiographs to define the end of active mandibular growth (Buschang, 2007).

108.3 Other Factors to Consider

The TMJs are the foundation for orthognathic surgery. If the TMJs are not stable and healthy, orthognathic surgical results may be unstable, with increased TMJ dysfunction and pain as a result. The TMJs must be appropriately evaluated before surgery. The most common TMJ disorder seen in patients requiring orthognathic surgery is the displaced articular disk. Significant problems can occur when orthognathic surgery is performed in the presence of untreated disk displacement (Goncalves et al., 2008). Our study evaluated 25 patients who had anteriorly displaced TMJ articular disks that were not treated when the orthognathic surgery was performed. Before surgery 36% of patients had some pain or discomfort, but 2 years after mandibular advancement, 84% of the patients had pain with a 70% increase in pain intensity. Postsurgery, condylar resorption occurred in 30% of the patients, which resulted in redevelopment of a jaw deformity and malocclusion (Goncalves et al., 2008). Other TMJ pathologic conditions that may affect treatment outcomes include condylar hyperplasia (Type 1 and Type 2), condylar hypoplasia, adolescent internal condylar resorption (AICR), idiopathic condylar resorption, osteochondroma, osteoma, reactive arthritis, rheumatoid arthritis, psoriatic arthritis, systemic lupus erythematosus, scleroderma, ankylosing spondylitis, and so forth. TMJ pathology must be assessed and properly managed to provide healthy, stable TMJs for a sound foundation and to achieve predictable results for orthognathic surgery. The TMJ conditions and pathology that affect growth will be discussed in the following chapter.

Nasal and oropharyngeal airway obstruction can have a profound effect on facial growth and development. Nasal airway obstruction is most commonly caused by hypertrophied turbinates, septal deviation or spurs, narrow nostrils, polyps, etc. Oropharyngeal airway obstruction can be caused by hypertrophied tonsils, adenoids, and/or soft palate/uvula, macroglossia, decreased oropharyngeal airway, retruded maxilla and mandible, transversely narrow dental arches, and intraoral tumors or other pathologies. Nasal airway obstruction creates obligate mouth breathing with subsequent downward and backward facial growth vector contributing to vertical maxillary hyperplasia as well as transverse maxillary hypoplasia with or without an anterior open bite. Addressing and correcting the nasal airway obstruction can be performed at the same time as the orthognathic surgery and may include partial nasal turbinectomies, septoplasty, removal of polyps, external nasal reconstruction. The oropharyngeal airway obstruction may require tonsillectomy, adenoidectomy, uvulopalatopharyngoplasty, and orthognathic surgery to advance the maxilla and mandible in a counter-clockwise direction to open the oropharyngeal airway.

The tongue is an important factor in jaw growth and development. Microglossia can cause underdevelopment of the jaws with lingual collapse of the dentoalveolar structures (Harvold, 1968). Macroglossia can result in overdevelopment of the jaws, especially the dentoalveolus. The etiology of macroglossia may be congenital (e.g., muscular hypertrophy, lymphangioma, or glandular hyperplasia) or acquired (e.g., cyst, tumor, acromegaly, or amyloidosis). The most common cause of macroglossia is muscular hypertrophy.

The tongue usually reaches its approximate adult size when a child reaches the age of 8 years (Proffit and Mason, 1975). An evaluation of the tongue should include clinical, radiographic, and functional assessments relative to interference with speech, mastication, airway, and treatment stability. Surgical reduction of the tongue can improve the stability and predictability of surgical outcomes in cases of absolute macroglossia. Wolford and Cottrell (1996) previously described the diagnosis of macroglossia and the indications for reduction glossectomy.

Other factors that can influence facial growth include genetics, mutations; developmental anomalies; endocrine disorders; trauma; infection; iatrogenic factors such as radiation, surgical trauma, medications, orthodontics, orthopedics; suture line ossification; ankylosis teeth or TMJ; systemic diseases; connective tissue/autoimmune diseases; neuromuscular disorders; tumors; and other pathologies. Any of these factors can affect the growth mechanisms of the facial structures.

108.4 Monitoring Facial Growth

Determination of growth rate and vector can be challenging. Because the jaws grow in all three dimensions, growth disturbances can also occur in more than one dimension. A good understanding of facial growth tendencies of the specific anatomical facial types (e.g., brachycephalic, normocephalic, or dolicocephalic) gives the clinician the important information about subsequent growth. Evaluation of the patient's medical and family history, as well as serial clinical and radiographic examinations, is helpful to identify growth imbalances in jaw structures. Comparison of serial lateral and anteroposterior cephalograms, and cephalometric tomograms that include the TMJ and posterior mandible can be extremely helpful in assessment of jaw growth. Specialized radiography (e.g., cone beam scan, computed tomography [CT] scans, magnetic resonance imaging [MRI], or nuclear scintigraphy) is indicated in certain cases, especially for identification of TMJ pathology. Hand–wrist films may be useful in determining the growth potential in some patients but are of little benefit in skeletal Class III patients with condylar hyperplasia. Serial dental models help in monitoring occlusal and dental changes.

108.5 Mandibular Deformities

108.5.1 Mandibular Hypoplasia

Mandibular hypoplasia is defined as retruded mandibular position resulting in a Class II skeletal relationship with either a normal or a deficient mandibular growth rate (Fig. 108.1a–d).

Normal growth rate. In patients with normal mandibular growth, the mandible grows from a retruded position relative to the normally positioned maxilla, or it may be smaller. With normal rates of maxillary and mandibular growth, the same Class II skeletal and occlusal relationship is maintained throughout growth (Emrich et al., 1965). This deformity can be corrected surgically during growth, with predictably stable results, by using the mandibular ramus osteotomies discussed below. With healthy TMJs and proper use of these techniques, the rate of growth is essentially unaltered by surgery, and harmonious postoperative maxillary (providing maxillary growth is normal) and mandibular growth can be expected with maintenance of the surgical result (Schendel et al., 1978; Snow et al., 1991) (Fig. 108.1).

Deficient growth rate. Patients with deficient mandibular growth will have progressively worsening mandibular retrusion and Class II malocclusion, as normal maxillary growth outpaces the deficient mandibular growth. If the deformity is corrected by surgery with mandibular advancement during growth, a Class II skeletal and occlusal relationship can be expected to recur, as the maxilla continues to grow normally and the mandible maintains its deficient growth rate (Huang and Ross, 1982). However, surgery during growth may be indicated in cases of severe deformities that adversely affect function (e.g., malnutrition resulting from masticatory dysfunction, airway compromise, or speech disorders) or psychosocial development. Under these circumstances, surgery during growth may improve the quality of life, but the patient and parents must be made aware that additional surgery will probably be necessary. Patients with deficient mandibular growth may have an associated TMJ pathology that requires surgical correction to achieve a stable outcome. Any of the ramus osteotomies discussed below could be used in deficient growth cases.

108.5.2 Mandibular Hyperplasia

Mandibular hyperplasia is defined as a protrusive mandibular position resulting in Class III skeletal and occlusal relationships. This condition may be initially seen with normal growth or with accelerated mandibular growth rates (Condylar hyperplasia Type 1). Condylar hyperplasia Type 1 can occur

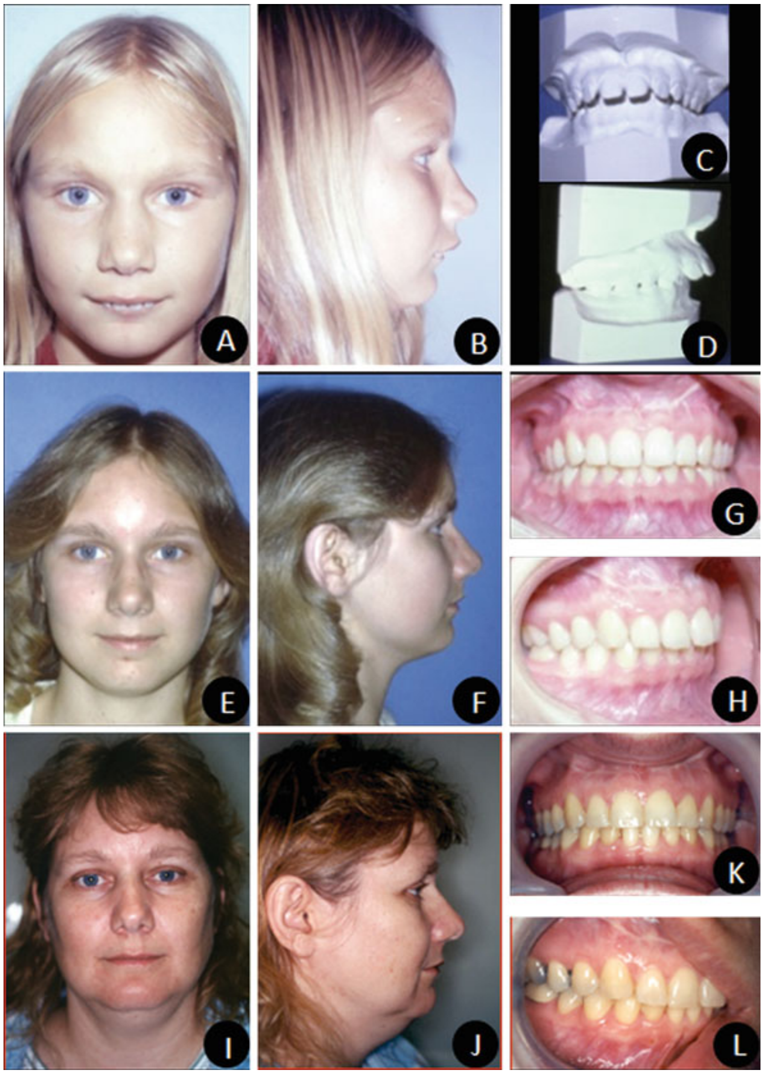


Fig. 108.1 This patient underwent mandible advancement using the sagittal split ramus osteotomy technique. (**a–d**) This 11-year-old female presented with mandibular hypoplasia and Class II malocclusion. (**e–h**) She is 5 years postsurgery at age 16 years showing good facial balance and Class I occlusion. (**i–l**) At 29 years postsurgery, age 40, she shows good stability of mandible projection and facial and occlusal results. "Material of the authors"

bilaterally or unilaterally with symmetric or asymmetric accelerated growth creating mandibular prognathism. Mandibular condylar hyperplasia Type 2 is related to unilateral condylar and mandibular enlargement secondary to an osteochondroma or osteoma and will be discussed in the next chapter on TMJ disorders (Wolford et al., 2009).

When the clinician treats mandibular hyperplasia, the patient's tongue size and its position must be carefully evaluated before surgery. The most common tongue-related factors affecting surgical results are macroglossia and habitual tongue placement. When the mandible is surgically moved posteriorly, the oral cavity volume decreases displacing the tongue posteriorly (Downie et al., 2000). An enlarged tongue or an abnormal tongue posturing habit may create postsurgical relapse by causing forward posturing of the condyle in the fossa, forward protrusion of the mandibular dentoalveolus, or shifting between segments that are wire fixated. The use of a reduction glossectomy may be indicated in specific cases (Wolford and Cottrell, 1996).

Normal growth rate. In patients with normal mandibular growth rates, the mandible initiates its growth from a forward position relative to the maxilla or the mandible is anatomically larger. With normal rates of maxillary and mandibular growth, the same Class III jaw relationship is maintained throughout growth. This deformity can be corrected with various ramus osteotomies during growth with predictable and stable results. With these techniques, the rate of growth should be unaltered by surgery and harmonious postoperative maxillary and mandibular growth can be expected, with maintenance of the surgical result.

Accelerated growth rate. In patients with accelerated mandibular growth, the deformity usually begins as a skeletal Class III relationship that becomes progressively more severe, or it begins as a Class I relationship and develops into a progressively worsening Class III relationship. The accelerated mandibular growth outpaces the normal maxillary growth. Note that maxillary growth deficiency with normal or accelerated mandibular growth can create the same Class III jaw relationship. Deficient maxillary growth must be ruled out because the type of treatment and timing for that condition is different. Typically, the increase in the mandibular growth rate almost always occurs in the condyles (condylar hyperplasia) and can cause elongation of the condylar head and neck as well as the mandibular body, which leads to development of dental compensations where the mandibular incisors become lingually inclined and the maxillary incisors become over angulated. The condition usually begins during the pubertal growth spurt, but it may precede or succeed it. The growth may continue far beyond the normal growth period into the middle twenties. Growth can be accelerated unilaterally or bilaterally and can be in a horizontal or vertical vector (9:1 ratio). Other TMJ pathologies that can cause unilateral excessive growth include osteochondroma, osteoma, tumors, fibrous dysplasia. Treatment considerations discussed here pertain to condylar hyperplasia.

There are essentially three options regarding the timing of surgery relative to active condylar hyperplasia growth (with option 3 being the authors' preferred method of management).

Option 1 is to defer surgery until growth is complete. This may require delaying surgery until patients are in their middle to late twenties. Consequently, they may have functional problems (mastication, speech), esthetic disfigurement, pain, and psychosocial stigmas associated with a severe facial deformity. Additionally, the magnitude of the deformity, if allowed to become fully manifested by this delay in treatment, may preclude an ideal result later. The hyperplastic condylar growth may result in severe deformation of the mandible. Compensatory changes will occur in the maxilla, dentoalveolar structures, and associated soft tissue structures, compromising the outcome and making the result less than ideal. This is particularly true in cases of unilateral involvement, which can lead to severe asymmetric deformities and can also result in TMJ internal derangement and dysfunction.

Option 2 is to perform surgery to posteriorly position the mandible during growth, with overcorrection of the mandible. The accelerated growth can be expected to continue after surgery, and additional surgery will be necessary if the overcorrection is insufficient or excessive. Early intervention may benefit the patient, however, relative to function, esthetics, and psychosocial concerns. If this alternative is chosen, the operation should be performed after the majority of maxillary growth is complete (girls, 14 years; boys, 17 years) to facilitate the estimation of overcorrection.

Option 3 is to surgically eliminate further mandibular growth with a high condylectomy (Fig. 109.2a, b from chapter "Temporomandibular joint (TMJ) pathologies in growing patients; affects on facial growth, and surgical treatment") and to simultaneously correct the jaw deformity (Wolford et al., 2009). Alternatively, the high condylectomy can be performed as stage 1 surgery, followed by orthognathic surgery at a later time. The high condylectomy removes the active growth center(s); and thus prevents further mandibular growth. If orthognathic and TMJ surgery are performed concomitantly, the SSRO is the procedure of choice because it maintains maximal soft tissue attachments and thus vascularity to the proximal segment. The ILO and VRO require increased striping of muscle and periosteum and may lead to vascular compromise of the proximal segment, in addition to causing difficulties with positional control of the condyle.

108.5.3 Treatment Modalities

With any of the following mandibular ramus surgical procedures, the preoperative rate of growth can be expected to be maintained after surgery. These techniques should neither stimulate nor hinder mandibular growth, provided that the TMJs are normal and healthy, the growth centers of the condylar heads are not damaged, and the articular disks are not displaced as a result of surgery. The vector of facial and mandibular growth, however, may be altered by a change in the orientation of the proximal segment and thus the condyle (Fig. 108.2) (Epker and O'Rayn, 1982). With any of the following techniques, if the proximal segment is rotated forward, an increased vertical facial growth vector will be seen postsurgery. Likewise, rotation of the proximal segment backward will result in a more horizontal facial growth vector postsurgery. Rigid fixation of the mandible compared with nonrigid fixation will improve immediate and long-term stability with all of the following techniques (Satrom et al., 1991).

Sagittal split ramus osteotomy (SSRO). The SSRO (Figs. 108.3 and 108.4) is more difficult to perform on younger patients because of greater bony elasticity, the thinness of the cortical bone, the presence of unerupted molar teeth in the surgical area, and the relatively shorter posterior vertical mandibular body height, as compared with adults. It can be used for moving the mandible posteriorly to correct mandibular prognathism or for mandibular advancement. It does have the advantages of easy application of rigid fixation as well as better positional control of the proximal segment and condyle compared to the other surgical ramus procedures. SSRO is best reserved for patients over the age of 12 years after the eruption of the permanent second molars, so that damage to these teeth during surgery can be avoided. Although the senior author (L.W.) has successfully performed this procedure on patients as young as 8 years old, we recommend waiting until at least age 12. In patients requiring TMJ surgery at the same operation (i.e., reposition articular disk, high or low condylectomies) the SSRO is the preferred procedure because it maximizes the vascularity to the

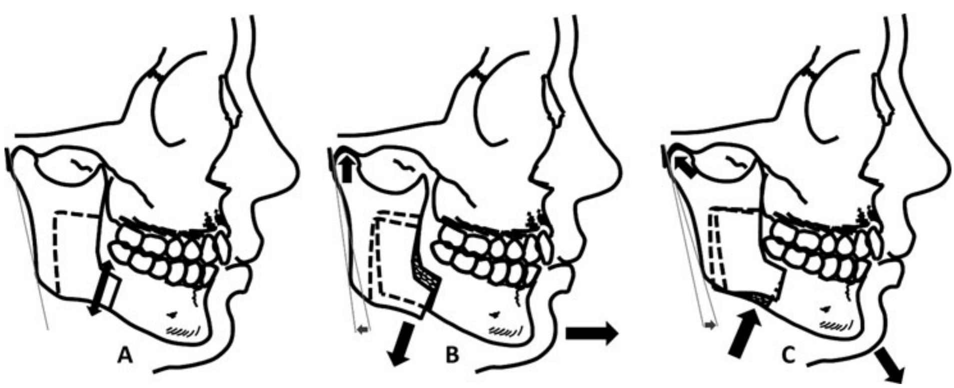


Fig. 108.2 The vector of facial and mandibular growth. (**a**) Rotation of the proximal segment can alter the vector of facial growth. (**b**) Rotation of the proximal segment down and backward will cause the mandible to grow in a more horizontal vector (**c**) rotation of the proximal segment upward and forward will cause the mandible to grow in a more downward vertical direction. "Material of the authors"

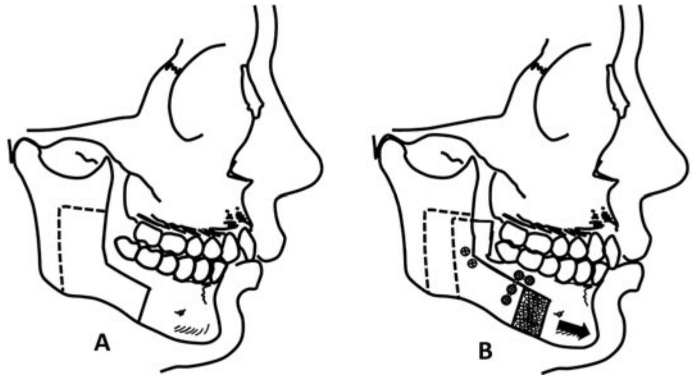


Fig. 108.3 Sagittal split ramus osteotomy procedure to advance the mandible. (**a**) Retrognathic mandible with the design of the osteotomy. (**b**) Mandible advanced and fixed with one "L" plate and four monocortical screws and two bicortical screws in the ramus. "Material of the authors"

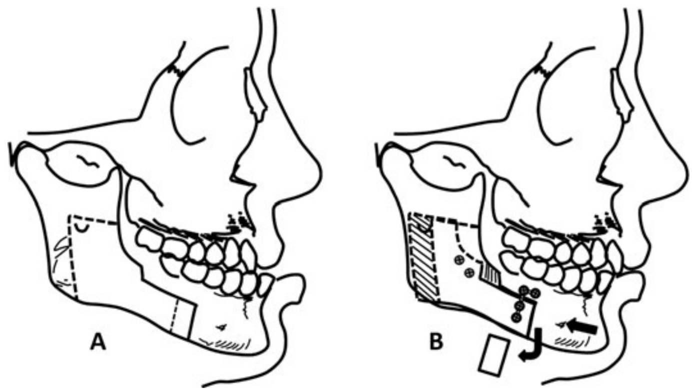


Fig. 108.4 Sagittal split ramus osteotomy to reposition the mandible backward. (**a**) Prognathic mandible with the design of the osteotomy. (**b**) Mandible repositioned backward and fixed with one "L" plate and four monocortical screws and two bicortical screws. The excess of bone on the proximal segment was removed to allow the bone segments to fit together appropriately. "Material of the authors"

proximal segment and allows better control of the condylar position (Fig. 108.1) (Wolford et al., 2009).

Inverted "L" osteotomy. The inverted "L" osteotomy (ILO) (Fig. 108.5) can be used to advance the mandible and vertically lengthen the ramus, but it may require bone or synthetic bone grafting to control the positional orientation of the proximal segment and to fill the bony voids between segments. The use of rigid fixation is recommended.

Vertical ramus osteotomy. The vertical ramus osteotomy (VRO) (Fig. 108.6) is more commonly used for moving the mandible posteriorly to correct mandibular prognathism than for mandibular advancement. It has significant limitations for mandibular advancement and vertical lengthening of the mandible and could require bone grafting with these movements to control positional orientation of the proximal segment and fill bony voids. The amount of mandibular advancement and vertical lengthening is limited by the temporalis muscle attachment and interference of the coronoid processes on the zygomatic arch. Thus, for larger movements a coronoidectomy may be needed, or preferably revert to other surgical options.

The application of rigid fixation can be technically difficult for VRO (Fig. 108.6), particularly from an intraoral approach. Without fixation, condylar position control may be inexact and can result in difficulties with postsurgical occlusion. The ILO and VRO can be performed on patients of virtually any age. Rigid fixation must be applied cautiously to avoid injury to developing teeth in younger patients.

Fig. 108.5 Inverted L osteotomy used to advance the mandible. (**a, b**) The gap created between the proximal and distal segments on larger movements requires grafting with bone or synthetic bone and stabilization with bone plates. “Material of the authors”

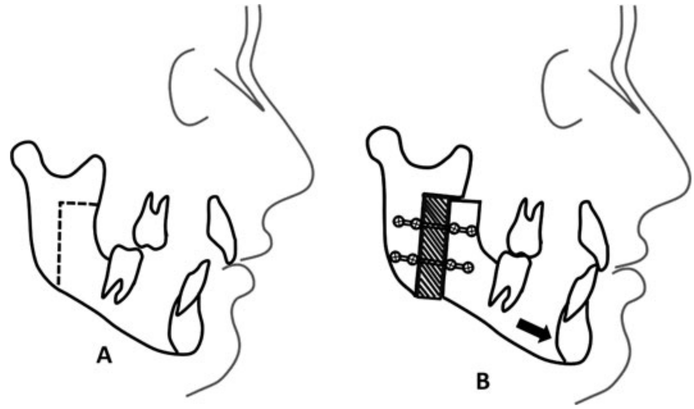
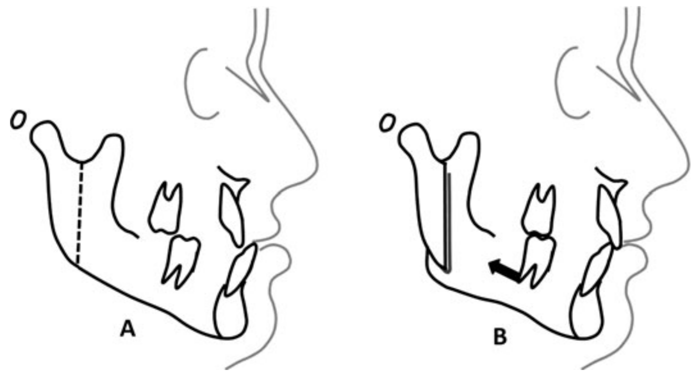


Fig. 108.6 Vertical ramus osteotomy (VRO) used to setback the mandible. (**a, b**) The mandible was positioned backward using the VRO. “Material of the authors”



High condylectomy. Surgically removing the superior 3–5 mm of the condylar head (Fig. 109.2a, b from chapter “Temporomandibular joint (TMJ) pathologies in growing patients; affects on facial growth, and surgical treatment”) will predictably stop anteroposterior and vertical growth of the mandible by removing the active growth center in the condyle (Wolford et al., 2009). Appositional mandibular growth and dentoalveolar growth will not be affected. TMJ function after surgery can be expected to remain normal if the condylar head is appropriately recontoured and the articular disk is repositioned and stabilized in a normal anatomical relationship between the condylar head and articular fossa. The Mitek bone anchor (Mitek, Westwood, MA) helps stabilize the repositioned disk to the condylar head. Its use has significantly improved the predictability of disk-repositioning surgery. The specific procedure to perform the high condylectomy will be discussed in Chapter 109.

Except in select cases, this procedure should generally be deferred until age 14 in females and age 16 in males when normal maxillary and mandibular growth are closer to completion. Since no further anteroposterior growth of the mandible can be expected after this procedure, continued maxillary growth usually results in a downward and backward growth vector for the maxillomandibular complex, but the occlusion should remain stable. In unilateral cases, the unoperated contralateral condyle will maintain normal growth and could cause shifting of the mandible toward the operated side. Therefore, in unilateral cases surgery should be deferred until age 15 years for females and 17–18 years in males. The severity of the deformity, however, may warrant earlier surgery in some cases. If the high condylectomies are done too early, then there is a risk of the maxilla growing forward at a normal rate with no AP growth of the mandible resulting in a Class II skeletal and occlusal relationship (Wolford et al., 2009).

108.6 Anterior Mandibular Dentoalveolar Deformities

Anterior mandibular dentoalveolar deformities have been defined as excessive, deficient, or asymmetric growth of the dentoalveolar structures. The condition may be due to overdevelopment or underdevelopment of alveolar bone, dental ankylosis, anodontia, premature tooth loss, macroglossia, microglossia, habitual factors, or genetics. The mandibular growth rate should not be affected by correction of these deformities unless adjacent teeth are damaged, which may result in dento-osseous ankylosis, a condition that will impair subsequent vertical alveolar growth. With orthodontics, the roots of the teeth adjacent to the vertical osteotomy can be diverged to create more space to facilitate the osteotomy and decrease the potential for root injury.

108.6.1 Treatment Modalities

Anterior and posterior mandibular subapical osteotomies. The anterior and posterior mandibular subapical osteotomies (Fig. 108.7) involve two vertical interdental osteotomies joined inferiorly by a horizontal osteotomy 4–5 mm below the tooth apices. The segment is placed in the desired position and stabilized, ideally with rigid fixation (Wolford and Moenning, 1989). Preoperative orthodontic treatment may be required to create adequate space between the roots of the adjacent teeth to safely complete the interdental osteotomies and decrease potential injury to the tooth roots. To avoid damage to the roots of developing teeth, which could result in ankylosis and alveolar growth impairment, the surgical procedure should be deferred until eruption of adjacent teeth in this region is essentially complete (i.e., when the patient is over age 12 years).

108.7 Mandibular Body Deformities

Mandibular body deformities are defined as excessive, deficient, or asymmetric development of the mandibular body. Correction of these deformities during growth should have no effect on subsequent mandibular growth, unless adjacent teeth are ankylosed or the developing teeth are damaged, leading to dento-osseous ankylosis, which will result in impaired vertical alveolar growth.

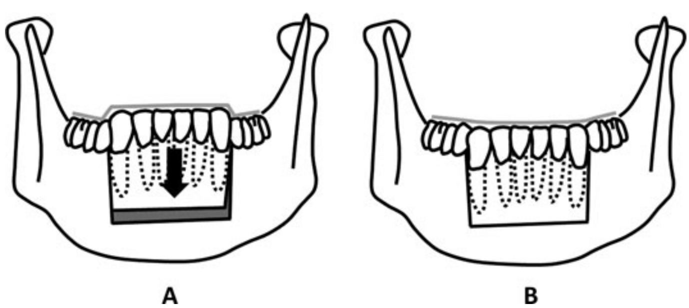


Fig. 108.7 Anterior mandibular subapical osteotomy. (**a**) Vertical interdental osteotomies are performed with a connecting horizontal osteotomy. The horizontal osteotomy should be positioned at least 5 mm below the apices of the teeth to minimize the risk of dental devitalization. (**b**) The segment can then be moved into position. “Material of the authors”

108.7.1 Treatment Modalities

Mandibular body osteotomy. A mandibular body procedure (Fig. 108.8) involves one or more osteotomies, extending the full vertical height of the mandibular body. These osteotomies are often performed between adjacent teeth. Rigid fixation and precise surgery will produce the most predictable results. Care must be taken to maintain the integrity of the inferior alveolar and mental nerves. It is recommended that this procedure be deferred until after the age of 12 years to minimize the risk of injury to the developing dental structures.

108.8 Chin Deformities

Deformities of the chin include excessive (macrogenia), deficient (microgenia), or asymmetric development. Chin deformities can occur in all three planes of space and can therefore affect the height, width, and anteroposterior dimensions of the anterior mandible. The treatment for macrogenia may involve osseous recontouring or spatial reorientation of the chin with osteotomy techniques. Microgenia may likewise be treated by altering chin position with osteotomies or with a graft, using bone, synthetic bone substitutes, or alloplastic implants (Moenning and Wolford, 1989). In younger patients in the mixed dentition there is an inherent risk of damage to developing teeth and to the inferior alveolar and mental nerves that closely approximate the inferior border of the mandible. Augmentation genioplasty with alloplastic implants that do not cause resorption of underlying bone can be performed at an earlier age, provided the implant can be stabilized without risk of injury to underlying dental structures.

108.8.1 Treatment Modalities

Osseous genioplasty. Various techniques are available for altering the dimensions of the chin by osteotomies (Fig. 108.9), including sliding horizontal osteotomy and the tenon and mortise technique. Bone segments may be fixed with wires, bone screws, or bone plates, and may require bone

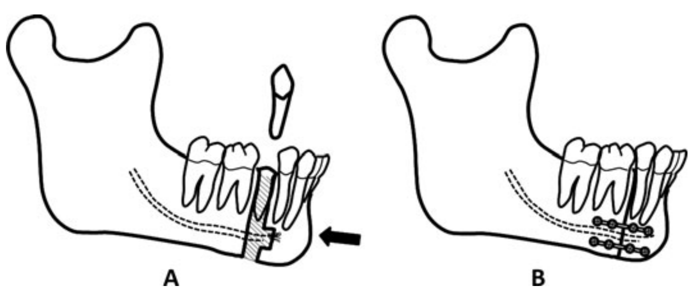


Fig. 108.8 Mandibular bodies deformities. (**a, b**) Mandibular bodies osteotomies can be performed in any area of the mandible to move the anterior segment of the mandible posteriorly or to alter the vertical and transverse position. Combining body osteotomies and sagittal split osteotomies of the ramus allows flexibility and movement of the posterior and anterior segments independent of each other. Rigid fixation maximizes stability and facilitates healing. "Material of the authors"

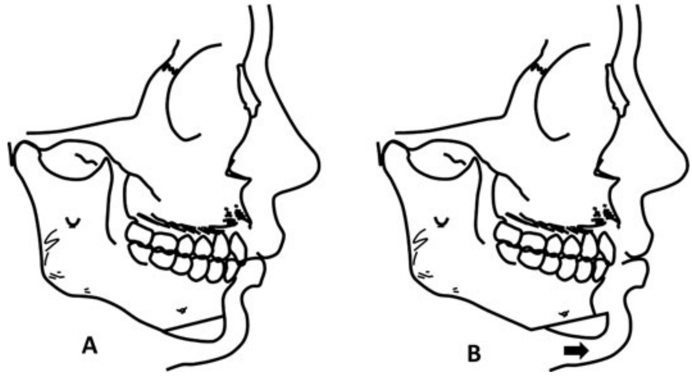


Fig. 108.9 Anterior mandibular horizontal osteotomy (osseous genioplasty). (**a, b**) This technique can be used to move the chin anteriorly, posteriorly, alter its vertical position, or change the transverse position. "Material of the authors"

or synthetic bone grafting, as in the case of vertical lengthening. These procedures have no significant effect on subsequent facial growth, with the exception of affecting appositional bone growth at pogonion, or if developing dental structures are injured, which may lead to dentoalveolar ankylosis and decreased vertical alveolar growth. The patient must be at a level of dento-osseous development (i.e., 12 years old or older), that will minimize the risk of damage to underlying teeth and neurovascular structures.

Augmentation genioplasty with alloplasts. Alloplasts (Fig. 108.10) that are proved not to cause bone resorption (porous block hydroxyapatite (Interpore 200, Interpore International, Irvine, CA) (Moenning and Wolford, 1989) and porous polyethylene (Medpor, Porex Surgical Inc., Newman, GA) can be placed in patients as early as age 8 or 9 provided they can be fixed to the bone without damage to underlying dental or neurovascular structures. Appositional growth at pogonion will be eliminated after placement of these implants. Certain alloplastic materials, (Proplast-Teflon [Vitek, Houston, Texas], Silastic [Dow Corning, Midland, Mo], and acrylic), have been documented to cause resorption of underlying bone, and their use is discouraged (Moenning and Wolford, 1989). It is best to wait until the patient is at least 12 years old before placing an alloplastic chin implant to minimize the risk of damage to underlying teeth and neurovascular structures.

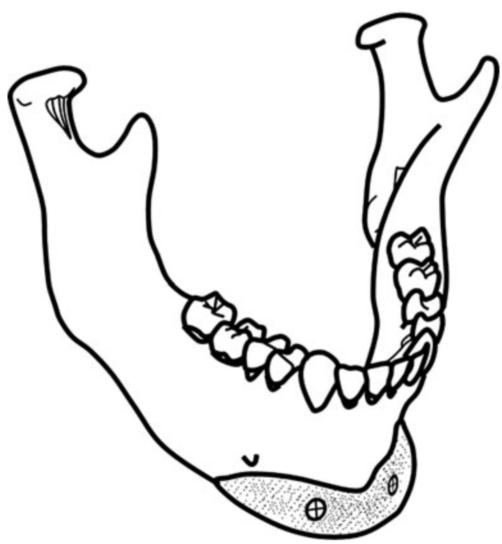


Fig. 108.10 Alloplastic implants. Alloplastic implants are available in many different sizes and can be used to augment the chin anteriorly. "Material of the authors"

108.9 Maxillary Deformities

108.9.1 Maxillary Hypoplasia

Maxillary hypoplasia is defined as deficient maxillary development and can occur in one or more of the three maxillary growth vectors including anteroposterior (AP), transverse, and/or vertical dimensions. Because the cause of this deformity is deficient maxillary growth, the jaw deformity usually gets progressively worse during growth. With deficient growth potential, normal growth cannot be expected after surgery. Correction of AP or vertical deficiencies during growth will result in recurrence of the Class III skeletal and occlusal relationship as the mandible continues to grow normally. Earlier surgery to advance, elongate vertically, and/or increase the transverse width of the maxilla may be indicated if significant functional, esthetic, and psychosocial impairments exist. When treating these cases during growth, the surgeon may choose to overcorrect the maxilla and allow the growing mandible to develop into it. If surgery is performed during growth, the patient and parents must be informed that future surgery will probably be necessary.

108.9.2 Maxillary Hyperplasia

Maxillary hyperplasia can occur in the horizontal or vertical vector and uncommonly in the transverse direction. Horizontal hyperplasia (maxillary protrusion) is defined as excessive forward growth of the maxilla that can result in a Class II skeletal and occlusal relationship. The condition is usually present early in life and may or may not get progressively worse with growth. No studies exist on facial growth after surgery in growing patients with this type of deformity. Postsurgical growth may be dependent on the procedure selected to correct the deformity.

Vertical maxillary hyperplasia, also known as vertical maxillary excess, is defined as an excessive vertical growth of the maxilla and may or may not include an anterior open bite deformity. It is often seen in patients with nasal airway obstruction that causes mouth breathing which is known to contribute to the development of this type of dentofacial deformity. This deformity can be corrected during growth with predictable results. However, vertical maxillary growth can be expected to continue postoperatively at the same rate as before surgery. While the maxilla continues to grow downward after surgery and the mandible continues to grow at a normal rate, the postoperative occlusal result should be maintained (Mojdehi et al., 2001). The vector of facial growth will continue to be downward and backward. AP maxillary growth cannot be expected after surgery if a Le Fort I osteotomy is used, but it may be preserved with the maxillary dentoalveolar (horseshoe) osteotomy (Fig. 108.11a–e).

108.9.3 Treatment Modalities

Le Fort I maxillary osteotomy. The Le Fort I osteotomy (Fig. 108.12), when performed during growth, inhibits further anterior growth of the maxilla (Friehofer, 1977; Mogavero et al., 1997). Vertical maxillary dentoalveolar growth will continue postoperatively at the same rate as before surgery (Epker et al., 1982; Washburn et al., 1982; Vig and Turvey, 1989; Mogavero et al., 1997). With normal mandibular growth a Class III skeletal and occlusal relationship will develop

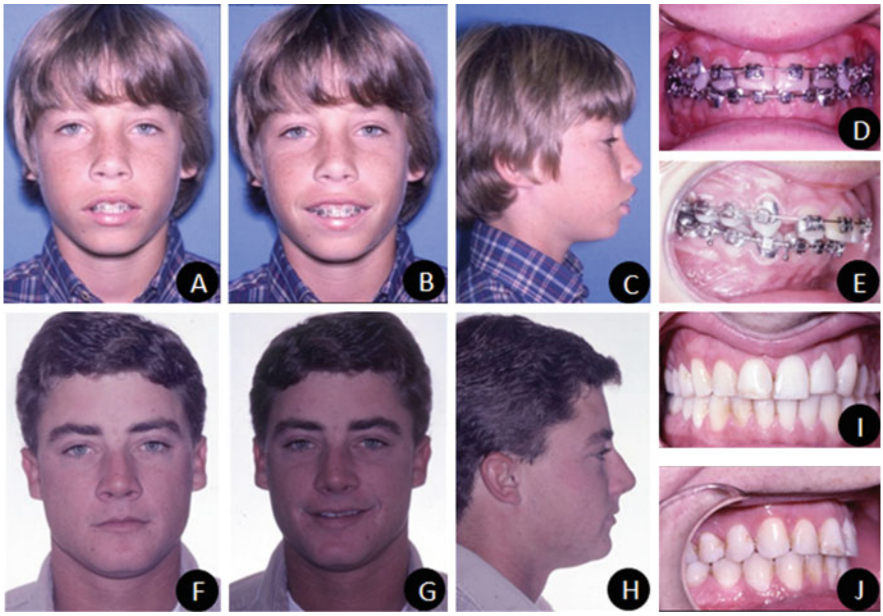


Fig. 108.11 This patient underwent bimaxillary surgery. (**a–e**) This 13-year-old male presented with maxillary hyperplasia (characterized by lip incompetence, gummy smile and increased incisor/lip relationship), mandibular hypoplasia, and Class II occlusion (**f–g**). The patient is 9 years postsurgery, age 22 years, showing good facial balance, lip competence, and stable skeletal and occlusion relationship. "Material of the authors"

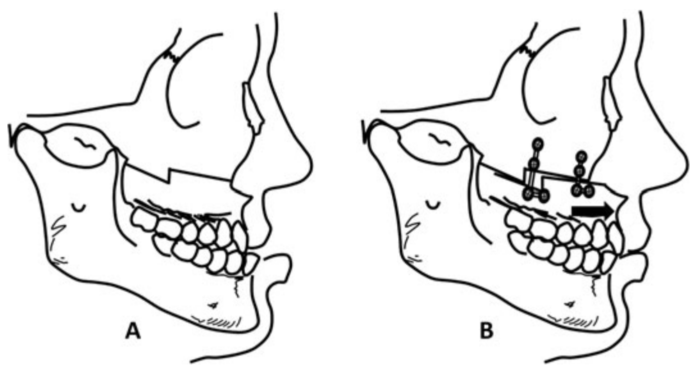


Fig. 108.12 The Le Fort I maxillary osteotomy. (**a, b**) The Le Fort I maxillary osteotomy allows the repositioning of the maxilla anteriorly, posteriorly, vertically, and laterally. Two bone plates are used on each side to stabilize the maxilla. If the maxilla is advanced or expanded significantly, then it is usually necessary to graft with bone or synthetic bone along the horizontal osteotomy. "Material of the authors"

after surgery for patients with presurgical maxillary hypoplasia or with normal maxillary growth. Although the Le Fort I maxillary osteotomy (Fig. 108.12) inhibits further anterior growth of the maxilla, patients with vertical maxillary hyperplasia can expect postsurgical vertical maxillary growth to continue at the same accelerated rate as before surgery until cessation of growth. In patients with normal mandibular growth, the maxillomandibular complex will grow in a downward and backward vector but the occlusion should remain stable (Epker et al., 1982; Mogavero et al., 1997; Mojdehi et al., 2001).

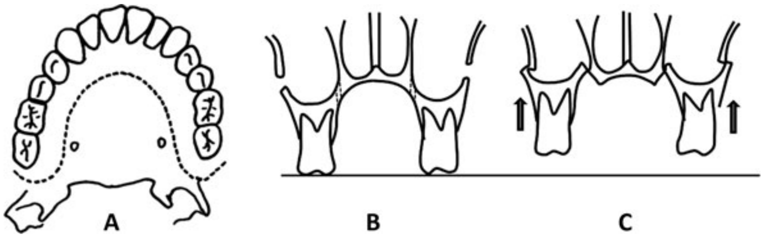


Fig. 108.13 The maxillary horseshoe technique. (**a**, **b**, and **c**) The maxillary horseshoe technique maintains the attachment of the palatal bone to the septum and lateral nasal walls but mobilizes and repositions the maxillary dentoalveolus. "Material of the authors"

The use of rigid fixation and appropriate grafting with either porous block hydroxyapatite (Interpore 200; Interpore International, Irvine, CA) or autogenous bone will maximize the stability and quality of the surgical outcome for all types of maxillary osteotomies (Satrom et al., 1991; Wolford et al., 2001).

Maxillary dentoalveolar (horseshoe) osteotomy. With the maxillary dentoalveolar osteotomy procedure (Fig. 108.13), the nasal septum remains attached to the stable palate, and only the dentoalveolar structures are mobilized. Therefore, AP maxillary growth may not be inhibited as it is with the Le Fort I osteotomy, with anterior maxillary growth expected to occur postsurgery at the same rate as presurgery. Unfortunately, there are no growth studies available on growth after maxillary dentoalveolar osteotomies. For maxillary hypoplasia the overall growth rate would be expected to remain deficient and result in the redevelopment of a skeletal Class III deformity. With normal or vertical hyperplastic maxillary growth and normal mandibular growth, there could be anterior maxillary growth maintained until normal cessation of growth. This procedure may offer the best potential for continued anterior maxillary growth after surgery. The maxillary dentoalveolar osteotomy is technically much more difficult to perform, particularly in patients with maxillary hypoplasia. In maxillary vertical hyperplasia, if done at an earlier age (i.e., 12 years in girls and 14 years in boys), there is a probability of excessive vertical maxillary growth rate recreating a vertical maxillary excess after surgery, although to a lesser extent than would occur if surgery was not performed. The occlusion should remain stable.

In vertical maxillary hyperplasia, Mogavero et al. (1997) demonstrated harmonious growth between the jaw structures when surgery was performed at a younger age. The horseshoe osteotomy, by keeping the nasal septum attached to the horizontal palatal plate, may provide continued anterior maxillary growth. However, this has not been clinically studied. Either of the maxillary procedures can be performed before the patient reaches age 10, provided sufficient space exists above the apices of the developing permanent teeth to place the osteotomies and apply fixation. Damage to developing tooth roots may result in dento-osseous ankylosis and localized dentoalveolar growth impairment. The technique is very challenging in the young patient in mixed dentition (Fig. 108.11f–j).

For both of the maxillary osteotomy techniques described here, the most predictable outcome can be expected if performed near to or after the completion of mandibular growth (approximately age 15 for females; age 17 or 18 for males), particularly for maxillary hypoplasia and normal maxillary growth. Serial lateral cephalograms are helpful in documenting cessation of mandibular growth. Theoretically, better postsurgical growth may be expected with the dentoalveolar osteotomy. Severe functional or psychosocial factors may indicate earlier treatment.

Surgically assisted rapid palatal expansion (SARPE). Surgically assisted rapid palatal expansion usually involves Le Fort I osteotomies without mobilization of the maxilla. It is a useful procedure in cases where the deficiency exists in the transverse dimension only. There are no studies available regarding growth after this procedure. In fact, this procedure may be contraindicated in most growing patients because the midpalatine suture has not normally closed; thus, the less invasive nonsurgical orthodontic/orthopedic expansion is possible. With SARPE, postoperative anterior maxillary growth may be inhibited by this procedure if the nasal septum is separated from the palatal bone. This procedure is rarely indicated in patients who are less than 15 years of age, but it can technically be done after complete root development and full eruption of the teeth adjacent to the vertical interdental osteotomy.

Double jaw surgery. In specific types of dentofacial deformities, surgically repositioning the maxilla and mandible at one operation (double-jaw surgery) can be performed during growth with predictable and harmonious growth after surgery (Fig. 108.11). Orthognathic surgery for the correction of vertical maxillary hyperplasia can be performed with corrective mandibular surgery for retrognathia or prognathism, if the preoperative rate of mandibular growth is normal, and the TMJs are healthy (Mogavero et al., 1997). The Le Fort I osteotomy will inhibit further anterior maxillary growth while allowing vertical maxillary growth to continue.

In cases involving mandibular prognathism secondary to active condylar hyperplasia, surgery involving high condylectomy will arrest the pathologic mandibular growth and can be combined with maxillary and mandibular osteotomies with predictable results, regardless of the rate of maxillary growth (Wolford et al., 2009). The high condylectomies should be performed first and the articular disk repositioned over the remaining condylar head, followed by routine double jaw surgery. When properly performed, the high condylectomies prevent further anterior growth of the mandible. With normal or deficient maxillary growth, the jaws and occlusion should remain in balance. In the presence of vertical maxillary excess, the vector of facial growth will be downward and backward. Surgical treatment of other combinations of deformities may not be predictable and should be performed after cessation of growth.

108.10 Cleft Palate Considerations

Although the facial growth potential in new born children with cleft lip and palate is relatively normal, multiple reconstructive maxillofacial surgical procedures to repair these clefts can result in impaired maxillary growth and development. Wolford et al. (2008) demonstrated that in cleft patients with maxillary hypoplasia or vertical hyperplasia, that following Le Fort I osteotomy to correct the dentofacial deformity and graft the alveolar cleft, there is resultant poor maxillary growth post surgery with development of skeletal and occlusal Class III relationships as well as transverse hypoplasia resulting in anterior and posterior occlusal cross bites. Orthognathic surgery may be performed on growing cleft patients when mandated by psychological and/or functional concerns. Careful case selection is imperative, and the surgeon must be cognizant of postsurgical outcomes when performing orthognathic surgery on growing cleft patients. No maxillary anterior or transverse growth can be expected as well as no compensatory increase angulation of the maxillary incisors can be expected. Cleft patients with proportionate presurgical growth exhibit disproportionate postsurgical growth, develop Class III skeletal and occlusal relationships as well as posterior crossbite as a result of adverse affects on maxillary growth. The presence of a posterior pharyngeal flap creates a greater decrease in anterior maxillary growth and significant increase in vertical growth.

Most cleft patients are best served by performing the orthognathic surgery after facial growth is complete (15 years old for females, 17–18 years old for males). However, selected patients can be treated surgically during growth if there are sound psychological and/or functional concerns. These patients should be treated with surgical over-correction in the anteroposterior and transverse dimensions. Patients who are still in mixed dentition phase must be operated carefully, specifically avoiding damage to developing permanent tooth buds. Careful case selection and appropriate surgery are imperative to minimize risks and the necessity for future surgery. In younger patients, considerations for distraction osteogenesis may be appropriate.

108.11 Conclusions

Pediatric and adolescent patients with dentofacial deformities may, at times, require surgical treatment during active growth because of functional, esthetic, and psychosocial factors. A good understanding of facial growth, available treatment options, and the effects of surgery on postoperative growth patterns will help the clinician improve treatment outcomes for these patients (Table 108.1). Serial clinical, dental model, and radiographic analyses are important in predicting growth rates and patterns for individual patients.

The information presented in this chapter is based on available research information and extensive personal clinical experience. It is not meant to be absolute, but instead, it should serve as a guide to formulate a specific treatment plan for each individual growing patient with respect to the appropriate type and timing of corrective surgical procedures on the mandible.

The type of facial deformity present and the specific growth vectors of the patient will affect the surgical outcome and must be carefully assessed before surgery. The patient and family must understand the expected results, potential risks, and possible complications that can occur as a result of early surgical intervention. Factors such as the presence of disproportionate mandibular and/or maxillary growth (excessive or deficient) and coexisting TMJ pathosis can significantly affect postsurgical growth and treatment outcomes and must be identified and treated appropriately.

108.12 Applications to Other Areas of Health and Disease

108.12.1 Normative Features of Growth

Psychological adaptation and quality of life in impaired growth

People with significant jaw deformities associated with abnormal jaw growth may also suffer from psychosocial problems associated with poor self-image.

Table 108.1 Key features of orthognathic surgery in patients during growth

1.	Facial and jaw deformities commonly occur during growth and development.
2.	Patients with dentofacial deformities may require surgical treatment during active growth because of functional, esthetic, and psychosocial factors.
3.	A thorough understanding of facial growth patterns and the effects of surgery on growth are essential, and each case needs to be evaluated individually.
4.	Surgical correction of jaw deformities can have adverse affects on subsequent growth, particularly maxillary surgery.
5.	Orthognathic surgery (corrective jaw surgery) is most predictable if done after cessation of growth, but some procedures can be done during growth with predictable outcomes.
6.	The TMJs must be healthy and stable (non-pathological) for predictable orthognathic surgical outcomes.

This table lists the keys features of orthognathic surgery in growing patients. “Material of the authors”

108.12.2 Adolescence

Male and female bone growth patterns in Chinese children and adolescents

Facial growth and development characteristics relating to facial deformities often develop during childhood and adolescence.

Summary Points

- Mandibular and maxillary deformities can grow at a normal, deficient, or excessive rates.
- This can create static or worsening jaw relationships with growth.
- Various mandibular and maxillary osteotomies can be used to correct these deformities.
- Mandibular osteotomies generally have minimal effect on mandibular growth.
- Maxillary LeFort I osteotomies inhibit forward maxillary growth, but vertical growth continues at the same rate as presurgery.
- Females usually have 98% of facial growth complete at 15 years and males at 17–18 years.
- The closer to the cessation of facial growth, the more predictable the surgical result.
- Temporomandibular joint pathology can affect facial growth and development and affect surgical outcomes of maxillary and mandibular osteotomies used to correct jaw deformities.

References

Adams GR. In: Miller A, editor. In the eye of the beholder: contemporary issues in stereotyping. New York, NY: Paeger; 1982. pp. 252–69.
Alley TR. In: Alley TR, editor. Social and applied aspects of perceiving faces. Hillsdale, NJ: 1988. pp. 167–18.
Broadbent BH Sr, Broadbent BH Jr, Golden WH. St Louis, MO: CV Mosby; 1975.
Buschang PH. In: Bell WH, Guerreiro CA. editors. Distraction osteogenesis of the facial skeleton. Hamilton, ON: BC Decker; 2007. pp. 141–51.
Downie M, Mehra P, Wolford L. J Oral Maxillofac Surg. 2000;58 Suppl 1:58–9.
Emrich RE, Brodie AG, Blayney JR. J Dent Res. 1965;44:947–60.
Epker BN, O'Ryan F. In: McNamara JA, Carlson DS, Ribbens KA, editors. The effect of surgical intervention on craniofacial growth. Ann Arbor, MI: University of Michigan; 1982. pp. 207–29.
Epker BN, Schendel SA, Washburn M. In: McNamara JA, Carlson DS, Ribbens KA, editors. The effect of surgical intervention on craniofacial growth. Ann Arbor: University of Michigan; 1982. pp. 231–50.
Friehofer HP. J Maxillofac Surg. 1977;5:267–97.
Goncalves JR, Cassano DS, Wolford LM, Santos-Pinto A, Marques IM. J Oral Maxillofac Surg. 2008;66:724–38.
Harvold EP. Am J Orthod. 1968;54:883–98.
Huang CS, Ross RB. Am J Orthod. 1982;82:89–102.
Leggett J. The human face. London: Constable; 1974.
Mac Gregor FC. Transformation and identity. New York, NY: Quadrangle; 1974.
Moenning JE, Wolford LM. Int J Adult Orthod Orthognath Surg. 1989;4:175–87.
Mogavero FJ, Buschang PH, Wolford LM. Am J Orthod Dentofacial Orthop. 1997;111:288–96.
Mojdehi M, Buschang PH, English JD, Wolford LM. Am J Orthod Dentofacial Orthop. 2001;119:106–16.
Proffit WR, Mason RM. J Am Dent Assoc. 1975;90:403–11.
Reid RR. Clin Plast Surg. 2007;34:357–60.
Satrom KD, Sinclair PM, Wolford LM. Am J Orthod Dentofacial Orthop. 1991;6:550–63.
Schendel SA, Wolford LM, Epker BN. Oral Surg Oral Med Oral Path Oral Radiol Endod. 1978;45:364–77.
Snow MD, Turvey TA, Walker D, Proffit WR. Int J Adult Orthodon Orthognath Surg. 1991;6:143–51.

van der Linden F. Facial growth and facial orthopaedics. Surrey, UK: Quintessence; 1986.
Vig KW, Turvey TA. Int J Adult Orthodon Orthognath Surg. 1989;4:110–28.
Washburn MC, Schendel SA, Epker BN. J Oral Maxillofac Surg. 1982;40:142–9.
Wolford LM, Cottrell DA. Am J Orthod Dentofacial Orthop. 1996;110:170–17.
Wolford LM, Moenning JE. Oral Surg Oral Med Oral Path Oral Radiol Endod. 1989;68:541–50.
Wolford LM, Karras SC, Mehra P. Am J Orthod Dentofac Orthop. 2001;119:102–5.
Wolford LW, Cassano DS, Cottrell DA, Mohamed ED, Karras SC, Goncalves JR. J Oral Maxillofac Surg. 2008;66:2524–36.
Wolford LM, Morales-Ryan CA, Garcia-Morales P, Perez D. Proc (Bayl Univ Med Cent). 2009;22:321–9.