Considerations for orthognathic surgery during growth, Part 1: Mandibular deformities

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Management of the growing patient with mandibular 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. Further, facial growth may continue 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 is 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 material presented here is based on the available research and the senior author's clinical experience of more than 25 years in the correction of mandibular deformities in the growing patient. Advantages and disadvantages of specific surgical techniques for correction of common mandibular deformities and pertinent age and surgical considerations are discussed. The material should be viewed as a general outline that provides broad guidelines for management of these patients. The management of maxillary deformities will be discussed in Part 2 of this article. (Am J Orthod Dentofacial Orthop 2001;119:95-101)

Qestions 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, and in boys by, approximately, age 17 or 18.[1,2] 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.[3,4] 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.[5,6] 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 2-part article 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. Part 1 deals with surgical treatment of mandibular deformities in growing patients, and Part 2 will focus on surgical correction of maxillary deformities and double-jaw surgery in growing patients. 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, other local or systemic factors, and the orthodontist's and surgeon's clinical abilities.

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.[7] The TMJs must be appropriately evaluated before surgery. The most common TMJ disorder seen in orthognathic surgery

patients is the displaced articular disk. Significant problems can occur when orthognathic surgery is performed in the presence of untreated disk displacement.[7,8] Before surgery, 36% of patients had some pain or discomfort, but 2 years after mandibular advancement, 88% of the patients had pain with increased intensity. After surgery, condylar resorption occurred in 30% of the patients, which resulted in redevelopment of a jaw deformity and malocclusion.[8] Other TMJ pathologic conditions that may affect treatment outcomes include condylar hyperplasia, condylar hypoplasia, idiopathic condylar resorption, osteochondroma, reactive arthritis, rheumatoid arthritis, psoriatic arthritis, systemic lupus erythematosus, scleroderma, and ankylosing spondylitis. TMJ pathology must be assessed and properly managed to provide healthy, stable TMJs for a sound foundation and the achievement of predictable results.

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. Macroglossia can result in overdevelopment of the jaws, especially the dentoalveolus. The etiology of macroglossia may be congenital (eg, muscular hypertrophy, lymphangioma, or glandular hyperplasia) or acquired (eg, 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.[9] 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 et al[10] previously described the diagnosis of macroglossia and the indications for reduction glossectomy.

Determination of growth rate and vector can be challenging. Because the jaws grow in all 3 dimensions, growth disturbances can also occur in more than 1 dimension. A good understanding of facial growth tendencies of the specific anatomical facial types (eg, brachycephalic, normocephalic, or dolicocephalic) gives the clinician important information about subsequent growth. Evaluation of the patient's medical and family history, as well as serial clinical and radiographic examinations, are 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 (eg, computed tomography [CT] scans, magnetic resonance imaging [MRI], or nuclear scintigraphy) are 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.

MANDIBULAR DEFORMITIES
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.

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.[11] 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 and mandibular growth can be expected with maintenance of the surgical result.[12-14]

Deficient growth rate. Patients experiencing deficient mandibular growth are initially seen with progressively worsening mandibular retrusion and Class II malocclusion, as normal maxillary growth outpaces the deficient mandibular growth. If the deformity is corrected surgically 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.[15] However, surgery during growth may be indicated in cases of severe deformities that adversely affect function (eg, 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.

Treatment modalities

With any of the following surgical procedures, the preoperative rate of growth can be maintained after
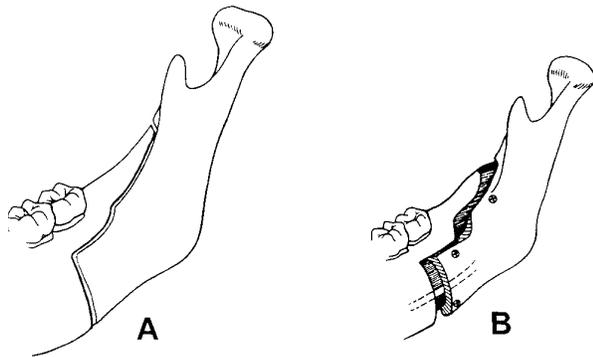
Fig 1. The SSRO procedure can be used to **(A** and **B)** advance the mandible or reposition it backward.
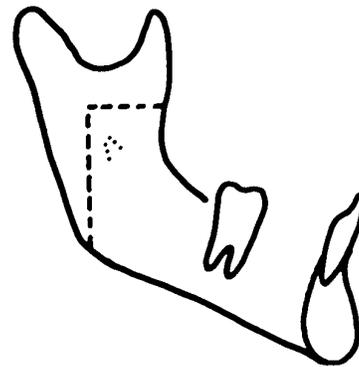

Fig 2. The ILO procedure can be used to advance the mandible or reposition it backward. When used to advance the mandible, the gap created between proximal and distal segments requires grafting with bone or synthetic bone.
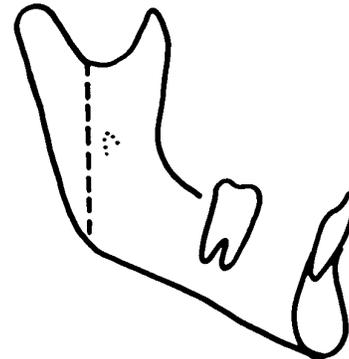

Fig 3. The VRO procedure can be used to advance the mandible or reposition it backward. The coronoid process limits the extent of movement. When used to advance the mandible, the gap created between proximal and distal segments requires grafting with bone or synthetic bone.

surgery. These techniques should neither stimulate nor hinder mandibular growth, provided that the TMJs are 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.[16] With any of the following techniques, if the proximal segment is rotated forward, an increased vertical growth vector will be seen after the operation. Likewise, rotation of the proximal segment backward will result in a more horizontal growth vector post-surgically. Compared with nonrigid fixation, the use of rigid fixation with all of the following techniques will improve immediate and long-term stability.[17]

Sagittal split ramus osteotomy. The sagittal split ramus osteotomy (SSRO)(Fig 1) 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, and the relatively shorter posterior vertical mandibular body height, as compared with adults. It does have the advantages of easy application of rigid fixation as well as better positional control of the proximal segment.

SSRO is best reserved for patients over the age of 12 years—that is, 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,[12,13] we recommend waiting until at least age 12.

Inverted "L" osteotomy. The inverted "L" osteotomy (ILO) (Fig 2) 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 3) can be used to advance the

mandible and vertically lengthen the ramus with appropriate bone or synthetic bone grafting as indicated to control the positional orientation of the proximal segment and fill bony voids. The amount of mandibular advancement and vertical lengthening possible with this technique 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 the clinician may need to revert to other surgical options.

The ILO and VRO can be performed on patients of virtually any age because the design of the osteotomies avoids developing teeth. However, care must be taken to avoid damage to developing teeth during application of rigid fixation.

Fig 4. High condylectomy procedure *(dotted line)* with articular disk repositioning provides a predictable method to stop mandibular growth, as well as good post-surgical TMJ function.

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 or accelerated mandibular growth rates.

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 volume of the oral cavity decreases. 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.[10]

Normal growth rate. In patients with normal mandibular growth rates, the mandible initiates its growth from a forward position relative to the maxilla, or it 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, and it must be ruled out because the type and timing of treatment 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 neck and mandibular body, which leads to development of dental compensations. The condition often begins during the pubertal growth spurt, but it may precede or succeed it, and the growth may continue far beyond the normal growth period into the middle and even the late 20s. 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 and fibrous dysplasia. Treatment considerations discussed here pertain to condylar hyperplasia.

There are essentially 3 options regarding the timing of surgery relative to 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 20s. Consequently, they may have functional problems (mastication, speech), esthetic disfigurement, pain, and psychosocial stigmas associated with a severe facial deformity.[18,19] 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 4) and to simultaneously correct the jaw deformity.[20] 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 stripping of periosteum and may lead to vascular compromise of the proximal segment, in addition to causing difficulties with positional control of the condyle.

Treatment modalities

With any of the following mandibular ramus procedures, the preoperative rate of growth can be expected to be maintained after surgery. Mandibular growth should not be affected by any of these techniques, provided that the condylar head is not damaged during surgery. The vector of facial growth, however, may be altered by a change in the orientation of the proximal segment and thus the condyle. The use of rigid fixation will improve long-term stability.

Sagittal split ramus osteotomy. The SSRO (Fig 1) is more difficult to perform on younger patients because of the greater bony elasticity, the decreased thickness of the cortical plates, the presence of unerupted molar teeth, and the relatively shorter posterior vertical mandibular body height in younger patients. It is the preferred technique when high condylectomy is performed simultaneously to stop excessive mandibular growth, because maximum vascularity to the proximal segment is maintained. Rigid fixation provides optimal long-term stability. Although the SSRO is more difficult to perform than the ILO or VRO, it is the preferred technique because it allows for good control of the condylar position.

SSRO is best reserved for patients over the age of 12—that is, after the eruption of the permanent second molars, so that damage to these teeth during surgery can be avoided.

Inverted "L" osteotomy and vertical ramus osteotomy. The ILO (Fig 2) and VRO (Fig 3) can be used effectively to correct mandibular prognathism. The amount of mandibular set-back possible with the VRO is limited by the temporalis muscle and the coronoid process, unless a coronoidectomy is performed. The application of rigid fixation can be technically difficult for both types of osteotomies, particularly from an intraoral approach. Without fixation, condylar position control may be inexact and can result in difficulties
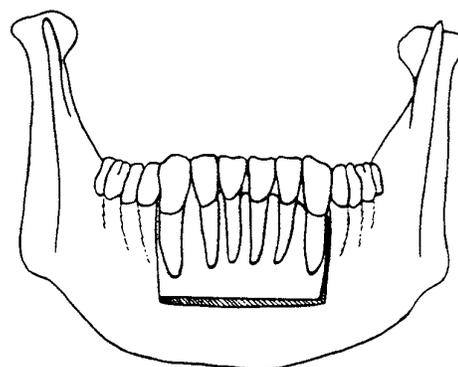

Fig 5. Anterior mandibular subapical osteotomy allows repositioning of the dentoalveolus.

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.

High condylectomy. Surgically removing the superior 3 to 5 mm of the condylar head (Fig 4) will predictably stop anteroposterior and vertical growth of the mandible by removing the active growth center in condylar hyperplasia.[20,21] 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, Mass) helps stabilize the repositioned disk to the condylar head. Its use has significantly improved the predictability of disk repositioning surgery.

Except in select cases, this procedure should generally be deferred until age 14 in girls and age 16 in boys—that is, 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. The severity of the deformity, however, may warrant earlier surgery in some cases.

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
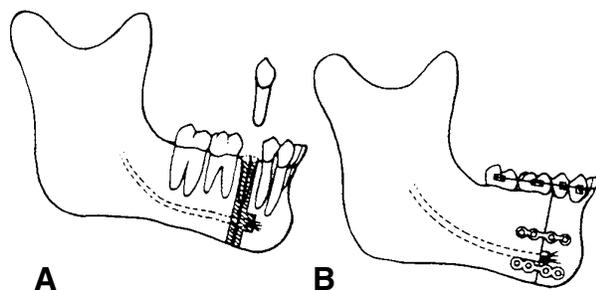
Fig 6. Mandibular body osteotomy **(A)** allows positional alteration in the body area. **(B)** Rigid fixation of segments is recommended.

Fig 7. Osseous genioplasty can be used to **(A)** augment or reduce chin prominence. **(B)** Alloplastic implants can also be used to augment chin.

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.

Treatment modalities

Anterior mandibular subapical osteotomy. The anterior mandibular subapical osteotomy (Fig 5) involves 2 vertical interdental osteotomies joined inferiorly by a horizontal osteotomy 4 to 5 mm below the tooth apices. The segment is placed in the desired position and stabilized, ideally with rigid fixation.[22] Preoperative orthodontic treatment may be required to create adequate space between the roots of the teeth to safely complete the interdental osteotomies. To avoid damage to the roots of developing teeth, which could result in ankylosis and alveolar growth impairment, this procedure should be deferred until eruption of adjacent teeth in this region is essentially complete (ie, when the patient is over age 12).

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.

Treatment modalities

Mandibular body osteotomy. A mandibular body procedure (Fig 6) involves 1 or more osteotomies, extending the full vertical height of the mandibular body.
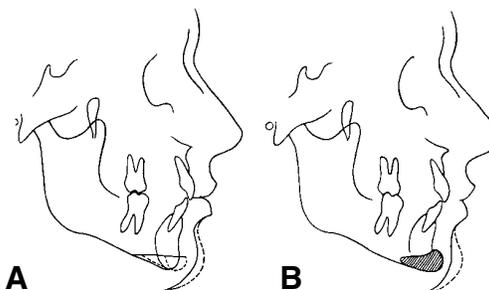
These osteotomies are often performed between adjacent teeth. Rigid fixation and precise surgery will produce the most predictable results. Care must be taken to maintain the integrity of the inferior alveolar and mental neurovascular structures. It is recommended that this procedure be deferred until after the age of 12 years to minimize the risk of injury to the developing dental structures.

CHIN DEFORMITIES

Deformities of the chin include excessive (macrogenia) or deficient (microgenia) development. Chin deformities can occur in all 3 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. In younger patients in the mixed dentition there is an inherent risk of damage to developing teeth and to the 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.

Treatment modalities

Osseous genioplasty. Various techniques are available for altering the dimensions of the chin by osteotomies (Fig 7, *A*), including sliding horizontal osteotomy and the tenon and mortise technique.[23,24] Bone segments may be fixed with wires, bone screws, or bone plates, and may require bone 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 dentoalve-olar ankylosis and decreased vertical alveolar growth. The patient must be at a level of dento-osseous development (ie, 12 years old or older), that will minimize the risk of damage to underlying teeth and neurovascular structures.

Augmentation genioplasty with alloplasts. Alloplasts (Fig 7, *B*) that are proved not to cause bone resorption (porous block hydroxyapatite,[25] and HTR[26]) can be placed in patients as early as age 8 or 9 to the early teens, 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.[25] Although certain alloplastic implants can be placed when the patient is 10 years old or younger, it is best to wait until the patient is at least 12 to minimize the risk of damage to underlying teeth and neurovascular structures.

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. Serial clinical, dental model, and radiographic analyses are important in predicting growth rates and patterns for individual patients.

The material presented in this article is based on available research information and extensive personal clinical experience. It is not meant to be absolute—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.

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