The Case for Surgical Expansion

Just as there are limits to sagittal Cl-II and Cl-III orthodontic camouflage treatment and certain cases require surgical correction, there are limits to orthodontic treatment in the transverse dimension.

In the 1995- Int. J. Adult Orthodon. Surg, we published indications for surgically assisted expansion.

- It has been established that no tooth measurement correlates with skeletal basal width and therefore, treatment objectives should be based upon clinical and radiographic characteristics of transverse deficiency especially for skeletally mature patients. Clinical inspection for transverse maxillary deficiency has been shown to be of inadequate diagnostic value. In the past, for the skeletal mature patient (15 to 16 years or older), and with a differential index that is less than or equal to 5mm--- orthodontic or orthopedic camouflage of the transverse skeletal dimension may be acceptable (reduced CT scan ideal).
- Treatment approaches depend upon maturity of the facial skeleton, severity of the skeletal pattern, periodontal susceptibility, type of appliance used, etc. (Examples: Hyrax, Haas-type or bonded appliance).
- Dental expansion and alveolar bending predispose to gingival recession and dental instability. Periodontal decortication procedures (less invasive) have made it possible to increase the alveolar limits of treatment. Bone screws have allowed us to change the basal dimension in transverse correction and they have extended the envelope of correction that is possible without the use of surgery. The limits of these procedures should be understood by all clinicians and will be discussed.

“There may be many ways to treat a malocclusion, but there can be but one diagnosis.”
Diagnosis and treatment of transverse maxillary deficiency

Treatment of skeletally mature patients is often complicated by inadequately treated or undiagnosed transverse skeletal discrepancy. This report emphasizes diagnosis of transverse maxillomandibular discrepancy and describes recommendations for treatment. Proper treatment strategy must consider the type and magnitude of transverse deficiency, patient's growth status, dentofacial esthetics, stability factors, and periodontal tissue health. Indications for surgically assisted maxillary expansion are listed, and the recommended surgical technique to improve frontal dentofacial esthetics, provide better stability, and enhance long-term periodontal health is described. Specific modifications in surgical technique to help prevent postoperative complications are included. New recommendations for sequencing, timing, and correction of transverse deficiency are presented. (Int J Adult Orthod Orthognath Surg 1995;10:75–96)

Introduction

There has been an increase in the number of adults seeking treatment for dentofacial deformities. This treatment may consist of orthodontics alone, or a combination of orthodontics and orthognathic surgery. Surgical procedures have classically included osteotomies to treat deformities in the vertical and sagittal planes. The posttreatment stability and relapse following orthognathic surgical procedures to correct these deformities have been well delineated.

The transverse dimension may be more crucial than either the anteroposterior or vertical dimensions in the achievement of a stable and functional occlusion. Unfortunately, since few orthodontists and oral and maxillofacial surgeons adequately evaluate the transverse dimension, treatment of skeletally mature patients is often complicated by an undiagnosed transverse maxillary deficiency. When a large transverse maxillary discrepancy exists and is diagnosed, adult patients have traditionally been treated with orthodontic expansion alone or segmental maxillary osteotomies, resulting in transverse maxillary instability and relapse following orthodontic appliance removal. The purpose of this paper is to identify clinical and radiographic characteristics of transverse maxillary deficiency and to discuss the methods used for diagnosis and treatment of this deformity in the skeletally mature patient.

Etiology of transverse maxillary deficiency

The etiology of transverse maxillary deficiency is multifactorial, including congenital, developmental, traumatic, and iatrogenic (ie, cleft palate repair) factors. A common example of a developmental etiology of transverse maxillary deficiency is the syndrome that results following a long-term oral thumb habit. This syndrome includes an anteri-
or open bite associated with unilateral or bilateral posterior crossbite and a high palatal vault (Fig 1). After cessation of the oral habit, the anterior open bite often resolves due to a passive settling of the maxillary anterior segment. However, the transverse maxillary deficiency does not routinely resolve and its correction eventually requires orthopedic or surgical intervention.

**Diagnosis of transverse maxillary deficiency**

Accurate diagnosis and treatment of maxillary transverse deficiency is critical to long-term stability of the correction of skeletal dysplasia. However, diagnosis of transverse maxillary deficiency in the patient in whom growth has slowed or the midpalatal suture has fused can be difficult. This may be because there are minimal soft tissue changes associated with isolated transverse maxillary hypoplasia. The soft tissue changes are limited to a degree of paranasal hollowing and a narrow nasal base. Deepened nasolabial folds and zygomatic hypoplasia are often seen, depending upon the associated maxillofacial deformities (Figs 2a and 2b). In contrast, isolated anteroposterior and vertical disharmonies are easier to diagnose since they often have obvious soft
Fig 3a (left) | Intraoral view of a patient with severe transverse maxillary hypoplasia. Note the bilateral palatal crossbite and crowded, rotated, and palatally and buccally displaced teeth.

Fig 3b (right) | Occlusal view of another patient with transverse maxillary hypoplasia. Note the narrow, tapering maxillary arch form (hourglass shape) and narrow, high palatal vault.

tissue anomalies (ie, protrusive or deficient chin or "gummy" smile). Consequently, when sagittal and vertical dysplasias exist concomitantly with a deformity in the transverse dimension, they often clinically mask the transverse maxillary deficiency. Therefore, it is not surprising that clinical inspection for transverse maxillary deficiency has been shown to be of unsatisfactory diagnostic value.⁶

Judgment involving the necessity for surgery in a maxillary transverse deficient patient requires an initial determination of the existence and severity of the discrepancy and differentiation between the skeletal and dental components of the deformity.⁷ An accurate diagnosis should involve both clinical and radiographic evaluations.

Clinical evaluation

There are several clinical indicators of maxillary transverse deficiency, including: unilateral or bilateral palatal crossbite; crowded, rotated, and palatally or buccally displaced teeth; a narrow tapering maxillary arch form often described as an hourglass shape; and a narrow, high palatal vault (Figs 3a and 3b).

When evaluating a crossbite, a delineation must be made between displacement of teeth relative to basal bone and a true skeletal crossbite due to a wide mandible or narrow maxilla. Dental crossbites with tilted teeth are easily treated with orthodontic therapy. Jacobs⁸ has stated that if a crossbite involves more than one or two teeth, the crossbite is probably skeletal in nature. Depending upon the degree of transverse dysplasia, crossbites can be unilateral, bilateral, skeletal, dental, or a combination of these. Unilateral dental crossbites occur less frequently; they are usually associated with mild maxillary transverse deficiency and often with a functional jaw shift (Figs 4a and 4b). Bilateral crossbites are more common and are associated with moderate to severe maxillary transverse deficiency. Skeletal crossbites result from one of the following maxillomandibular combinations: (1) narrow maxilla, normal mandible; (2) normal maxilla, wide mandible; (3) narrow maxilla, wide mandible. Transverse maxillary deficiency in the patient exhibiting a narrow maxilla and wide mandible is the most difficult to correct and is the most susceptible to relapse. This is because the mandible can be narrowed less effectively, necessitating that a majority of the correction of the transverse discrepancy be performed in the maxilla.

As mentioned previously, disharmony in the other dimensions of the maxillomandibular skeleton are often associated with maxillary transverse deficiency and may mask its diagnosis. Since during growth the maxilla enlarges in a vertical, anteroposterior, and transverse direction,⁹ the most common deformities associated with transverse maxillary deficiency are maxillary vertical and/or anteroposterior hypoplasia. Other associated dentofacial deformities include mandibular prognathism, mandibular sagittal deficiency, apertognathia, and repaired cleft palate.
Radiographic evaluation

The posterior-anterior (PA) cephalogram is the most readily available and reliable radiograph for identification and evaluation of transverse skeletal discrepancy. A standardized PA cephalometric radiographic technique that will allow superimposition of radiographs, comparison of linear measurements, and evaluation of radiographs over time should be employed. Ricketts developed the Rocky Mountain Analysis, and he suggested norms and chose specific radiographic landmarks and measurements to assess transverse discrepancy between the maxillae and mandible (Figs 5a and 5b). These landmarks are JR (jugale right), JL (jugale left), AG (antegonion right), GA (antegonion left), ZR (zygomatic right), and ZL (zygomatic left). Using these landmarks, the effective maxillary width, effective mandibular width, and the frontolateral facial lines can be constructed.

The effective maxillary width defines the width of the maxilla and is the linear measurement between the points JL and JR (bilateral points on the jugal process at the intersection of the outline of the
Two Methods for Determination of the Existence of a Transverse Maxillomandibular Width Differential

1. Maxillomandibular Width Differential

<table>
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<tr>
<th>Normal</th>
<th>Patient</th>
<th>Difference</th>
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<td>Max-Mand Width Differential (R)</td>
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</tr>
<tr>
<td>Max-Mand Width Differential (L)</td>
<td>10 ± 1.5 mm</td>
<td></td>
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<tr>
<td>Total Transverse Discrepancy</td>
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2. Maxillomandibular Transverse Differential Index

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<th>Change/Yr. to age 16</th>
<th>Norms (Expected)</th>
<th>Patient (Actual)</th>
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<td>Effect. Mandibular Width GA to AG</td>
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<tr>
<td>Effective Maxillary Width JR to JL</td>
<td>62 ±3 mm +0.6 mm</td>
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Normal Values

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<th>Mand.</th>
<th>Diff.</th>
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<td>66.2</td>
<td>85.8</td>
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Expected Maxillomandibular Diff. = Expected Mand. Width - Expected Max. Width _______ mm
Actual Maxillomandibular Differential = Actual Mand. Width - Actual Max. Width _______ mm
Expected- Actual Maxillomandibular Differential = _______ mm
maxillary tuberosity and the zygomatic buttress). The effective mandibular width defines the width of the mandible and is the linear measurement between the points AG and GA (bilateral points at the lateral inferior margin of the antegonial protuberance, just below the antegonial trihedral area). The frontolateral facial lines are two lateral lines constructed from ZR, ZL (bilateral points on the medial margins of the zygomaticofrontal suture, at the intersection of the orbit) to the points AG and GA (Fig 5a).\textsuperscript{5,11}

Using these landmarks, two separate differential measurements are utilized to evaluate transverse maxillary deficiency radiographically: (1) the maxillomandibular width differential and (2) the maxillomandibular transverse differential index. The maxillomandibular width differential is a measurement from the frontolateral facial line to JL and JR, respectively, along the effective maxillary width line (Fig 5a). This measurement is calculated independently for each side and compared with a normal value of 10 ± 1.5 mm. If this radiographic measurement is greater than 10 mm, a transverse discrepancy between the maxilla and mandible is present.\textsuperscript{5,11} The difference between the measured distance and 10 mm summed from each of the two sides is the total transverse deficiency (Fig 5b). This method is useful for determining the total discrepancy and demonstrating if there is a greater deficiency on one side or the other. However, it is not useful for determining in which arch the discrepancy is located.

The maxillomandibular transverse differential index is the expected maxillomandibular difference (an established norm for different ages) minus the actual measured maxillomandibular difference. The expected maxillomandibular difference is defined as the age-appropriate--expected AG-GA distance minus the age-appropriate--expected J point-J point distance. The actual maxillomandibular difference is defined as the actual AG-GA measurement minus the actual J point-J point measurement (Fig 5b).\textsuperscript{11} If in a skeletally mature patient (15.5 years or older) the maxillomandibular transverse differential index is greater than 5 mm, surgically assisted expansion may be indicated. If the differential index is less than or equal to 5 mm, orthodontic or orthopedic expansion may effectively correct or camouflage the transverse skeletal problem. This method allows easier identification of which arch is deficient or excessive because actual values can be compared to normal values. Normal values have been suggested for the Caucasian race and should not be considered normal values for all races and ethnic groups.

Although the PA cephalometric radiograph is the current standard for the evaluation of the transverse skeletal dimension, frontal tomography is an accurate method for diagnosis of transverse skeletal deficiency and monitoring transverse expansion (Figs 6a to 6d). While CT scanning currently may be the ideal radiographic technique for evaluation of this deformity, its use is not cost effective and necessitates an unacceptable level of radiation exposure to the patient.

Treatment of transverse maxillary deficiency

After a diagnosis of transverse maxillary deficiency has been established using clinical arch width measurements and radiographic techniques, treatment options can be determined and the appropriate treatment approach selected. The correction of transverse maxillary deficiency should be accomplished by rapid maxillary expansion (RME), either orthopedic or surgical. The efficacy and long-term stability of RME depends upon the nature of the expansion forces used and the degree of maturity of the facial skeleton.\textsuperscript{12} To achieve the required expansion and stability, transverse maxillary expansion should be accomplished by sutural adjustments in the craniofacial complex, not by alveolar remodeling and dental tipping.\textsuperscript{13,14} The method of correction chosen is dependent upon several fac-
Figs 6a to 6d  Standardized frontal tomograms obtained before (a,c) and after (b,d) surgically assisted maxillary expansion.

Fig 6a (left)  Pre-expansion through first premolar region. Note intact palate and appliance with closed midpalatal jack screw.

Fig 6b (right)  Postexpansion through first premolar region. Note radiographic magnitude of the separation in the palate and the expanded midpalatal jack screw.

Fig 6c (left)  Pre-expansion through the first molar region. Note intact palate and closed midpalatal jack screw.

Fig 6d (right)  Postexpansion through the first molar region. Observe magnitude of the midpalatal split and expansion of the jack screw appliance.

Fig 7  Pretreatment full facial photograph of a patient with severe transverse maxillary hypoplasia. Note negative space (defined as the space between the corner of the mouth and the buccal surfaces of the maxillary dentition present during full smile). After expansion of the maxilla, negative space will be decreased and the corners of the mouth will be filled with tooth structure.

Factors, such as type of transverse deficiency (skeletal, dental, or some combination), patient's skeletal growth status (whether it has essentially ceased; i.e., fusion of the maxillofacial sutures), magnitude of the transverse discrepancy based upon radiographic analyses, and type of periodontal tissues exhibited by the patient.

Benefits of correction of transverse maxillary deficiency include improved dental and skeletal stability; less need for tooth removal for orthodontic alignment of the dentition; improved esthetics by the elimination of negative space (Fig 7) leading to increased buccal tooth visibility when smiling; potential for improved long-term periodontal health; and, occasionally, improved nasal respiration due to reduced nasal resistance.13,16
Orthopedic maxillary expansion

Orthopedic maxillary expansion (OME) is accomplished by placing transversely directed forces in the orthopedic range on the maxilla to achieve transverse maxillary expansion. Angle first described opening of the midpalatal suture by OME in 1860. The technique was attempted in both adults and children with mixed results during the next century. The concept was reintroduced by Haas in 1961. Orthopedic expansion has been successful primarily in children prior to sutural closure. Transverse maxillary growth significantly slows, and the maxillotlacial sutures close around 14 to 15 years of age in females and 15 to 16 years of age in males. Orthopedic expansion is accomplished with a Haas-type or bonded appliance (Figs 8a to 8d). Rapid, as opposed to slow, maxillary expansion is employed to maximize skeletal expansion over dental expansion. The most effective results have been obtained when one of

the several designs of the jack screw appliance has been used. The Haas-type appliance has acrylic palatal flanges incorporated into the appliance and has been shown to preferentially result in skeletal expansion with less dental tipping (Fig 9). However, because of the anchorage with acrylic palatal pads, there is increased risk of palatal tissue impingement if adequate sutural release does not occur orthopedically or by surgical assistance. The Hyrax appliance is similar in design but only has the expansion screw and a metal framework without acrylic palatal coverage (Fig 10). Its use has been shown to result in more dental tipping and less skeletal expansion for late-treatment patients and adults. The occlusal-coverage Haas-type appliance is basically a hybrid of the Haas appliance and a flat-plane occlusal-coverage splint (Fig 11). It must be physically bonded to the maxillary teeth. Its use is recommended in patients with a periodontally compromised dentition because it incorporates more teeth.
Orthopedic maxillary expansion results in more widening at the canines than at the molars (with a 3:2 ratio) and is always composed of skeletal (sutural opening), dental (tipping), and alveolar (bending and remodeling) changes. It has been demonstrated that the major resistance to expansion of the maxilla stems from the increase in sutural resistance attendant to skeletal maturity. Therefore, as a child matures, more force is required and less skeletal expansion and more dental tipping occur. Krebs demonstrated this in a study using metal markers during orthopedic transverse maxillary expansion in children and adolescents. The children exhibited 50% skeletal and 50% dental expansion, while the adolescents showed 35% skeletal and 65% dental expansion. After orthodontic appliance removal, the dental tipping and alveolar bending components of transverse expansion tend to regress. Therefore, when orthopedic maxillary expansion is used to correct transverse maxillary deficiency, overcorrection by as much as 50% is recommended. Overcorrection is not recommended for surgically assisted expansion.

After sutural closure or completion of transverse growth, orthopedic transverse maxillary expansion is largely unsuccessful because the expansion is primarily composed of alveolar or dental tipping with little or no basal skeletal movement. This can lead to many problems for the adolescent or adult patient, including an inability to activate the expansion appliance, severe pain upon activation of the appliance, pressure necrosis of the palatal tissue beneath the expansion appliance, tipping and extrusion of the maxillary teeth, bending of the alveolar bone, uncontrolled relapse following orthodontic appliance removal (often resulting in an open bite) and periodontal complications.
which leads to tipping of the maxillary teeth through buccal cortical plate and, in the presence of inflammation, results in gingival recession in posterior segments. This also predisposes the patient to gingival recession and dental instability. However, as previously mentioned, if in the adult patient the clinical and radiographic analyses are not significant for transverse maxillary deficiency (<5 mm total maxillomandibular discrepancy), sufficient buccal maxillary bone may remain to allow dental tipping and camouflage the skeletal pattern.

**Surgically assisted maxillary expansion**

Indications for surgically assisted maxillary expansion (SME) include the following: (1) maxillary transverse deficiency with >5 mm maxillomandibular discrepancy by PA cephalometric analysis; (2) significant transverse maxillary deficiency associated with a narrow maxilla and wide mandible; (3) failed orthodontic/orthopedic expansion; (4) large amount (>7 mm) of expansion required (therefore, correction with two-piece Le Fort osteotomy is unstable); (5) extremely thin, delicate gingival tissue or presence of significant buccal gingival recession in the canine-premolar region in the maxilla; and (6) skeletal age of 15 years or older.32

The three principal areas of maxillary support are the nasomaxillary, zygomaticomaxillary, and pterygomaxillary buttresses (Fig 13). Choice of maxillary osteotomies is a critical determinant of whether the effects of the expansion appliances are predominantly orthopedic or orthodontic in nature.11 The diverse maxillary osteotomies that have been proposed to facilitate lateral maxillary expansion reflect the conflicting opinions about the primary area of resistance to maxillary expansion in the craniofacial skeleton. The surgical dilemma is to reconcile optimal therapeutic outcome with a procedure that is minimally invasive.12 Brown12 first described SME in 1938, performing only a midpalatal split. In a histologic study, Timms16,37 hypothesized that the midpalatal suture was the major resistance to transverse expansion and, therefore, also advocated an isolated midpalatal osteotomy. Other authors advocated isolated lateral maxillary dentoalveolar osteotomies.38 Still others postulated that the midpalatal suture and zygomatic buttresses were both major areas of resistance, and they treated patients with lateral maxillary and midpalatal osteotomies.24-45 Kennedy et al.47 investigated areas of resistance to transverse maxillary expansion and the effects of different osteotomies on expansion in the rhesus monkey. He found that the lateral maxillary osteotomy was the most effective and that the most effective expansion occurred when the lateral osteotomy was combined with a midpalatal osteotomy. He also demonstrated that the effects of SME are not limited to the dentoalveolar structures. As the palate is expanded, many sutures of the skull are opened and distorted.47 However, stud-
Fig 13  Diagram of the three principle maxillary buttresses: nasomaxillary, zygomaticomaxillary, and pterygomaxillary. Resistance to transverse maxillary expansion also arises from the midpalatal suture.

...ies investigating the effects of craniofacial forces in animal models have limited clinical bearing due to gross morphologic dissimilarities in the facial skeleton. Other authors have recommended sectioning of virtually all of the maxillary bony articulations (zygomaticomaxillary buttresses, midpalatal suture, and pterygomaxillary junction). An investigation by Shetty et al. attempted to give a biomechanical rationale for the placement of osteotomies during SME by analyzing the internal stress response following SME in a photoelastic model. A photoelastic model was fabricated from a human skull, a Hyrax appliance was placed, sequential cuts were performed on the model, and alterations of the internal stresses were recorded after each cut. They found that all of the bony buttresses of the maxilla contributed resistance to expansion, but the midpalatal suture followed by the pterygomaxillary articulations were the primary areas of resistance. They also found that forces due to appliance activation have deep anatomic effects with stresses present at sites distant to force application. Even though there are problems with the reliability and validity of this study, it provides important insights into areas of resistance to transverse expansion in the adult human skull.

Surgical technique

The technique that has provided the most predictable results is basically a subtotal Le Fort I osteotomy. Ideally, prior to the maxillary surgery the mandibular dentition should be decompensated to allow assessment of the amount of transverse expansion that will be required. In addition, the maxillary expansion device should be placed in the oral cavity by the orthodontist the day before the procedure, and the appliance activation key should be present in the operating room. The technique can be summarized as follows (Figs 14a to 14f):

1. Bilateral osteotomy from the piriform rim to the pterygomaxillary fissure. This osteotomy is parallel to the maxillary occlusal plane with a step at the buttress, and bone is removed in the buttress to allow expansion.
2. Release of the nasal septum.
4. Osteotomy of the anterior 1.5 mm of the lateral nasal wall.
5. Bilateral release of the pterygoid plates from the tuberosity of the maxilla.
6. Activation of maxillary appliance with a total widening of 1.0 to 1.5 mm, and evaluation for independent expansion and mobility of both sides of the maxilla.
7. Soft tissue closure including alar cinch and V-Y closure to control the soft tissues of the nasal base and upper lip. These tissues can be predictably preserved in their preoperative condition or manipulated with use of the alar cinch and V-Y closure. Prevention of nasal changes can be critical.
Figs 14a to 14t Technique of surgically assisted maxillary expansion.

Fig 14a Haas palatal expansion device cemented in place prior to surgery.

Figs 14b and 14c Diagram and clinical view of osteotomy of the maxilla from the piriform rim to the pterygomaxillary fissure. This osteotomy is parallel to the maxillary occlusal plane with a step at the buttress. Bone is removed in the buttress to allow expansion.

Figs 14d and 14e Diagram and clinical view of release of the nasal septum with a double-balled nasal/septal osteotome.
Figs 14f to 14h  Diagram and two clinical views of the midline palatal osteotomy. The osteotomy should first be directed caudally to split the alveolar bone, then posteriorly to split the hard palate.

Fig 14i  Diagram of osteotomy of the anterior 1.5 mm of the lateral nasal wall.
Fig 14j and 14k Diagram and clinical view of release of the pterygoid plates from the tuberosity of the maxilla.

Figs 14l and 14m Expansion key and clinical view of activation of the maxillary appliance with a total widening of 1.0 to 1.5 mm.

Fig 14n (left) Diagram of the completed SME.

Fig 14o (right) Occlusal view diagram of the expansion device in place and the vector of expansion.
Fig 14p Clinical example of the soft tissue closure including alar cinch and V-Y closure to control the soft tissues of the nasal base and upper lip.

Figs 14q to 14s Clinical occlusal, frontal intraoral, and occlusal radiographic views of the maxilla following 2 weeks of expansion.

Fig 14t Clinical occlusal view of the maxilla 6 months after SME.
Sectioning of the posterior portions of the thin lateral wall of the nasal cavity is superfluous because it offers virtually no resistance to lateral movement of the maxilla. In fact, the lateral walls help maintain the spatial relationship of the mobilized maxilla. Release of the pterygoid plates is necessary because unlike the maxilla, which is composed of two bones, the sphenoid is a single bone with both pterygoid processes attached. Therefore, the pterygoid processes must be separated from the maxillae to allow posterior maxillary expansion.

Following the surgical procedure, the maxilla should be allowed to remain stationary for 5 days prior to initiation of expansion of the maxilla at 0.5 mm (one turn in the morning and one turn at night) a day. This is based on Ilizarov's work in the extremities (analogous to the SME), which demonstrates that a healing period of 5 days allows capillary healing across the osteotomy area. Re-establishment of this blood supply should lead to earlier and more complete ossification of the expanded defect. Ilizarov has demonstrated that an expansion rate of 0.5 to 1 mm a day does not outstrip the blood supply.

During postoperative expansion, the patient should feel little discomfort. If pain is experienced, either inadequate mobilization was achieved during surgery, a bony interference is present, or the expansion device is not functioning correctly. However, symptoms of tightness and minor discomfort in the nasal root/glabellar area and posterior orbit are not uncommon and can be explained anatomically. These symptoms in the nasal root/glabellar area are due to an outward rotation of the maxillary halves around an axis of rotation located near the frontonasal suture, because the lateral nasal walls were not sectioned during the surgical procedure (Fig 15). The pressure felt in the posterior orbit is due to the small articulation of the palatine bone within the posterior orbit, as well as the fact that the posterior portion of the sinus (palatine bone) was also not sectioned during the procedure and is subjected to lateral forces during expansion. Palatal expansion must occur within 4 weeks or the osteotomy sites may heal before the required expansion has been obtained.

During the period of active expansion, a red patch of gingival tissue should be seen medial to one or both central incisor teeth (Fig 16). This is merely immature keratinized tissue that arises where rapid tooth movement exceeds the ability of the gingival tissue to mature. It is a sign of successful skeletal separation and, ideally, is present bilaterally.

Surgical transverse changes are less stable for a longer period of time than most other surgical or orthodontic movements, and it takes months to achieve bony continuity in the midpalatal osteotomy following surgically assisted maxillary expansion. Therefore, some form of skeletal retention is recommended for 6 to 12 months. Either the expansion device is kept in place for more than 6 months while the mandible is
Figs 17a and 17b  Retention of the transverse expansion is necessary for months following SME.

Fig 17a (left)  Haas expander as a retention device. Observe immature tissue.

Fig 17b (right) Palatal coverage retainer as a retention device. Note how the acrylic does not contact the anterior maxillary teeth, allowing orthodontic alignment and diastema closure during the retention period.

Figs 18a and 18b  Patient whose appliance was overheated during fabrication, leading to deformation of the metal frame rather than expansion of the appliance.

Fig 18a (left) Occlusal view prior to removal of the appliance. Patient experienced pain from the palatal with each activation of the expansion key. Also observe the lack of a midline maxillary diastema and palatal ulceration distal to the appliance on the right side.

Fig 18b (right) Occlusal view after appliance removal demonstrating a large ulcer on the right side of the palate extending up onto the alveolar process.

being coordinated, or the appliance is removed (not prior to 3 months) and a palatal coverage retainer, transpalatal bar, or other removable appliance can be placed (Figs 17a and 17b).

This surgically assisted maxillary expansion technique, monitored postoperative expansion, and adequate postoperative retention have provided extremely stable results and minimized alveolar/dental tipping, which has been frequently associated with orthopedic expansion in adult patients.

Intraoperative complications of SME are similar to those following Le Fort I osteotomy. Postsurgical complications can be divided into those due to inadequate release of the maxillae and those due to problems with the expansion device. Those due to inadequate surgery include pain, dental tipping, gingival recession in the canine/premolar regions, palatal tissue impingement by the expansion device, and postorthodontic transverse relapse. Problems with the expansion appliance include failure of the appliance to expand, appliance deformation due to solder overheating during fabrication (Figs 18a and 18b), and stripping of the midpalatal screw (Fig 19).

Factors such as the patient's age, presence of a palatal torus, presence of or tendency toward an anterior open bite, need for a secondary Le Fort I osteotomy, extremely tapered arch form, and requirement for only unilateral maxillary expansion may modify this basic surgical technique.

There is increased facial resistance to expansion with increasing maturity and age. The major site of resistance is not usually the midpalatal suture but the remaining maxillary articulations. Therefore, to achieve stable, adequate, asymptomatic expansion, more extensive surgery may need to be performed for older patients, often requiring their
overnight stay in the hospital. While SME has been recommended as an outpatient procedure, this practice should be limited to younger patients (since they require less extensive surgery) to ensure that adequate maxillary expansion is achieved and surgical and medical complications are minimized.

A palatal torus can be a significant hindrance to palatal expansion because tori are composed of dense cortical bone. Presence of a palatal torus in a patient requiring surgical maxillary expansion can be treated two ways. The most ideal treatment is to surgically remove the torus 4 to 6 months prior to the SME procedure. Concomitant removal of the torus with SME requires modification of the basic procedure. The expansion device cannot be cemented in place prior to SME and must be fabricated on a model in which the torus has been removed. Since a midpalatal incision will be required to remove the palatal torus, the blood supply to the maxilla will need to be preserved by performing the lateral, pterygomaxillary, and anterior midpalatal osteotomies through vertical incisions in the buccal mucosa combined with subperiosteal tunneling. After the torus is removed through the midpalatal incision, parasagittal palatal osteotomies are completed through this incision. The expansion appliance is then tested to ensure that it has no direct contact on the palatal closure and is cemented to the teeth in the operating room.

When performing SME on patients with a true skeletal open bite (long face) or open bite tendency, care should be taken to prevent worsening of the open bite. This requires modification of the SME technique. If a ramped cut is made from the piriform rims to the maxillary buttress (the anatomic location of the maxillary first molar), the maxilla moves inferiorly preferentially at the first molar as it is expanded (Fig 20a). This can worsen an open bite condition or cause an open bite tendency to become a true skeletal open bite, necessitating a secondary Le Fort osteotomy for correction. This problem can be avoided by per-
Figs 21a and 21b. Right and left views of high SME cuts in a patient with severe transverse maxillary deficiency and concomitant anteroposterior and vertical maxillary hypoplasia that will require a secondary Le Fort osteotomy for correction.

Figs 21c and 21d. Right and left views of healing of SME cuts at subsequent Le Fort procedure. Note incomplete healing of the bone on the face of the maxilla and posterior to the butresses. If the design of the secondary osteotomy had not been used during the SME procedure, complications (such as fracture of the face of the maxilla) may have been encountered during the application of rigid fixation.

Figs 20a and 20b. Right and left views of a step cut in the maxillary buttress region with the desired amount just anterior to the bone. The right side shows the bone removed to occur in the vertical plane.

Forming all osteotomies of the anterior and lateral maxillary walls parallel to the maxillary occlusal plane. This necessitates a step cut in the maxillary buttress region. For transverse expansion to occur without bony interference in the buttress region, bone in the amount of just less than half of the desired amount of skeletal expansion must be removed at the vertical step cut in the buttress area (Fig 20b).

If a secondary Le Fort I osteotomy is planned because of concomitant transverse maxillary deficiency and another skeletal deformity requiring surgical correction (i.e., vertical or anteroposterior deformity, anterior open bite, asymmetry, occlusal cant), the osteotomies during the SME should be placed in the location of the planned osteotomy cuts of the future Le Fort procedure. This is recommended because the osteotomies in the anterior and lateral maxillary walls seldom completely heal following SME, and this incomplete healing may compromise the positioning or ability to place rigid fixation plates. For example, in a patient with transverse maxillary deficiency who has maxillary and zygomatic anteroposterior deficiency that requires a future high (or quadrangular) Le Fort osteotomy, the SME cuts must be made high on the face of the maxillae. If they were made low and healing was inadequate, after the high cuts were made the maxilla would be prone to fracture during or following application of the rigid fixation plates (Figs 21a to 21d).

For the less frequent situation in which a patient requires unilateral expansion of the maxilla due to a unilateral transverse deficiency, a unilateral SME can be performed. The procedure is the same as for the bilateral SME, but osteotomies are performed only on one of the maxillae.

On the operated side, the transverse stability is similar to that seen with SME performed with bilateral osteotomies. However, on the non-operated side, dental tipping can be prevented by cross-tooth elastics and less relapse of the transverse expansion will follow appliance removal.
**SME versus segmental Le Fort I osteotomy**

When maxillary transverse deficiency will be followed by a Le Fort I osteotomy to correct another skeletal maxillary deformity, a segmental Le Fort I osteotomy should be considered. There are many differences between the SME and segmental maxillary osteotomies when used to correct transverse maxillo-mandibular discrepancy.

One major difference is stability of transverse maxillary correction following SME and segmental maxillary osteotomy. As for the stability of SME, Pogrel et al. studied 12 adult patients, all of whom were still in orthodontic appliances 1 year following surgery, and found only 11.8% relapse at the maxillary first molar. Bays, in a retrospective study of 19 patients who were out of appliances more than 6 months, found 8.8% relapse at the canines, 1% at the first premolar, and 7.7% at the first maxillary molar. Several authors have reported less stability with surgical-only correction of the transverse component with segmental maxillary osteotomies in adult patients. Stephens found 30% and 23% relapse at the canine and molar, respectively, in 15 patients who had segmental maxillary osteotomies with follow-up averaging 47.5 months after debanding. Phillips et al. retrospectively studied the transverse stability in 39 patients who had undergone a two-piece (n = 26) or a three-piece (n = 13) Le Fort osteotomy. The postdebanding follow-up was 14 to 47 months (mean = 24.4 months). They found significant transverse relapse in both the two- and three-piece Le Fort osteotomies following debanding, from 11% at the canines to 47% at the second molar for the two-piece group and from 30% at the first premolar to 51% at the first molar in the three-piece group.

There are also other differences between the SME followed by a secondary one-piece Le Fort I osteotomy and segmental maxillary osteotomies. The pattern of transverse expansion is different for SME than for segmental osteotomies. Following SME, more expansion occurs at the canines and less at the molars, whereas following segmental Le Fort osteotomy, more expansion is seen at the maxillary molars than at the canines. This makes anatomic sense because the maxillae articulate superiorly and posteriorly. During SME not all of the maxillary articulations are severed (lateral maxillary walls and palatine bones are left essentially intact), so there would be more resistance to posterior expansion of the maxilla.

Surgically assisted maxillary expansion is usually performed early in the treatment sequence. Early expansion of the maxilla allows orthodontic alignment in the severely crowded maxillary arch without removal of teeth. In contrast, non-extraction treatment of patients having maxillae expanded with segmental osteotomies is more difficult and leads to further posttreatment instability and relapse because orthodontic expansion of the dentition is needed to align the teeth prior to surgery. Extraction of teeth may not be necessary because teeth are in an already small maxilla, which after transverse expansion will require more tooth structure.

The segmental Le Fort osteotomy is a much more difficult, lengthy, and morbid procedure than SME or a one-piece Le Fort osteotomy. Complications, ranging from periodontal defects to loss of bony segments and teeth due to vascular compromise, are much more common following segmental maxillary osteotomy than either SME or one-piece Le Fort I osteotomy. The major disadvantage to a treatment plan that includes SME followed by a one-piece Le Fort osteotomy instead of a segmental Le Fort osteotomy is that two general anesthetics are required. For a patient who has had SME and requires a Le Fort osteotomy for correction of another skeletal maxillary deformity, a secondary procedure under general anesthesia must be performed following orthodontic decompensation of the maxillary and mandibular dentition. This is in contrast to a pieced Le Fort osteotomy where correction in all of the planes of space is completed during one surgical procedure. However, while the total time
under anesthesia is approximately the same, the potential postoperative morbidity is reduced when SME is followed by a one-piece Le Fort osteotomy.

In view of the significant advantages described above, treatment recommendations for sequencing and correction of transverse deficiency have been suggested. Orthodontic/orthopedic expansion should be attempted in patients who require only maxillary transverse expansion, where the differential is less than 5 mm, transverse growth potential exists, and normal gingival tissues are present in the posterior areas. If the transverse differential is greater than 5 mm, SME should be considered early in the treatment sequence (following buccal decompensation of the mandibular dentition). If the patient requires a Le Fort osteotomy for another skeletal deformity, and the transverse skeletal discrepancy is 6 mm or less, a segmental Le Fort osteotomy should be seriously considered. However, when a segmental Le Fort osteotomy is employed in the patient with a transverse skeletal differential greater than 6 mm, complete expansion at the molars is difficult to achieve at the time of surgery and even more difficult to retain postsurgically. Therefore, the SME should be performed at the beginning of the treatment followed by a secondary one-piece Le Fort I osteotomy after orthodontic decompensation of the dentition, with special care taken to design the SME osteotomies where future Le Fort cuts will be made.

Summary

The diagnosis and treatment of sagittal and vertical deformities has become routine for some orthodontic and oral and maxillofacial surgery teams. However, treatment difficulties and relapse associated with many patients may be due to undiagnosed or inadequately treated transverse discrepancies. The diagnosis of maxillomandibular transverse discrepancy may be difficult. This is especially true for adult patients, in whom an underlying skeletal transverse maxillary discrepancy may be masked by sagittal and vertical deformities. If appropriate clinical and radiographic assessments are made, and the correct diagnosis is determined and treatment sequence applied, transverse discrepancy can be treated with improved long-term stability, better dentofacial esthetics, and better periodontal health.

References

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