CLINICIANS' CORNER

Maxillary expansion: Clinical implications

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Clinicians frequently expand the maxilla to correct certain malocclusions. The effects of expansion on facial structures, dentition, and periodontium are reviewed. The implications of these findings for the treatment of patients who need maxillary expansion are discussed. (AM J ORTHOD DENTOFAC ORTHOP 1987;91:3-14.)

Key words: Maxillary expansion, review, treatment

Rapid maxillary expansion (RME) is a dramatic procedure with a long history. E. H. Angell[1] reported on the procedure in 1860, and since then it has gone through periods of popularity and decline. In the late 1940s, Graber[2] advocated RME for the treatment of cleft lip and palate patients. Since then clinicians have increasingly included RME in the treatment of their patients.

Although clinicians agree about many of the indications for and outcomes of RME, a review of the literature[1-65] indicates that numerous disagreements persist about the procedure. Haas,[22] Isaacson and Murphy,[32] and Wertz[64] advocated splitting of the midpalatal suture to widen narrow maxillary arches. On the other hand, Graber[2] believed that the technique was originally dropped because of development of open bites, relapse, and the fact that improvement of nasal breathing was only temporary. Furthermore, orthodontic appliances routinely achieve the needed maxillary intercanine and intermolar expansions. Graber asks, "What are the criteria for lateral apical base deficiency?"

Indications for RME. Patients who have lateral discrepancies that result in either unilateral or bilateral posterior crossbites involving several teeth are candidates for RME.[23,24,64] The constriction may be skeletal (narrow maxillary base or wide mandible), dental, or a combination of both skeletal and dental constriction.

Anteroposterior discrepancies are cited as reasons to consider RME.[2,22-25,64] For example, patients with skeletal Class II, Division 1 malocclusions with or without a posterior crossbite, patients with Class III malocclusions, and patients with borderline skeletal and pseudo Class III problems are candidates if they have maxillary constriction or posterior crossbite.

Cleft lip and palate patients with collapsed maxillae are also RME candidates. Finally, some clinicians use the procedure to gain arch length in patients who have moderate maxillary crowding.

According to Bell,[5] the enhanced skeletal response that accompanies RME redirects the developing posterior teeth into normal occlusion and corrects asymmetries of condylar position. This should allow more vertical closure of the mandible, and eliminates both functional shifts and possible temporomandibular joint dysfunction.

Contraindications for RME.[3,64] Patients who cannot cooperate with the clinician are not candidates for RME. Patients who have a single tooth in crossbite probably do not need RME. Patients who have anterior open bites, steep mandibular planes, and covex profiles are generally not well suited to RME. Patients who have skeletal asymmetry of the maxilla or mandible, and adults with severe anteroposterior and vertical skeletal discrepancies are not good candidates for RME. Reservations about the patients who have marked skeletal problems are qualified if orthognathic surgery is planned.

The following factors need to be considered during treatment planning to determine whether to expand the dental arches conventionally or with RME: (1) the magnitude of the discrepancy between the maxillary and mandibular first molar and premolar widths; if the discrepancy is 4 mm or more, one should consider RME, (2) the severity of the crossbite, that is, the number of teeth involved, and (3) the initial angulation of the molars and premolars—when the maxillary molars are buccally inclined, conventional expansion will tip them further into the buccal musculature; and if the mandibular molars are lingually inclined, the buccal movement to upright them will increase the need to widen the upper arch.

ETIOLOGY

The causes of buccolingual discrepancies could be either genetic or environmental. According to Graber,[2] and Harvold, Cheirici and Vargervik,[26] many con-

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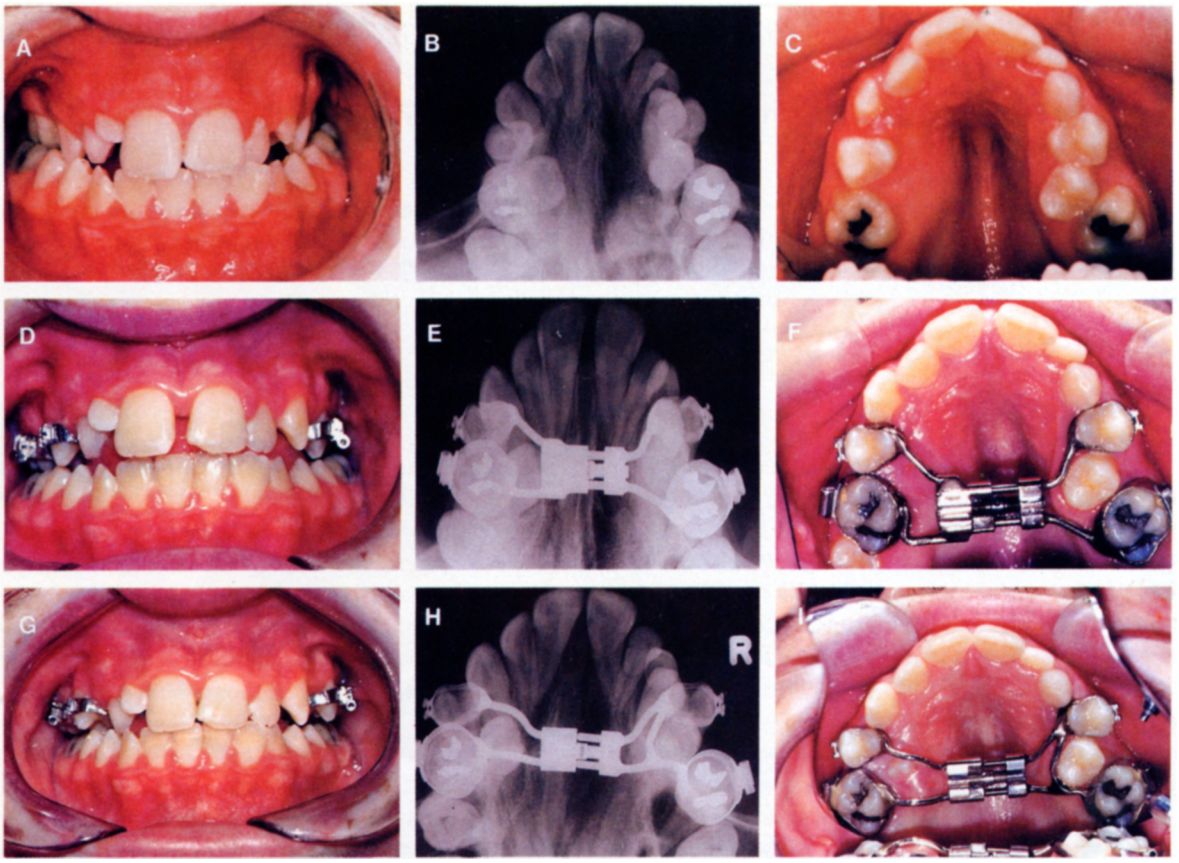

Fig. 1. Frontal, occlusal radiograph and occlusal views before (**A** through **C**), during (**D** through **F**), and after (**G** through **I**) rapid maxillary expansion.

stricted maxillary dental arches are the result of abnormal function. Harvold in his experimental work created narrow maxillary dental arches in rhesus monkeys by converting them from nasal to obligatory oral respiration. All patients considered for RME should be examined for nasal obstruction and, if obstruction is found, they should be referred to an otolaryngologist before orthodontic treatment for examination and treatment of the problem.

APPLIANCES

Removable expansion plates are not recommended if significant skeletal changes are required. Midpalatal splitting with such appliances is possible, but not predictable. For these appliances to be effective, they must be used in the deciduous or early mixed dentition and must have sufficient retention to be stable during the expansion phase.[35,55]

The fixed split acrylic appliance consists of an expansion screw with acrylic abutting the alveolar ridges. The expansion screw can be either a spring loaded or nonspring-loaded jackscrew. The advocates of the tissue-borne fixed appliance believe that it causes a more parallel expansion force on the two maxillary halves and that the force is more evenly distributed on the teeth and the alveolar processes.[22,24] The appliance is attached to the teeth with bands on the molars and first premolars.

A number of all metal appliances have been used to expand arches. The Arnold expander, the Coffin palatal arch, and the quad-helix appliance have been used to accomplish "slow" palatal expansion, particularly in the deciduous and early mixed dentitions. For a more controlled expansion and a more assured palatal splitting, the use of sturdier appliances is recommended. The hygienic appliance (Hyrax*) is essentially a nonspring-loaded jackscrew with an all wire frame (Fig. 1). This frame is soldered to the bands on the abutment teeth. The advocates of this appliance believe that it causes the least irritation to the palatal mucosa and is easier to keep clean. The Minne† expander is a heavy caliber coil spring that is expanded by turning a

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nut to compress the coil. Two metal flanges perpendicular to the coil are soldered to the bands on the abutment teeth.

Spring-loaded screws and the Minne expander may continue to exert expansion forces after completion of the expansion phase unless they are partially deactivated.

Chaconas and Caputo[9] designed a three-dimensional anatomic model duplicated from a human skull and used different birefringent materials to simulate the various craniofacial structures. They compared five appliances—the Haas expander, Minne expander, Hyrax, quad helix, and a removable expander. They found that each appliance produced different load–activation characteristics. Stresses produced by fixed appliances were concentrated in the anterior region of the palate, progressing posteriorly toward the palatine bones. These stresses radiated superiorly along the perpendicular plates of the palatine bones, the lacrimal, nasal, and zygomatic bones, and the pterygoid plates of the sphenoid. The authors believed that the quad helix, although it caused palatal separation, was the least effective orthopedic device. They also observed that the removable expanders were displaced before producing sufficient pressure to cause midpalatal splitting.

EFFECTS OF RME ON THE MAXILLARY COMPLEX

Rapid maxillary expansion occurs when the force applied to the teeth and the maxillary alveolar processes exceeds the limits needed for orthodontic tooth movement. The applied pressure acts as an orthopedic force that opens the midpalatal suture. The appliance compresses the periodontal ligament, bends the alveolar processes, tips the anchor teeth, and gradually opens the midpalatal suture.[22] Ekström, Henrickson, and Jensen[15] found that the mineral content within the suture rose rapidly during the first month after the completion of suture opening. In the bone beside the suture, the mineral content decreased sharply during the first month, but returned to its initial level within 3 months. Ten Cate, Freeman, and Dickinson[58] found that opening of the suture involves tissue injury followed by a proliferation repair phenomenon that ultimately leads to regeneration of the suture.

Viewed occlusally, Inoue[31] found that the palatine processes of the maxillae separated in a nonparallel—that is, in a wedge-shaped—manner in 75% to 80% of the cases observed. Wertz's study[64] of three dry skulls, one adult and two in the mixed dentition, also indicated that the shape of the anteroposterior palatal separation was nonparallel in all three skulls (Fig. 1, *E*).

Viewed frontally, the maxillary suture was found to separate superoinferiorly in a nonparallel manner.[22,24,64] The separation was pyramidal in shape with the base of the pyramid located at the oral side of the bone (Fig. 2).

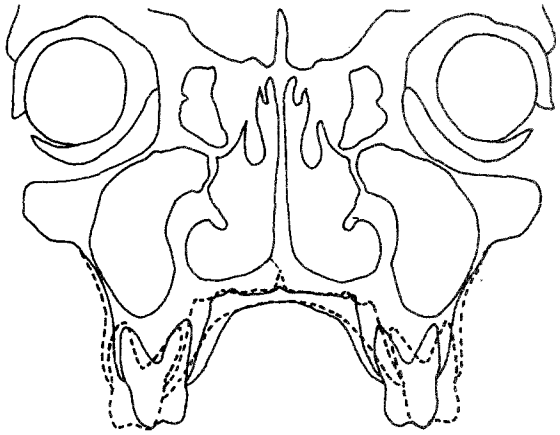

Fig. 2. Coronal section at the level of the first molars. During RME *(dashed lines)*, the midpalatal suture opens with an inverted V shape, the maxillae separate, the alveolar ridges tip and bend buccally, the teeth move bodily and also tip within the alveoli, and the mucoperiosteum of the palate stretches.

The magnitude of the opening varies greatly in different individuals and at different parts of the suture. In general, the opening is smaller in adult patients. The actual measurement ranges from practically no separation to 10 mm or more.[36-39]

Relation between amount of sutural separation and extent of molar expansion. Krebs[37-39] studied maxillary expansion with metallic implants. He placed implants in the alveolar process lingual to the upper canines and along the infrazygomatic ridge, buccal to the upper first molars. He found that the mean increase in intermolar distance measured on casts was 6 mm, while the mean increase in infrazygomatic ridge implants was 3.7 mm. In 20 of 23 patients examined, the amount of sutural opening was equal to or less than one half the amount of dental arch expansion. He also found that the sutural opening was on average more than twice as large between the incisors than it was between the molars.

Changes during fixation and retention. Krebs[37-39] noted that although dental arch width was maintained during fixed retention, the distance between implants in the infrazygomatic ridges decreased during the 3 months of fixed retention by an average of 10% to 15%. This relapse continued during retention with removable appliances. After an average period of 15 months, approximately 70% of the infrazygomatic maxillary width increase was maintained.

Maxillary halves. Krebs[37] showed that the two halves of the maxilla rotated in both the sagittal and frontal planes. Haas[22] and Wertz[64] found the maxilla to

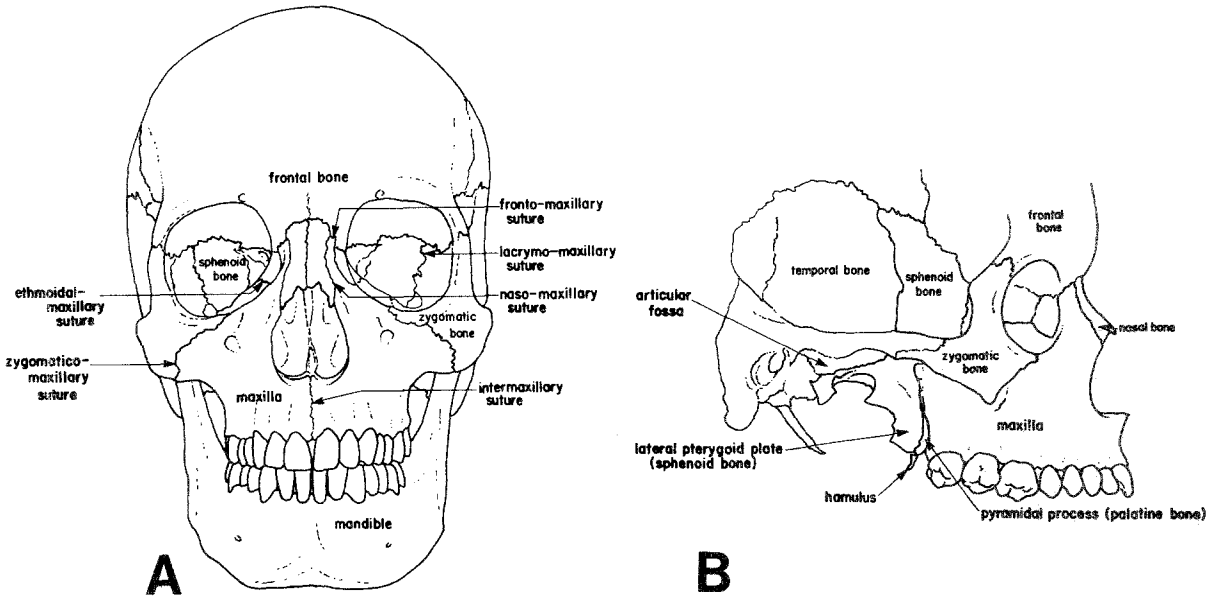

Fig. 3. The bony articulations of the maxillae. **A**, Frontal view. **B**, Lateral view.

be more frequently displaced downward and forward. The final position of the maxilla, after completion of expansion, is unpredictable and it has been reported to return, partially[24] or completely,[64] to its original position.

In the frontal plane, the fulcrum of rotation for each of the maxillae is said to be approximately at the frontomaxillary suture.[22,24,64] Using implants,[29] the maxillae were found to tip anywhere between $-1°$ and $+8°$ relative to each other. This tipping explains some of the discrepancy observed between molar and sutural expansions. Tipping of the two maxillae results in less width increase at the sutural level than at the dental arch level.

Palatal vault. Fried[17] and Haas[22,23] reported that the palatine processes of the maxilla were lowered as a result of the outward tilting of the maxillary halves. On the other hand, Davis and Kronman[12] reported that the palatal dome remained at its original height.

Alveolar processes. Because bone is resilient, lateral bending of the alveolar processes occurs early during RME (Fig. 2). Most of the applied forces tend to dissipate within 5 to 6 weeks. After stabilization is terminated, any residual forces in the displaced tissues will act on the alveolar processes causing them to rebound.[33]

Therefore, one can appreciate the need for overcorrection of the constricted dental arches to compensate for the subsequent uprighting of the buccal segment.[23,64]

Maxillary anterior teeth. From the patient's point of view, one of the most spectacular changes accompanying RME is the opening of a diastema between the maxillary central incisors (Fig. 1). One can understand how the opening of such a space would alarm both patient and parents. It is estimated that during active suture opening, the incisors separate approximately half the distance the expansion screw has been opened,[22] but the amount of separation between the central incisors should not be used as an indication of the amount of suture separation.[64]

Following this separation, the incisor crowns converge and establish proximal contact. If a diastema is present before treatment, the original space is either maintained or slightly reduced. The mesial tipping of the crowns is thought to be caused by the elastic recoil of the transseptal fibers. Once the crowns contact, the continued pull of the fibers causes the roots to converge toward their original axial inclinations. This cycle generally takes about 4 months.

The maxillary central incisors tend to be extruded relative to the S-N plane and in 76% of the cases they upright or tip lingually. This movement helps to close the diastema and also to shorten arch length. The lingual tipping of the incisors is thought to be caused by the stretched circumoral musculature.[23,64]

Maxillary posterior teeth. With the initial alveolar bending and compression of the periodontal ligament, there is a definite change in the long axis of the posterior teeth. Hicks[29] found that the angulation between the right and left molars increased from 1° to 24° during expansion. Not all of the change, however, is caused by alveolar bending, but is partly due to tipping of the

teeth in the alveolar bone. This tipping is usually accompanied by some extrusion.[8,29]

Palatal mucoperiosteum, periodontal tissues, and root resorption. As the maxillae separate, the palatal mucoperiosteum is stretched. Cotton[10] suggested that the postexpansion angular changes of the maxillary first molars may be related to the stretched fibers of the attached palatal mucosa. He found that all maxillary molars in his animal study demonstrated an average 10° decrease in angulation after active expansion and this decrease occurred regardless of whether an actual increase in molar angulation had occurred during the treatment period. Maguerza and Shapiro[45] attempted to relieve the stretch of the mucoperiosteum after "slow" expansion by making incisions along the palate down to the cortical bone, 3 mm away from the teeth. The incisions did not effectively reduce the relapse tendency. Whether such incisions might be effective with RME expansion or whether the incision wound itself causes contraction is yet to be determined.

Greenbaum and Zachrisson[20] evaluated the effects of orthodontic treatment alone, RME (tissue-borne fixed appliance), and slow (quad-helix) palatal expansion on the periodontal supporting structures located at the buccal aspects of the maxillary first permanent molars. They found that the differences among the groups were not significant and were clinically of small magnitude.

Other investigators[4,42,43] reported marked buccal root resorption of the anchor teeth during RME and fixed retention. These defects tended to gradually repair. Barber and Sims[4] noticed that root resorption was not present in the neighboring but nonanchored premolars.

Effects of RME on the mandible. It is generally agreed that with RME there is a concomitant tendency for the mandible to swing downward and backward. There is some disagreement regarding the magnitude and the permanency of the change.[23,24,64] The fairly consistent opening of the mandibular plane during RME is probably explained by the disruption of occlusion caused by extrusion and tipping of maxillary posterior teeth along with alveolar bending. RME should be cautiously performed on persons with steep mandibular planes and/or open bite tendencies.

Effects of RME on the mandibular teeth. Following RME, the mandibular teeth have been observed to upright[23,24] or to remain relatively stable over the short period of treatment.[64] Gryson[21] recorded changes in maxillary and mandibular intercanine and intermolar widths before and after expansion in 38 patients. The ages of the groups ranged between 6 and 13 years. The mean increase in the mandibular intermolar width was 0.4 mm; most patients either had no change or showed an increase of up to 1 mm. There was no correlation between the change in mandibular intercanine and intermolar distances with respect to the increase in maxillary intercanine and intermolar distances. Therefore, one can conclude that in general RME could influence the mandibular dentition, but the accompanying changes are neither pronounced nor predictable.

Effects of RME on adjacent facial structures. An examination of occlusal films[64] showed that the opening of the midpalatal suture extends through the horizontal plates of the palatine bones, but the distance between the two expanded halves is very narrow. Kudlick,[40] in a study on a human dry skull that simulated in vivo response of RME, concluded the following: (1) all craniofacial bones directly articulating with the maxilla were displaced except the sphenoid bone, (2) the cranial base angle remained constant, (3) displacement of the maxillary halves was asymmetric, and (4) the sphenoid bone, not the zygomatic arch, was the main buttress against maxillary expansion. Gardner and Kronman,[18] in a study of RME in rhesus monkeys, found that the lambdoid, parietal and midsagittal sutures of the cranium showed evidence of disorientation, and in one animal these sutures split 1.5 mm. Therefore, RME could affect relatively remote structures and is not limited to the palate.

It is important for the clinician to remember that the main resistance to midpalatal suture opening is probably not in the suture itself, but in the surrounding structures, particularly the sphenoid and zygomatic bones. The maxillae articulate with ten other bones of the face and cranium (Fig. 3). The sphenoid bone that forms the midsagittal part of the anterior and middle portions of the cranial base lies just posterior to the maxillae (Fig. 4). The pterygoid plates of the sphenoid, although bilaterally positioned, do not have a midsagittal suture that allows them to be displaced laterally. The pyramidal processes of the palatine bones interlock with the pterygoid plates (Fig. 4). This confining effect of the pterygoid plates of the sphenoid minimizes dramatically the ability of the palatine bones to separate at the midsagittal plane.[64] As the maxillae start to separate, the zygomatic processes offer some resistance to expansion, but the system of sutures allows the expanded structures to adjust and/or relocate. Farther posteriorly, the pterygoid plates can bend only to a limited extent as pressure is applied to them and their resistance to bending increases significantly in the parts closer to the cranial base where the plates are much more rigid.[60]

Because of their relative rigidity, skeletal tissues offer the immediate resistance to the expansion force. But another equally important factor is *the soft-tissue complex* that invests these skeletal structures. The mus-

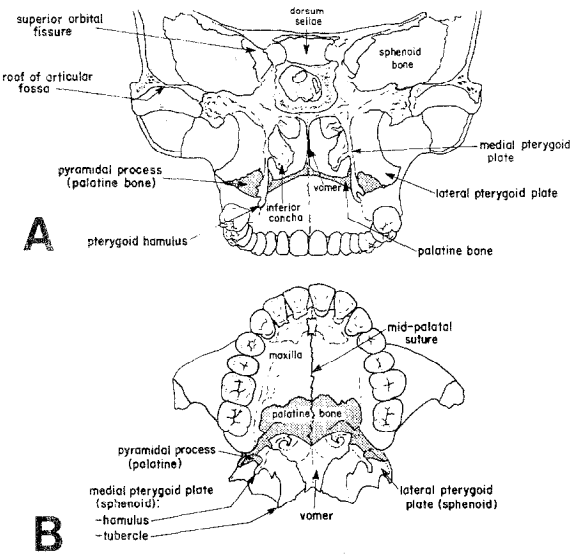

Fig. 4. Posterior **(A)** and inferior **(B)** views of the maxillae that illustrate how the pyramidal processes of the palatine bones are interlocked between the lateral and medial pterygoid plates of the sphenoid bone.

cles of mastication, the facial muscles, and the investing fascia are relatively elastic and can be stretched as the expansion force is applied. But the ability of the stretched muscles, ligaments, and fascia to permanently adapt to the new environment is a matter that deserves further investigation. Orthodontists are acutely aware of the limitations imposed by the soft tissues when teeth are moved.

RME and nasal airflow. Anatomically, there is an increase in the width of the nasal cavity immediately following expansion, particularly at the floor of the nose adjacent to the midpalatal suture.[22-24,64] As the maxillae separate, the outer walls of the nasal cavity move laterally. The total effect is an increase in the intranasal capacity. The nasal cavity width gain averages 1.9 mm, but can widen as much as 8 to 10 mm[19] at the level of the inferior turbinates, while the more superior areas might move medially.[53]

Using computed tomography, Montgomery and associates[50] found that the effects of RME on the nasal cavity are not uniform and the changes in the nasal dimensions are progressively less toward the back of the nasal cavity.

Hershey, Stewart, and Warren,[28] and Turbyfill[61] reported a reduction of nasal airway resistance by an average of 45% to 53% with RME. This reduction was maintained after the removal of the expansion device. Warren[62] believes that although the actual increase in binasal width is small, it should be remembered that airflow varies inversely as the fourth power of the radius of the tube through which it passes.

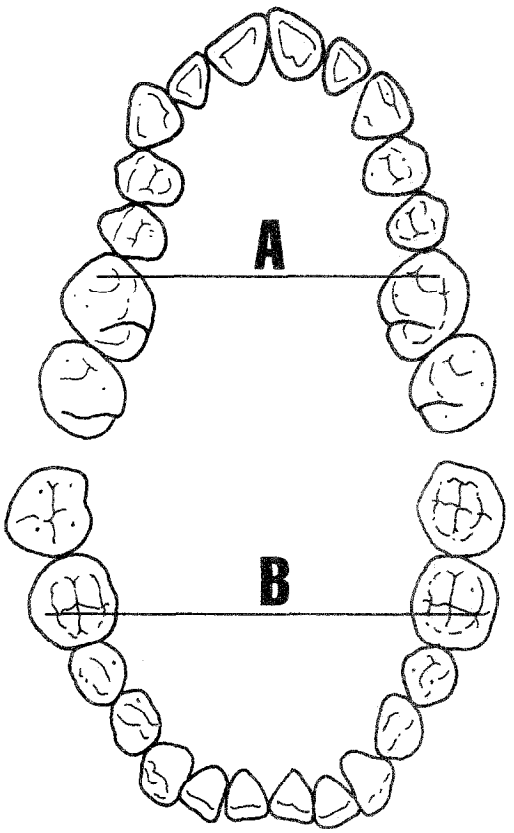

Fig. 5. To estimate the need for expansion, measure the distance between the mesiobuccal cusp tips of the maxillary molars **(A)** and the buccal grooves at the middle of the buccal surfaces of the mandibular first molars **(B).** Subtract B from A. The mean differences in persons with normal occlusion are +1.6 mm (males) and +1.2 mm (females).

Wertz[64] expanded the midpalatal suture in two groups of patients with bilateral posterior crossbite—one group had difficulty in nasal respiration and the other group had normal nasal breathing. Nasal airflow was measured at rest and after mild exercise before and after RME. In the group with breathing difficulty, he found that only one of four experienced an increase in nasal airflow; the other three experienced a mild decrease. The group with no difficulty in respiration experienced either a mild increase or mild decrease in nasal airflow. All patients recorded an increased capacity for nasal air volume when measured during maximum effort. Wertz concluded that opening the midpalatal suture for the purpose of increasing nasal permeability cannot be justified unless the obstruction is shown to be in the lower anterior portion of the nasal cavity and accompanied by a relative maxillary arch width deficiency.

Graber[2] believes that the claims of improved nasal breathing apparently as a result of RME are most likely only temporary. More important, 12-year-old children

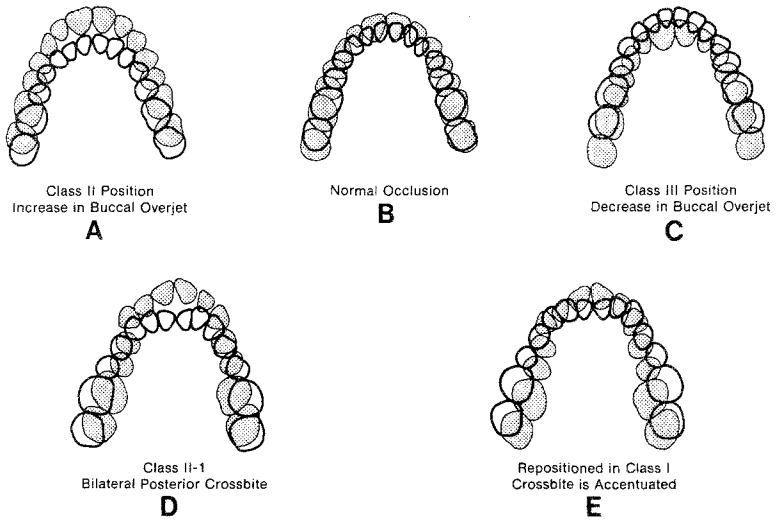

Fig. 6. The effect of anteroposterior position of the arches on buccal overjet is shown when a normal occlusion **(B)** is shifted to a Class II molar position **(A)** that increases buccal overjet and to a Class III molar position **(C)** that decreases buccal overjet. Buccal overjet, in a Class II malocclusion with bilateral posterior crossbite, is shown in **D.** The severity of the crossbite is shown in **E** when the lower arch of the Class II patient is brought forward to a Class I molar position. In general, correction of anteroposterior jaw relations worsens posterior crossbites in Class II patients, but improves posterior crossbites in Class III patients.

have much more lymphoid tissue than adults and the lymphoid tissues can act to block nasal breathing. Spontaneous regression of lymphoid tissues during growth automatically improves nasal breathing, even if nothing is done to the palate.

Therefore, it can be concluded that the effect of RME on the nasal airway will to a great extent depend on the cause, location, and the severity of the nasal obstruction. Hence, the effect can vary from no appreciable change to a marked decrease in nasal airflow resistance.

EFFECT OF AGE

Growth at the midpalatal suture was thought to cease at the age of 3 years.[44] By means of implants, Björk and Skieller[6] found that growth at the suture might be occurring as late as 13 years of age. Persson and Thilander[54] in a study on cadavers found that 5% of the suture was obliterated by age 25 years, yet the variation was such that a 15-year-old cadaver had an ossified suture, while a 27-year-old cadaver had an unossified suture. Thus, RME in both adolescents and adults may involve fracturing of the bony interdigitations.

Brin and associates[7] evaluated the relationship between RME and cyclic nucleotides in the suture. They concluded that older animals are less responsive to the applied forces than younger animals, hence the decreased ability of the older group to adapt to the forces of RME. Most investigators[32,38,64,65] agree that RME with midpalatal splitting can be accomplished in both youths and adults, but with advancing maturity, the rigidity of the skeletal components limits the extent and the stability of the expansion.

Wertz[64] reported an interesting age difference in intermolar width changes following RME. He divided his sample into 3 age groups: under 12, 12 to 18, and over 18 years. He found that after expansion and during fixed retention there was little relapse in any of the three groups (-0.5, -0.6, and -0.5 mm, respectively). On the other hand, each age group behaved differently from the time of appliance removal to the end of retention. The group under 12 years of age had a further increase in intermolar width of approximately 16%, the 12 to 18 years group had a relapse of approximately 10%, and the over 18 years group had a relapse of approximately 63%.

The optimal age for expansion is, therefore, before 13 to 15 years of age. Although it may be possible to accomplish expansion in older patients, the results are neither as predictable nor as stable.

FORCE APPLICATION AND RESIDUAL LOADS

Zimring and Isaacson[65] found that the maximum load produced by a turn of the jackscrew occurred at the time of turning and began to dissipate soon after. Isaacson, Wood, and Ingram[33] reported that 3 to 10 lb of force can be produced by single turns of the jackscrew appliance with cumulative loads of 20 lb or more

after multiple daily turns. Separation of the central incisors occurred between the ninth and 12th turns in all patients, and was not accompanied by any increased subjective symptoms or drop in recorded load.

An age differential was noted in the time required to dissipate loads produced by the appliance. Younger patients dissipated the load produced by a twice-daily activation schedule for a relatively longer period of time than did the older patients. Isaacson, Wood, and Ingram,[33] and Zimring and Isaacson[65] suggested that slower rates of expansion would allow for physiologic adjustment at the maxillary articulations, and would prevent the accumulation of large residual loads within the maxillary complex.

Rapid versus slow RME. There are two schools of thought concerning the speed of palatal splitting.[5,16,22,37,64] Advocates of "rapid" expansion (1 to 4 weeks) believe that it results in minimum tooth movement (tipping), and maximum skeletal displacement. Advocates of "slower" expansion (2 to 6 months) believe that it produces less tissue resistance in the circummaxillary structures and better bone formation in the intermaxillary suture, and that both factors help minimize postexpansion relapse.

Slow expanders like the quad helix and W-spring can transmit forces ranging between several ounces and two pounds.[16] They can separate the maxillae, particularly in the deciduous and mixed dentitions. The rate of separation varies between 0.4 and 1.1 mm per week and can result in an increase in intermolar width of up to 8 mm. Skeletal changes are estimated to be 16% to 30% of the total change and vary with age.[5]

The rate of rapid maxillary expansion is 0.2 to 0.5 mm per day and can result in an increase in intermolar width of up to 10 mm. Skeletal changes are approximately 50% of the total change.[37-39]

Additional studies on subjects matched for age and severity of malocclusion are needed to evaluate the long term results of "slow" vs. "rapid" expansion.

Orthopedic forces during RME. The idea of influencing the mobile maxillae during and after expansion has been explored. Haas[22] applied mesially and distally directed forces to the maxillae following RME and suggested that the orthopedic response in many patients was increased. On the other hand, in a study on RME in 20 monkeys, Henry[27] found that it did not enhance the susceptibility of the maxilla to posterior orthopedic movement following application of heavy distal forces.

METHOD OF RETENTION AND RELAPSE TENDENCIES

Retention and relapse. Hicks[29] observed that the amount of relapse is related to the method of retention after expansion. With no retention, the relapse can amount to 45% as compared with 10% to 23% with fixed retention and 22% to 25% with removable retention. Krebs[38,39] found that after fixed retention was discontinued, there was a substantial reduction in dental arch width. This tendency continued for up to 5 years.

After a review of the literature, Bell[5] concluded that slow expansion is less disruptive to the sutural systems. Slow expansion that maintains tissue integrity apparently needs 1 to 3 months of retention, which is significantly shorter than the 3 to 6 months recommended[15] for rapid expansion. Mew[46] advocates a total retention period of 1½ to 4 years, depending on the extent of expansion.

Surgical midpalatal splitting. Because the results of RME in adults are unpredictable, different surgical approaches are used to help correct maxillary constrictions. Palatal expansion can be accomplished by surgically moving the maxillae or by surgically undermining the maxillae to facilitate expansion using an RME appliance. The surgical approaches are either corticotomies of the buccal surfaces of the maxillae or more extensive surgery involving the separation of the maxillae from the pterygoid plates. With true unilateral skeletal maxillary constriction, surgical expansion of the collapsed side offers a distinct advantage, particularly when bilateral expansion of the two halves is not indicated.

When the clinician considers moving the maxillary segments laterally during a surgical procedure, it should be remembered that this instantaneous expansion of the maxilla is limited in part by the amount the palatal mucoperiosteum can be stretched. For patients who require a significant amount of surgical expansion, orthodontic or rapid expansion of the maxillae before surgical treatment would be helpful. The stretch of the mucoperiosteum resulting from RME will allow greater latitude in moving the maxillae during the surgical expansion.

Long-range studies on the stability of "surgical" expansion are not available in the literature.

ESTIMATING NEEDED EXPANSION

The following measurements will help clinicians estimate how much expansion is needed (Fig. 5): (1) measure the distance between the most gingival extension of the buccal grooves on the mandibular first molars or, when the grooves have no distinct terminus on the buccal surface, between points on the grooves located at the middle of the buccal surfaces; (2) measure the distance between the tips of the mesiobuccal cusps of the maxillary first molars; and (3) subtract the mandibular measurement from the maxillary measurement.

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Patient Instructions for Maxillary Expansion Appliances

The appliance given to you will widen (expand) your upper dental arch. The key that we gave you fits into the appliance. The key is put into the appliance, and moved backward to turn the expansion screw. Turn the key backward as far as it will go, so that the key can be put into the appliance for the next turn. Either you or your parent can turn the expansion screw with the key.

The schedule for turning the appliance with the key is as follows:

____ turns for ____ days. From ____/____/____ to ____/____/____; then,
one turn for ____ days. From ____/____/____ to ____/____/____; or
one turn every other day. From ____/____/____ to ____/____/____.

Please follow the suggested schedule. Too many turns may cause discomfort. Too few turns will not produce the desired results.

If you feel discomfort, pain or dizziness, stop turning the appliance and call the office.

Please keep a long piece of string attached to the expansion key to avoid accidental swallowing of the key when turning the appliance.

A space will open between the upper front teeth during the first two weeks as the appliance widens the arch. Do not get alarmed, this is an expected change. The space will disappear in the following two weeks as the front teeth come back together.

Please use your toothbrush to clean the teeth and appliance. With good oral hygiene, you will protect against cavities and gum disease.

Your next appointment with us is on ____/____/____. If you have any questions about the appliance, please contact the office.

Fig. 7. Instructions for patients who undergo rapid maxillary expansion.

The average differences in persons with normal occlusion are +1.6 mm for males and +1.2 mm for females.[57] The discrepancy between the maxillary and mandibular measurements is a good estimate of how far the maxillary molars must be expanded. One should overexpand the molars 2 to 4 mm beyond the required distance to allow for the expected postfixation relapse.[46] The expansion screw should provide, at least, this calculated amount of expansion.

These estimates assume a Class I molar relationship. If the malocclusion will be corrected to a Class II or III molar relationship, the corresponding arch segments should be measured when estimating the amount of expansion necessary.

In treating Class II patients, unless a buccal overjet is present, correction of the anteroposterior discrepancy without maxillary arch expansion will result in various degrees of buccolingual malrelationships of the posterior segments. To avoid such an occurrence, it is necessary to expand the maxillary arch either conventionally or with RME. Similarly, in Class III patients one has to differentiate between a crossbite created by the anteroposterior discrepancy and the crossbite that is present even after the correction of the molar relationship (Fig. 6).

Clinicians need to accurately determine both the need for and the magnitude of maxillary expansion. Data on what is considered to be the maximum amount that a maxillary arch can be expanded are not available. This would vary between individuals and according to the severity of the malocclusion, but 10 to 12 mm should be considered as the upper limit of RME correction. For discrepancies of this magnitude, clinicians must consider a combined orthodontic–surgical approach in order to provide a more stable result.

JACKSCREW TURN SCHEDULES

Zimring and Isaacson[65] recommend the following turn schedules: (1) *young growing patients*—two turns each day for the first 4 to 5 days, one turn each day for the remainder of RME treatment; (2) *adult (nongrowing) patients*—because of increased skeletal resistance, two turns each day for the first 2 days, one turn each day for the next 5 to 7 days, and one turn every other day for the remainder of RME treatment.

CLINICAL ADVICE FOR RME PATIENTS

1. Postpone extraction of first premolars until palatal expansion is completed because these teeth, together with the first molars, are often used as abutment teeth for anchoring the appliance. If premolars have not erupted, second deciduous molars with adequate root structures can be used. Howe[30] suggested a bonded appliance that would incorporate deciduous teeth.

2. When possible, avoid orthodontic movement of the maxillary posterior teeth prior to RME. Mobile teeth may tip faster during expansion.

3. The vertical positioning of the expansion screw is a function of the width of the palate and the size of the screw. For patient comfort and for mechanical advantage, position the screw as superiorly as possible in the palatal vault.

4. Start turning the jackscrew 15 to 30 minutes after the appliance is inserted to allow sufficient setting time for the cementing medium. Each turn of the screw opens the appliance ¼ mm. Provide the patient with an instruction sheet listing the turn schedule and possible symptoms that might accompany RME (Fig. 7). Ask the patient to report to you any unusual symptoms such as pain or dizziness. If these symptoms persist, either decrease or discontinue the turn schedule.

5. Tie a string or dental floss to the turn key to prevent it from being swallowed. Solder the key handle closed to avoid slippage of the floss.[50]

6. See the patient at regular intervals during the expansion phase of treatment. Measure the distance between the two halves of the expansion screw to determine how much the screw has been turned. Discuss discrepancies between this measurement and the turn schedule with the patient.

7. Monitor the midpalatal suture with weekly maxillary occlusal films. The suture will open within 7 to 10 days in most patients. If the suture does not split within 2 weeks,[60] the lack of skeletal response may result in tipping of the teeth and possible fracture of the alveolar plates.

8. After the expansion is completed and the screw is immobilized, the appliance acts as a fixed retainer for a period of 3 to 6 months to allow the tissues to reorganize in their new positions and also allow the forces created by the expanding appliance to dissipate. The greater the magnitude of expansion, the longer the period of *fixed* retention.

9. After removing the RME appliance, place a transpalatal holding arch between the maxillary first molars to minimize relapse tendencies.

10. At the end of the expansion stage and during fixation, the maxillary posterior segments are usually overexpanded. During the orthodontic treatment phase, incorporate some expansion in the maxillary arch wire. Avoid lingual crown torque of the maxillary molars and/or buccal crown torque of the mandibular molars because such forces may reintroduce the crossbite problem.

11. In a patient with a severely constricted palate, the clinician might consider some of the following options: (a) expand the palate in two phases, (b) initiate expansion as early as possible, (c) prolong the period of fixed retention, (d) consider extraction of teeth in one or both jaws to facilitate constriction of the dental arches, (e) overexpand the maxillary arch, and (f) use an expander that will maximize skeletal movements. For patients with narrow palates, clinicians may choose a telescopic screw, an interchangeable screw, or construct two appliances with progressively larger screws.

12. Possible immediate effects of premature appliance removal include dizziness, and a feeling of heavy pressure at the bridge of the nose, under the eyes, and generally throughout the face. Blanching of the soft tissues overlying these areas and blanching between the central incisors have been reported.[65] Some of these symptoms continued over a period of 19 hours during which the appliance was out of the mouth. In that period the measured relapse was only 1.5 mm in transpalatal dimension. Similar symptoms occur if the appliance is removed for repairs or recementation during the expansion phase or if the force is deactivated rapidly.[65] Therefore, perform any appliance manipulation while the patient is seated securely in a dental chair. Avoid making the patient stand immediately after appliance removal.

SUMMARY

Clinicians frequently correct absolute or relative maxillary–mandibular buccolingual discrepancies with rapid maxillary expansion. In this review the indications and contraindications of the procedure were outlined. The effects of expansion on the maxillary and mandibular structures were discussed as well as the implications these changes have on the clinical management of patients who can benefit from this procedure.

How to calculate the required amount of maxillary molar expansion is presented together with a suggested activation schedule for different ages.

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CORRECTION

In an article entitled, "Effect of Transcutaneous Electrical Nerve Stimulation for Controlling Pain Associated With Orthodontic Tooth Movement," by Drs. Roth and Thrash, which appeared in the August 1986 issue of The JOURNAL, the intensity range of the Alpha-Stim model 2000 was incorrectly reported to be 25 to 500 mA (milliamperes); the correct intensity range of the Alpha-Stim 2000 is 25 to 500 μA (microamperes).