

Treatment modalities of skeletal maxillary deficiency: A review

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ABSTRACT

Maxillary constriction can be skeletal, dental or a combination of both. The expansion of the midpalatal suture is used to treat maxillary width deficiencies; it is performed through rapid maxillary expansion, used in children and adolescents and surgically assisted rapid maxillary expansion which is an alternative for adolescents and the only option for widening the maxilla in adults. During maxillary expansion, not only skeletal effect is achieved, but also dentoalveolar tipping occurs. Various treatment modalities have been used for maxillary expansion. These protocols are generally divided into rapid maxillary expansion and slow maxillary expansion and several appliances are used as palatal expanders. Widening of the maxilla not only corrects the transverse dimension and the cross-bite but also leads to an increase of nasal width, that improving quality of sleep. The procedure is stable if a retention period of at least three-six months is assured, depending on type of expansion.

Keywords: cross bite; maxillary expansion; maxillary expansion techniques

INTRODUCTION

Maxillary constriction with posterior crossbite can cause functional shifting which affects jaw growth, space deficiency in the dental arch, facial and occlusal disharmony (1-7).

Usually, when the transverse skeletal discrepancy exceeds 6 mm, maxillary expansion is indicated (8). Rapid maxillary expansion (RME) is a common technique to correct maxillary transverse deficiency in younger patients. Although possible, the results are not predictable or stable in older patients. At this point, surgically assisted RME (SARME) is the option, with nonsurgical expansion preferred in patients with a transverse discrepancy of up to 5 mm (9,10).

Ultimately, every clinician must apply a patient-centric approach. The surgical approach might be advisable in patients with extreme maxillary hypoplasia requiring extensive expansion or be pre-

ferred for patients who have significant gingival recession or sleep apnea (11-13).

Thus, this study was conducted to review the indication of maxillary expansion, its effects, stability and methods used, according to the most recent studies.

ANATOMY

Understanding the mechanisms by which craniofacial sutures respond to mechanical force is essential for improving orthodontic treatment strategies. Accordingly, scientists are increasingly interested in delineating the events that occur at the cellular and molecular levels during the application of mechanical forces across craniofacial sutures.

Craniofacial sutures and synchondroses are flexible, dynamic and respond to different types of mechanical stimuli. Taking advantage of these properties, orthopaedic-orthodontic therapy utiliz-

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es applied mechanical stress to stimulate or inhibit bone growth or to modify direction of growth changing cellular activities within craniofacial sutures and synchondroses. Hard palate consists of the horizontal processes of the palatine bone posterior to the transverse palatine suture and the palatine processes of the maxillary bone anterior to that suture. Both bones are joined by sutures which are arranged in two anatomical planes, the transverse and sagittal one. This structure allows the palate to grow in two directions, elongate in the sagittal direction and widen in the lateral direction (14,15). Palatal growth and suture morphology in humans have three stages according to Melsen: the suture is broad and Y-shaped in the infantile period, it becomes longer in the vertical aspect and started to become interdigitated in the juvenile period and finally, in the adolescent stage it is very tortuous with increased interdigitation (16).

Recently Angelieri et al. has described five (A-E) radiographic stages of midpalatal suture maturation, which has the potential to avoid side effects of rapid maxillary expansion failure and unnecessary SARME. When rapid maxillary expansion is performed in the human palate, the opening of the midpalatal suture is not the only effect; the circummaxillary sutures separating maxilla from adjacent facial bones are also affected (17,18). As a result, they show highly variable bony displacement responses (19,20).

MECHANISM

Mechanical displacement

During rapid maxillary expansion suture separates superoinferiorly in a nonparallel manner, the separation being pyramidal in shape with base of the pyramid located at the oral side of the bone and the center of rotation located near the frontal-nasal suture. In the sagittal plane, the structures along the midline show an anterior displacement, whereas the lateral structures demonstrate a posterior displacement. In the vertical plane, the entire maxillary complex descends downward more or less in a parallel manner, whereas the lateral structures demonstrate an upward displacement (21).

Stress distribution

Stress produced by the expansion appliance is concentrated in the anterior region of the palate.

The initial effects of the expansion are observed in the central incisor region then stress radiates from the midpalatine area superiorly along the perpendicular plates of the palatine bone to deeper anatomic structures. The buttressing of the maxillary tuberosity with the pterygoid plates of the sphenoid bone allow the forces to then radiate to the base of the medial pterygoid plate. From this region, the stresses then spread further superiorly toward the malar and the zygomatic bones. Heavy stress was observed in the area of the base of pterygoid plates of sphenoid bone. If the maxilla is fused to the pterygoid plates, as is probable the case in adult patients, intermaxillary expansion would be difficult to obtain. Unlike the maxillae, the pterygoid processes are not individual bones, but parts of the same cranial bone – the sphenoid. So, even if SARME is advocated, the osteotomized maxillae and palatine bones would move apart on application of expansion forces, but the fused pterygoid processes which cannot separate, tend to splay outward (21).

In children and adolescents, the midpalatal and circummaxillary sutures generate less resistance to expansion forces, thus limiting the development of internal stresses in the dentoalveolar region. Consequently, maxillary expansion is accompanied by sutural adjustments in the craniofacial complex in remote regions, rather than by alveolar remodelling or tipping (21).

These adaptive changes cannot be exploited following skeletal maturation because the sutures are no longer patent and the expansion forces are now resisted by the reinforcing buttresses of the midfacial skeleton. Although expansion can be achieved in adults, displacements are noted more in the structures located anteriorly and along the midline, while the posterior and lateral structures demonstrate minimal displacement but high stress. RME must be used judiciously in adults, because of its far-reaching effects involving heavy stress being noted at the sphenoid bone, zygomatic bone, nasal bone, and their adjacent sutures (21). A more invasive SARME technique can significantly reduce the resultant stress. However, this benefit should be weighed against the risk of increasing complications associated with more extensive surgeries. When a more conservative surgical technique is selected, it would be preferable to perform a midpal-

atal split rather than zygomatic buttress osteotomies, as indicated by the stress-strain distribution and displacement pattern associated with different SARME techniques (22).

The development of a diastema is a predictor that adequate expansion is occurring. If no diastema appears, one might suspect that there is no separation of the hemimaxillae, and that the buccal segments are tipping.

TREATMENT MODALITIES

Various treatment modalities have been proposed and used for *skeletal* maxillary expansion. These protocols are generally divided into rapid maxillary expansion (RME) and slow maxillary expansion (SME) based on the activation intervals and force exerted by the appliances (23). Several appliances are used as palatal expanders. Fixed appliances such as Haas and Hyrax with jackscrews can be used for both SME and RME, while, removable expansion plates and quad helix are designed for SME (24,25).

In RME treatment, the expansion screw is activated one or two times a day which is equal to a 0.25-0.5 mm expansion force of about 100 N. SME appliances with screws are activated once or twice a week and exert a force of about 20 N. Thus, SME can elicit more efficient skeletal changes and more stable results by allowing more time for adaptation (26). The bone of the midpalatal suture responds to compressive and tensile forces. However, since the expansive force is directed to the teeth, dental movement and alterations in tooth inclination relative to the supporting bone structure are inevitable. Although the most desirable type of tooth movement is bodily movement, palatal expansion leads to some extent of molar tipping. It is believed that the skeletal-to-dental movement ratios vary according to type of expander appliance, the protocol of activation and stage of the patient growth. Comparing removable appliances with fix appliances it is considered that the degree of buccal molar tipping, the crestal and apical level of stress, the overall stress in periodontium of anchor and in both cortical and spongy bone, is higher in the first ones (27). Finally, it should be noted that the high forces generated by rapid maxillary expansion (RME) and the rapid displacement or deformation of the facial

bones would result in a marked amount of relapse in the long term, whereas relatively slower expansion of the maxilla would probably produce less resistance in the nasomaxillary complex. These findings led Işeri and Ozsoy to propose a protocol, named semi-rapid maxillary expansion (SRME) with RME followed by slow maxillary expansion, immediately after the separation of the midpalatal suture. The schedule consists of two turns each day for the first 5 to 6 days followed by three turns each week for the rest of the RME treatment (28).

Perillo proposed a new protocol, called mixed maxillary expansion, which is able to separate the two maxillary halves at the first appointment so that the expansion forces are completely applied to the maxillary bone. This protocol allows major skeletal effects but only and minor dental effects (29). Other protocols alternate rapid expansion and rapid constriction to activate the craniofacial sutures. This activation pattern is particularly effective to enhance the orthopedic effects of posterior-anterior traction of the maxilla achieved by a face mask in class III (30-32).

In recent years, another palatal expander has been developed with a jackscrew attached to the palatal vault by a temporary anchorage device: the microimplant assisted rapid palatal expander (MARPE), used to combat undesired dental effects by achieving pure skeletal changes. The main difference compared with RME is the incorporation of microimplants into the palatal jackscrew to ensure expansion of the underlying basal bone, minimizing dentoalveolar tipping and expansion. The literature shows a lack of knowledge and data regarding MARPE in the orthodontic community, yet many clinicians continue to utilize the device in practical or educational settings. Tausche reported that a MARPE is a viable expansion technique, allowing for the protection of teeth and preventing buccal tipping of the posterior dentoalveolar segment by 10° (33). Nienkemper reported that the previously mentioned side effects of RME appliances can be minimized using a MARPE (34). MARPE is also beneficial in young dolichofacial patients by helping to prevent bone bending and dental tipping and in patients with sutures that are fused, because less tipping occurs with a more lateral translation of the complex by placing expansion forces closer to the maxilla's center of resistance (35). The disadvan-

tages of MARPE are the invasiveness of the micro-implants and the increased risk of infection.

Many studies compared the effect of bone-borne versus tooth-borne palatal expanders. The results concluded that even though bone anchored technique can reduce the periodontal damage and root resorption of supporting teeth, dental and skeletal effects of tooth-borne and bone-borne devices are comparable so the selection of an expansion device should be based on each individual patient's requirements (36-38). The soft tissue behavior of the sutures exposed to loading can be used to predict which activation method may provide the most physiologic expansion (39).

EFFECTS

One of the biggest challenge of RME appliances is the achievement of true orthopaedic changes via skeletal expansion. During maxillary expansion, not only skeletal effects are achieved; approximately 50% of the expansion achieved by RME in children is skeletal (40). Handelman estimated that skeletal expansion is only 18% in adults compared to 56% in younger patients (41). Bacetti showed that only 0.9 mm of skeletal expansion is achieved in RME patients treated during or after the peak of skeletal maturation, while 3 mm of skeletal expansion is obtained in patients treated before the peak (42). Garret has shown that RME treatment produces 49% dental tipping, 38% skeletal expansion, and 13% alveolar tipping (43). A cone beam computed tomography study performed by Kartalian found an increased width of 2.08 mm, 2.25 mm, and 5.4 mm in the nasal floor, hard palate, and dental level, respectively (44).

Transverse maxillary deficiency is commonly found in patients with sleep apnea and is also related to abnormal breathing patterns. Maxillary expansion promotes widening of the nasal floor and reduces the resistance to airflow having a positive influence on nasopharynx function. It was reported that RME therapy produces a significant increase in nasal width of 37.2% and a decrease in maxillary sinus width. Garib specified the increase in nasal floor width as equal to one-third of the expander's jack screw opening (45). More recently, Christie reported a nasal width increase of 2.73 mm (33.23% of the jackscrew opening) at the first permanent molar (46).

RME therapy results in a combination of arch widening and reorganization of the hard palate. The palatal vault is reshaped and the palatal volume is increased upon the completion of expansion therapy so that RME is a potential additional treatment in children with obstructive sleep apnea. It has been hypothesized that, since the maxillary bones form a half of the nasal cavity's structures, when the mid-palatal suture is open, the nasal cavity's lateral walls are also displaced apart, and its volume increases, and upper airway resistance decreases over time. The quality of sleep of these children improves after RME, regardless of the severity of their respiratory obstruction. RME is a useful treatment option for improving the quality of sleep even in normal children but who are at higher risk of developing a sleep disorder due to their craniofacial morphology (47-50).

Both, SARME and RME have similar and significant effects on craniofacial airway dimensions with comparable results in tooth-borne and bone-borne appliances (51-54).

After surgically-assisted rapid maxillary expansion, the most obvious changes to the external features of the nose occur at the most lateral alar bases. The difference in lateral displacement profoundly influenced the perception of a more rounded nose. Patients with narrow and constrained nostrils can benefit from these changes (55).

During rapid maxillary expansion (RME), heavy orthodontic forces are transmitted to the maxilla through the teeth, and unfavorable changes may occur in the anchor teeth and their supporting tissues, including buccal crown tipping, root resorption, reduction of buccal bone thickness, marginal periodontium and bone loss (56-57).

STABILITY

The literature is unanimous in advocating that a period of at least three months is necessary for bone repair after RME. According to systematic reviews regarding long-term stability of the expansion, only approximately 25% of the initial achieved widening remains. Therefore it is essential to overcompensate the active expansion and to stabilize the result with a sufficient duration of the retention period. Since the procedure of RME performed after the pubertal peak tends to show more relapses, it is

important to plan a sufficient retention period with older patients. Although retention after RME has been widely examined, there is still no clear statement about the minimal retention time in postpubertal patients. A retention period longer than six months seems to be beneficial to prevent relapses in postpubertal patients (58).

If one looks at the stability of the skeletal changes with SARME, it should rank high in the hierarchy of stability of orthognathic surgery, but if one looks at the dental changes, 64% of the patients had more than 2 mm of change and 22% had more than 3 mm of change. This could be attributed to several factors, such as the device itself, the surgical technique, or the timing of the observations, but for all other surgeries, pre-surgical orthodontic preparation is done and few if any dental movements are needed after surgery. This is not the case for SARME. Many dental movements, including correction of overexpansion, are done after the expander is removed to achieve archform coordination (59). In SARME relapse is time-related and is most pronounced during the first 3 years after treatment. Thus, the retention period should be extended and should be considered for this period. Digital radiographs may be a valuable tool to evaluate alterations in the midpalatal suture that occur during the expansion treatment (60).

CONCLUSIONS

With both SARME and RME, successful expansion of maxillary dentoalveolar structures and the nasal cavity and palatal widening could be achieved as long as the treatment indication is based on the skeletal age of the patient, transverse needs and maturation of the midpalatal suture. In children, approximately half of the expansion is skeletal and half is dentoalveolar. The type of the expansion shifts from skeletal to dentoalveolar in mature individuals, who are the candidates for SARME. Dental and skeletal effects of tooth-borne and bone-borne devices are about the same, so the selection of an expansion device should be based on patient's preferences. Maxillary expansion procedures correct the cross bite, widen the nasal floor reducing the resistance to airflow being a treatment tool in patients with sleep apnea and a prophylactic measure in children with craniofacial disorders. Regarding the long-term stability of the expansion, only approximately a quarter of the initial achieved widening remains. Therefore it is essential to overcompensate expansion and to stabilize the result with an adequate duration of the retention period.

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