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Rapid Maxillary Expansion: A Review of Appliance Designs, Biomechanics and Clinical Aspects

Abstract: Rapid maxillary expansion (RME) is an orthopaedic procedure that utilizes heavy forces to correct transverse maxillary arch discrepancies. There is a substantial body of literature relating to the various designs of RME devices and their clinical indications.
CPD/Clinical Relevance: To provide the dental practitioner and orthodontist with evidence-based facts about types, designs and uses of RME appliances and to promote understanding of their biomechanical effects.
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Rapid maxillary expansion (RME) is not a new concept; it was first described and used, 150 years ago, on a 14-year-old female patient, utilizing heavy forces to correct a transverse maxillary arch discrepancy.[1] The efficacy of the procedure has, however, been questioned and challenged over the years. It was originally thought that separation of the mid-palatal suture was either impossible, due to the buttressing effect of the circum-maxillary sutures or, if successful, it was considered to be a dangerous procedure.[2,3] This paper will discuss in detail the biomechanics, clinical considerations, differing designs, expansion and retention regimens, as well as highlight potential problems encountered with RME.

Biomechanics of RME

The dentition and the craniofacial bones are constrained bodies by the periodontium and the sutures, respectively. The biomechanical principles involving tooth movement can be applied to the craniofacial bones using RME,[4] however, the magnitude of the forces required to separate the mid-palatal suture is approximately 900–4500 grammes, which is very different from that required to move teeth, about 10–150 grammes. The theoretical principle behind substantial force application is to disarticulate the circum-maxillary suture with resultant orthopaedic expansion before teeth respond.[5,6]

Clinical considerations

It has been proposed that the optimum age for RME is within the range 10–14 years, and is gender dependent. If RME is used in older patients, particularly females, then the rigidity of the surrounding bones may limit the amount of expansion achieved and the overall stability.[7]

Patients of optimum age presenting with 4–6 mm of unilateral or bilateral posterior crossbite can be treated with RME, especially if the buccal teeth are not buccally inclined, to allow for an element of buccal tipping during expansion.[7,8] Other 'claimed' clinical applications for RME are:

1. Space provision to provide relief of

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mild crowding.[9]
2. Interceptive treatment of palatally impacted canines.[10,11]
3. Treatment of Class III malocclusion in growing patients when it is used in conjunction with maxillary protraction appliances. Principles behind this combination are to disarticulate the circum-maxillary sutures with an element of anterior displacement of the maxilla as a result of the pivoting effect of the pterygoid plates during palatal separation, as well as correcting the associated crossbite. Vaughn *et al* in 2005 showed no benefit in the use of RME in conjunction with protraction headgear unless it is related to genuine maxillary constriction.[12]
4. Improvement of nasal airflow in patients suffering from nasal obstruction.[13]
5. Improvement of hearing in patients who suffer from conductive hearing loss as a result of Eustachian tube stenosis or middle ear problems. The recovery in hearing is thought to occur due to the functional normalization of the pharyngeal ostia of the Eustachian tube, secondary to the orthopaedic effects of the RME treatment, which subsequently decreases the incidence of recurrent serous otitis media.[14,15] However, there is some contention concerning the effect of RME on hearing, with one study reporting that an improvement in hearing was not maintained in the long term.[16]
6. Assisting in the control of Nocturnal Enuresis (NE) as NE has a significant association with upper airway obstruction and mouth-breathing issues.[17]
7. Treating patients suffering from headaches. One study showed that primary headache symptoms disappeared in 32 patients and reduced in rate and intensity in 9 patients after RME therapy.[18]

Design of rapid maxillary expanding appliances

RME appliances may be tooth-borne, tooth-tissue borne, bone-borne, or a combination. Generally, the RME design includes an expansion screw that may be attached to orthodontic bands, bonded/cemented directly to the dentition, skeletally retained, or a combination.

Banded RME appliances

Banded RME appliances could be either tooth-borne, such as Hyrax/Biedermann and Isaacson appliances; or tooth-tissue-borne, like Haas and Derichsweiler appliances.

The Haas design consists of an expansion screw, connecting bars and a palatal plate (acrylic or metal). The connecting bars are soldered/welded to the buccal and palatal surfaces of each pair of bands or embedded in the capping component, if the appliance is a bonded type (Figure 1). It has been suggested that the palatal plates allow the appliance to be tooth-tissue-borne with more parallel expansion forces to the alveolar components. However, this design has the potential for causing palatal tissue damage and irritation.

The Derichsweiler appliance is similar to the Haas design except for the absence of buccal connectors (Figure 2). The Hyrax appliance is a tooth-borne RME and consists of an expansion screw that is soldered/welded directly to the cemented bands on the abutment teeth (Figure 3). It has been suggested that this design is easier to keep clean than the other designs.[19] The Isaacson design (tooth-borne RME), also known as the Minne-Expander, is similar to the Hyrax expander with the exception that the expansion screw is replaced with a coil spring that can be compressed by turning a nut (Figure 4). Its main disadvantage is the continuous expansion force that may continue during the passive phase as a result of the latent kinetic energy accumulated in the spring.[19]

Bonded RME appliances

Most of the bonded RME appliances are tooth-tissue-borne unless the capping is limited to the occlusal surface. The advantage of a bonded RME device is the increased rigidity of the appliance, which is claimed to be associated with the minimal tipping of the abutment teeth.[20] The bonded RME appliance consists of cobalt chrome occlusal capping linked to the expansion screw via an acrylic connector[21] (Figure 5); alternatively, the occlusal capping may be totally constructed from acrylic[22] (Figure 6).

Bone-borne expanders

Bone-borne expanders or Micro-implant Assisted RME (MARME) is a relatively new development in the field of maxillary expansion. It has been reported that these appliances can overcome the drawbacks associated with conventional tooth-borne and tooth-tissue-borne appliances, for instance, tipping and periodontal damage of the anchor teeth.[23,24] (Figure 7).

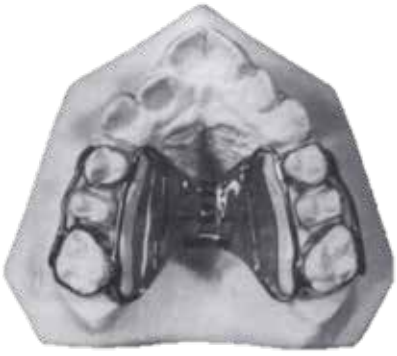

Figure 1. Haas appliance.

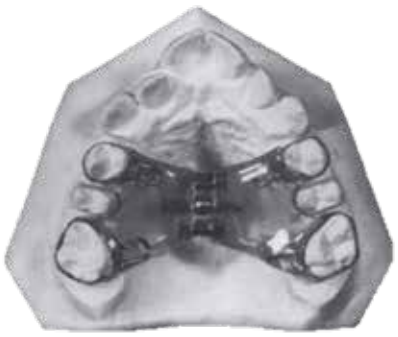

Figure 2. Derichsweiler appliance.

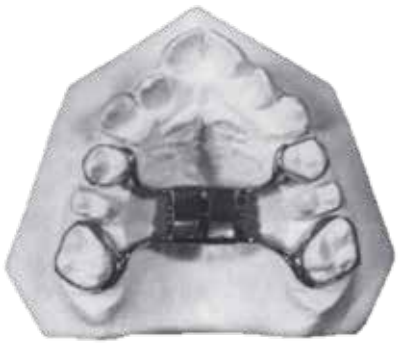

Figure 3. Hyrax appliance.

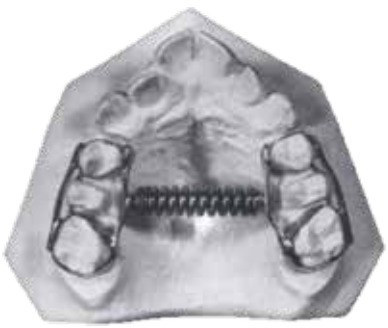

Figure 4. Isaacson appliance.

Hybrid hyrax

It is an expander bonded by an occlusal cap to abutment teeth and anchored by palatal temporary anchorage devices (TADs) to reduce anchor teeth tipping while maximizing the orthopaedic

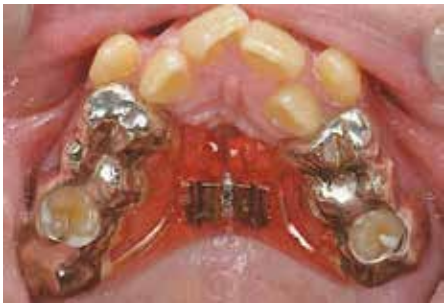

Figure 5. Metallic cap splint (tooth-tissue borne appliance).

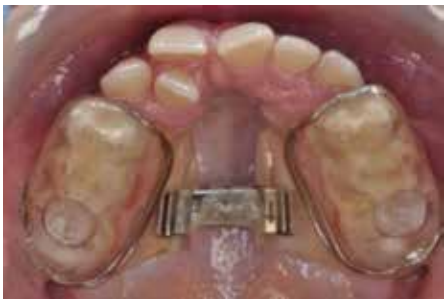

Figure 6. Acrylic cap splint (tooth-tissue borne appliance).

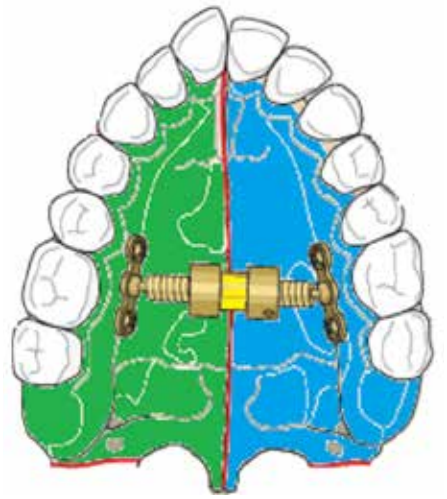

Figure 7. Bone-borne expander.

Figure 8. Hybrid hyrax expander (Courtesy of Professor Ali Darendeliler, University of Sydney, Australia).

outcomes. For this reason, it is considered a hybrid appliance as it is both a bone-borne and a tooth-borne appliance[25] (Figure 8).

Haas regimen	Two turns per day, after meals, until the desired expansion has been achieved
Timms regimen	For adolescents: Two turns per day until the desired expansion has been achieved For adults: Four quarter turns per day until the desired expansion has been achieved
Isaacson regimen	Two turns per day for the first 4–5 days followed by one turn per day for the remainder of RME treatment
Hybrid regimen	Combination of two or more of the above as per clinician preference

Table 1. Conventional activation protocol for RME treatment.

Activation regimen

In general, overexpansion, by 2–4 mm beyond the required expansion or until the maxillary palatal cusps are levelled with the buccal cusps of the mandibular teeth, had been suggested to compensate for potential relapse.[26,27] However, the maximum amount of expansion that can be achieved is in the region of 10–12 mm; hence, if further expansion is required Surgical Assisted Rapid Palatal (Maxillary) Expansion (SARPE or SARME) should be considered.[7] The literature describes a variety of conventional activation protocols that can be used for activating RME appliances[28] (Table 1).

Recently, Alternate RApid Maxillary Expansions and Constrictions (Alt-RAMEC) protocol was developed. It was originally used for treating cleft-related Class III malocclusions.[29] The original appliance system consists of a double-hinged expander and intra-oral βeta titanium maxillary protraction (β-Ti) springs. The β-Ti spring is similar in design to Jasper Jumper bite correctors but assists in maxillary rather than mandibular protraction. The β-Ti spring attached to the mandibular first molars posteriorly and the maxillary archwire anteriorly and the spring rests in the buccal sulcus. The expansion screw is adjusted by alternating a weekly period of expansion followed by a weekly period of constriction. It was claimed that Alt-RAMEC protocol initiates bone resorption behind the maxillary tuberosity and loosening of the maxillary halves which, in combination with the maxillary protraction spring, results in fast and significant dentoskeletal expansion and forward maxillary displacement.[30]

Another activation regimen is the one used in conjunction with jaw surgery (SARPE). As mentioned earlier, SARPE is indicated for the treatment of an adult patient with severe maxillary transverse deficiency (greater than 6 mm) and/or previously failed orthopaedic expansion. It encompasses a conventional Le-Fort I osteotomy with partial or full surgical disarticulation of the maxilla. Following the osteotomy, the maxilla should be allowed to remain stationary for five days (latency period) to allow capillary healing across the osteotomy area prior to initiation of expansion at a rate of 0.5–1mm per day. Although SARPE was thought to lead to a more stable result when compared to immediate one-day surgical expansion or conventional RME expansion, the latest systematic review failed to show any significant difference regarding the stability in comparison to conventional RME.[31]

Relapse and retention

Following an active expansion, a period of retention is required for at least three months to allow bony infill in the space between palatal shelves.[20] It also allows the residual load of the screw/spring to dissipate. There are many retention modalities secondary to RME[32] (Table 2, Figures 9–12).

The degree of maxillary expansion stability is variable among literature; some studies reported no relapse for the first five years after treatment,[8] while others showed that 50% of the achieved expansion relapsed 5–15 years post-expansion.[33]

Many factors influence the degree of relapse after RME expansion, such as a patient's gender and age, with a greater amount of relapse in adult compared to adolescent patients. [34] Moreover, high stability is associated with the elimination of the aetiological habits and the achievement of a good buccal segment intercuspation.[35]

Method of Retention	Results
No retention	Highest risk of relapse
RME appliance could be kept passive after locking the screw for 3–6 months (Figure 9)	Stable short-term results Risk of decalcification and gingival irritation Risk of cementation failure
Transpalatal arch (TPA) with horizontal palatal arms (Figure 10)	Non-compliance Better stability than URA Cleansable method Extra appliance cost Interference of the horizontal arms with teeth movement during fixed appliance treatment phase
Upper removable appliance (URA) (Figure 11)	Require patient compliance Speech interference

Table 2. Retention modalities secondary to RME.

Success factors

The success of RME depends on many factors, primarily the rigidity of the appliance. It has been proposed that the expansion created by bonded RME appliances is less prone to relapse as the rigid bonded RME appliance is efficient in transmitting the expansion force to the basal maxillary bone with minimal dental tipping.[36]

Another factor that affects the success of RME is teeth utilization. Incorporating as many teeth as possible into the appliance design is crucial in reducing the load/force on individual teeth and the subsequent buccal tipping of the anchor teeth. Additionally, the type of the expansion unit is another relevant factor; for instance, spring-loaded expansion system has less rigidity and thus less orthopaedic effect than a screw component.

Furthermore, the position of the expansion unit plays an important part in defining the consequences of the RME. Usually, the screw has to be position at the centre of rotation for maximum effect, which theoretically lies in the middle of the palate in the primary dentition. However, the centre of rotation moves posteriorly to the embrasure between the second premolar and the first permanent molar, in the permanent dentition.[37] Regarding the superior-inferior position of the expansion unit (screw or spring), an infinite element model study revealed extrusive and distal movements would be encountered if the expansion unit is placed close to the palate. While, if expansion unit is positioned away from the palate, then posterior teeth would be tipped buccally and moved mesially.[38]

Oral hygiene is an essential patient-related factor in the success of RME as the RME increases the risk of decalcification and inflammation of the palatal mucosa. For this reason, the Hyrax design is favoured for its minimal palatal and dental coverage.

Potential problems encountered with RME

One of the most common side-effects of RME is pain and soreness during the active phase of expansion. In 98% of cases treated with RME, the pain generally occurs during the first six turns and diminishes thereafter. It was also found that pain is correlated with the expansion regimen, especially if the rate of expansion exceeds one turn per day.[39] Moreover, the use of RME has been reported to be associated with the transient pulpal, periodontal damage, as well as minimal loss of alveolar bone support.[40] Short-term, gingival tissue irritation and inflammation is a very common problem resulting from pressure necrosis and plaque accumulation around the appliance component, making oral hygiene suboptimal.[41]

Additional complications seen after RME treatment are bone dehiscence and Orthodontically Induced Iatrogenic Root Resorption (OIIRR) of the anchor teeth secondary to the heavy expansion forces[42] and a higher force distribution, in particular following the Hyrax appliance.[43] However, one research group reported no difference in OIIRR between the Haas group (tissue-borne) and cast cap splint group (tooth-borne).[44] Rare transient complications of the RME are dizziness, epistaxis, temporary diplopia or even compression of the occulomotor nerve, in particular secondary to SARPE.[45]

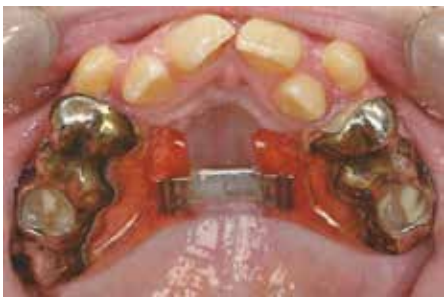

Figure 9. The screw of the RME is secured with composite and the appliance left passive as retainer.

Figure 10. TPA with horizontal arms.

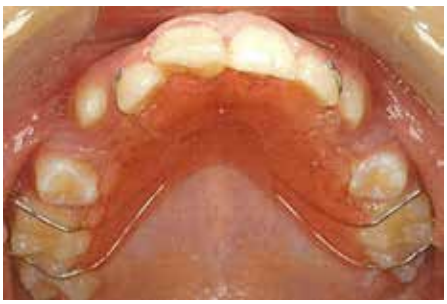

Figure 11. URA as retainer after RME.

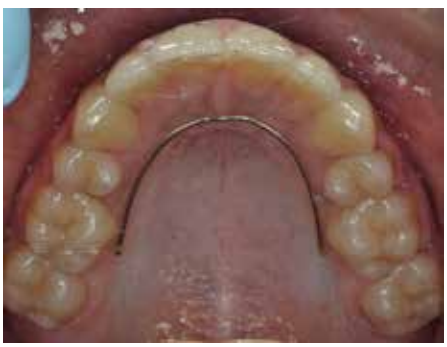

Figure 12. Modified PFR reinforced with 1 mm stainless steel wire.

Conclusion

There are various designs for RME appliances available to the orthodontic practitioner, ranging from banded designs, bonded designs, tooth, tissue, bone-retained RME or hybrid designs. The literature shows various uses

of RME appliances ranging broadly from treatment of a constricted maxilla to bed-wetting. The success of the RME treatment is dependent on careful appliance design and the successful splitting of the mid-palatal suture.

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