International Journal of Dentistry and Oral Science (IJDOS)
ISSN: 2377-8075

Microimplant-Assisted Rapid Palatal Expansion (MARPE) - A Comprehensive Review

Review Article

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Abstract

Maxillary transverse deficiency routinely requires expansion of the palate. In growing patients, well-documented expansion modalities are slow maxillary expansion (SME) and rapid palatal expansion (RME). However, in mature patients due to the complexity of interdigitation of midpalatal suture and decreased elasticity of bone, palatal expansion is challenging. Patients are frequently suggested to go for a more invasive procedure, like the Surgically Assisted Rapid Palatal Expansion(SARPE) expansion. More recently, with the emergence of implants, researchers havevalidated that it is possible to expand the maxilla in adult patients without carrying out osteotomies.This comprehensive review provides fundamental information, different designs,recent updates, surgical guides, clinical significance and limitations ofMicroimplant-Assisted Rapid Palatal Expansion(MARPE), which has become a generic term for the maxillary expansion appliance which transmits expansion forces to basal bones by a miniscrew anchorage system.MARPE represents a valid alternative to surgery in treating mature patients with a transverse maxillary deficiency with greater stability, safety, and fewer side effects.

Keywords: Maxillary Expansion; Microimplant-Assisted Rapid Palatal Expansion (MARPE); Maxillary Skeletal Expander (MSE); Maxillary Transverse Deficiency; Rapid Maxillary Expansion.

Introduction

A genomic biomarker is a measurement of the expression, function aMaxillary transverse deficiency is one of the most pervasive problems in the craniofacial region prevalent in all age groups, from deciduous to permanent dentition [1]. It has been reported that 9.4% of the entire population and nearly 30% of the adult orthodontic patients have a maxillary transverse deficiency [1]. However, some reported that the prevalence of maxillary transverse deficiency ranges from 8% to 23% in mixed and deciduous dentitions and less than 10% in adults [2]. Maxillary transverse deficiency has multifactorial etiology and some of the most prevalent factors are narrow palatal dimensions, inheritance, ectopic eruption, impaired maxillary transverse growth associated with a palatal cleft and breathing disordersand soft tissue imbalance like prolonged digit sucking, lower tongue position [3]. When the maxilla and mandible fail to properly orient in the transverse dimension, odontogenesis continues its processand teeth eruption inabnormal positions leading to malocclusion [4, 5]. If maxilla mandibular transverse discrepancies are not treated in an appropriate time, they can aggravate and metamorphose into more complex malocclusion, hindering facial growth and development [6]. Maxillary transverse deficiency impacts the occlusion not only in the transverse plane but also in the vertical and sagittal planes leading to intricate situations, such as posterior unilateral or bilateral crossbites, crowding, scissor bite, non-carious cervical wear, adverse periodontal stress, low masticatory ability, functional shift of the mandible, faulty buccolingual tipping of posterior teeth, asymmetric mandibular position in growing patients, joint disor-

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Received: April 28, 2021
Accepted: October 20, 2021
Published: October 26, 2021

Citation: Tamanna Hoque, Dilip Srinivasan, Sangeetha Morekonda Gnaneswar, Sushil Chakravarthi, Krishnaraj Rajaram, Ravi Kannan. Microimplant-Assisted Rapid Palatal Expansion (MARPE) - A Comprehensive Review. *Int J Dentistry Oral Sci.* 2021;8(10):4848-4852. doi: http://dx.doi.org/10.19070/2377-8075-21000980

ders and muscle function disharmony. However, the grave consequence of maxillary transverse deficiency is the narrowing of the nasal cavity, which increases nasal air resistance and might become an etiologic factor of Obstructive Sleep Apnea Syndrome (OSAS) [6, 7]. In Class III malocclusions nearly half of the patients have maxillary skeletal retrusion, which contributes to transverse discrepancies between the maxilla and mandible [8]. Dental crowding and posterior crossbite are two easily recognizable clinical features of transverse deficiency, while exaggerated buccal flaring of the maxillary dentition and deep Curve of Wilson in the lower dentition can mask the maxillary transverse constriction [7].

Traditionally, to correct transverse maxillary deficiencies RME (Rapid Maxillary Expansion) and SME (Slow Maxillary Expansion) appliances have been effectively used for years, despite certain negative side effects like undesirable tooth tipping, limited skeletal movement, root resorption, bone dehiscence, thinning of the buccal cortical bone and relapse. For Adults due to the complexity of interdigitation of midpalatal suture and decreased elasticity of bonealternative methods like Surgically assisted RPE (SARPE) which increases expansion possibilities, long term stability and success, with reduced side effects, have been developed. Despite its benefits, the procedure has its impediment of surgical morbidity, high cost, periodontal complications [6]. With the advent of orthodontic mini-implants, the possibilities for pure orthopedic movement in the expansion of maxilla with RME are explored around the world. This novel system, called Micro-implant-Assisted Rapid Palatal Expansion (MARPE), transmits expansion forces to basal bones by a miniscrew anchorage system.Theterm MARPE became a generic term, although designs and activation protocols differed greatlywith different appliance models. Due to different expansion force vectors and magnitude, different dimensions of the implants, widely varying in anchor location and the relative position of jackscrew to the skeletal anchor, different designs yield varying results, often in contradiction to each other [9]. Some MARPEs are tooth-bone-anchored or hybrid and others are purely bone-borne [10].

Review Result

The treatment envelope of maxillary transverse deficiency has been broadened to treat adult patients without surgery with MARPE [11] (Fig.1).

Discussion

The midpalatal suture changes with age

Mid palatal sutural studies by Melsen [12] Isaacson et al [13] have revealed a relationship between the increased interdigitation of the midpalatal suture with the age of the subjects in hindering maxillary separation. They also emphasized that the maximum resistance is not due to the midpalatal suture but by the surrounding maxillary articulation.Bishara and Staley [14] suggest that the resistance to mid-palatal suture openingwas noticed at the sphenoid and zygomatic bones, particularly at the superior parts of the pterygoid plates of the sphenoid bone, and anterior part of the zygomatic bone. Wertz [15] reported that the fulcrum of maxillary separation tends to be displaced more inferiorly, nearer to the activating force with an increase in age. The fulcrum may be high near to frontomaxillary suture in children, whereas in adolescents the fulcrum is much lower. These variances in age-dependent effects may be due to the increased resistance in circum-maxillary sutures during maxillary separation.

Fernanda Angelieri et al [16] studied the Cone-beam computed tomography images of 140 subjects. They divided the Mid Palatal Suture into five stages of maturation and defined them as:

1. Stage A- straight high-density sutural line, with no or little interdigitation.
2. Stage B- the scalloped appearance of the high-density sutural line.
3. Stage C- two parallel, scalloped, high-density lines that were close to each other, separated in some areas by small low-density spaces.
4. Stage D- fusion completed in the palatine bone, with maturation progressing from posterior to anterior.
5. Stage E- the fusion of the midpalatal suture has occurred in the maxilla.

The study concluded that at stage C, a less skeletal response would be expected than at stages A and B with the conventional RME approach. For patients at stages D and E, surgically assisted RME would be necessary.

Conversely, Wehrbein et al [17] emphasized that the term 'suture fusion' should be avoided in terms of radiologic terminology as they found that a radiologically invisible mid-palatal suture is not the histological equivalent of a fused or closed suture after analyzing the palatal suture status of young adults ranging from 18 to 38 years of age.

Different designs of bone-borne palatal expanders using micro-implants [1]

Figure 1.

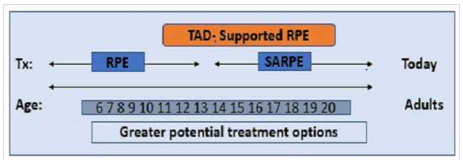

Figure 2.

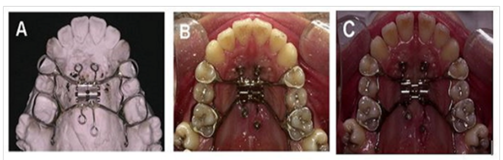

Figure 3.

Figure 4.

Figure 5.

Table 1.

Suggested expansion rates for different age groups		
Age of the patient	**Initial expansion rate**	**Expansion rate after opening of the diastema**
Early teens	3 turns/week	3 turns/week
Late teens	1 turn/day	1 turn/day
Adults	2 turns/day	1 turn/day
Older patients (>30 years)	2 turns/day	1 turn/day

Type 1: miniscrews placed lateral to midpalatal suture
Type 2: miniscrews placed at the palatal slope
Type 3: miniscrews as in type 1 but with additional conventional Hyrax arms

MARPE Design

Lee et al [18] used a Hyrax screw with an orthodontic miniscrew also called a hybrid expander (Fig.2), two miniscrews placed anteriorly in the palatal rugae and two posteriorly in the parasagittal area. The activation protocol followed was one-quarter of a turn (0.2 mm) once a day, with a total activation period of 40 days and a 3-month retention period thereby successfully treated severe transverse discrepancy 20-years-old patient.

Cunha et al [19] suggested that the position of posterior miniscrews in MARPE may have a crucial role in providing adequate stress distribution, favoring the complete disjunction of the midpalatal suture with type I palatal split pattern (Fig.3).

Lim et al [20] suggested that the expansion effects of MARPE were not limited to the maxilla only but also extended to the circummaxillary structures and that the maxillary halves showed buccal rotation, with the rotational center located near the frontonasal suture. MacGinnis et al [2] used the finite element method (FEM) to demonstrate that by changing the location of the expansion screw, the stress distribution on the craniofacial complex is altered. Likewise, placing the jackscrew closer to the center of resistance, a more horizontal translation of the maxilla takes place with less resultant buccal tipping. They also concluded that MARPE propagates less stress to the buttresses and adjacent locations in the maxillary complex compared to the conventional RPE.

MSE (Maxillary Skeletal Expander) developed by Dr. Won moon[9]is a unique lineage of MARPE. It causes expansion of the entire midface, agitating all peri-maxillary structures. When MSE is applied in combination with FM (face mask), almost negligible vertical side effects are detected, the existing anteroposterior dental compensation can be reversed, the maxilla advances efficiently in large magnitude, and resulted in some skeletal protraction even in mature patients. This combination simulates distraction-like movement, which forms a promising basis for non-surgical orthopedic treatment modality for Class III adult patients. The unique position of miniscrew in MSE (Fig.4) in the superior and posterior aspect of the palate with four long implants engaging the palatal bone bicortically gives a significant advantage in overcoming the resistance from zygomatic buttress bones and pterygopalatine sutures, possibly leading to a more parallel expansion in contrast to many other designs of MARPE.

Carlson et al [21] suggested that the size of the jackscrew must be chosen based on the maximum screw size that would adequately fit in the palatal vault, concurrently allowing close adaptation of the appliance to the tissue surface between the maxillary first molars. This position exerts lateral forces against the pterygomaxillary buttress of the bone, which is a major resistance factor in maxillary expansion. The expansion rate (Table 1) was selected based on the protocol developed by Dr. Won Moon through clinical experience with the MARPE appliance [21].

Clement. A and Krishnaswamy N. R.[22] concluded that MSE used in young adults produced 61% of the degree of expansion at skeletal level, 20%alveolar, and 19% dental expansion. Cantarella D et al [23] evaluated midfacial skeletal changes in the coronal plane in late adolescent patients treated with a bone-anchored maxillary expander using CBCT and found significant lateral displacement of the zygomaticomaxillary complex and outward rotation of zygomatic bone along with the maxilla with a common center of rotation located near the superior aspect of the frontozygomatic suture which ultimately leads to negligible dental tipping of the molars. Cantarella D et al [24] study, revealed that the opening of the mid-palatal suture in the anterior region was 4.8mm and at the posterior nasal spine was about 4.3mm and the percentage of the mid-palatal split in the PNS was 90% that of ANS, showing near the parallel opening.

Selection of mini-implants and site of placement

Nojima et al [25] suggested the following steps to select the length of miniscrews to be used in the MARPE: 1. Procurement of dental casts, 2. Selection of DICOM visualization software and maxilla orientation in CBCT images. 3. Measurement of bone thickness on the coronal section of CBCT images. 4. Evaluation of expander miniscrews fixation rings. 5.Selection of miniscrew. The total length of the miniscrew (MI) is represented by the variables: bone thickness (o), adding 1.0 to 2.0 mm which is necessary for the miniscrew tip to surpass the cortical plate of the nasal fossa, soft tissue thickness (m), fixation ring thickness (a), distance from the ring to the palatal surface (d). The equation employed to calculate the total miniscrew length is described, with the value in millimeters, as $MI = o + m + a + d + (1 \text{ or } 2)$. Lee et al [26] suggested the use of bicortical (cortical bone of palate and nasal floor) mini-implant anchorage over monocortical anchorage to enhance mini-implant stability, mitigate mini-implant deformation and fracture, more parallel expansion in the coronal plane, and increased expansion during bone-borne palatal expansion. Peri-implant stress was preeminent in the monocortical anchorage model compared with both bicortical anchorage models. Wilmes B et al [27] found that the area immediately posterior to the palatal rugae, and the paramedian area referred to as the "T-Zone", is amore suitable region for insertion of palatal mini-implants due to the available bone volume and bone is much thinner in posterior and lateral areas. Lombardo et al [28] FEM study demonstrated that a miniscrew of diameter 2 mm and length 11 mm inserted into the palate can withstand loads between 240 and 480gf (gram force), without causing a fracture to the bone, even in the absence of osseointegration.

Surgical guide for MARPE

A surgical guide is an essential tool for correctly placing implants, which aims to achieve a perfect interrelation of digital planning and actual placement. It allows the three-dimensional orientation of the expander close to the palate and guides perforations of mini-implants, which is required to establish anchorage in areas with adequate bone, assuring the system stability and a successful outcome.Bruno L Minervino et al [29] suggested two fundamental aspects concerning planning for the placement of MARPE. Firstly, suture evaluation by CBCT to assess the possibility of expansion secondly three-dimensional positioning of both expander and mini-implants to assure insertion in an area with bone support. Intraoral scanning of the maxilla is required followed by superimposed to the computed tomography, using points at the teeth region as a reference which allows determination of the correct position between intraoral scanning and the tomography. After this initial merging, the third digital file, namely the stereography of the MARPE expander, is also merged. Finally, the expander and four mini-implants are positioned using the software. Miniscrew Assisted Palatal Appliance (MAPA) system protocol – Maino G et al [30] introduced a new high-precision 3D Method of the palatal miniscrew placement technique to prevent damage to the anatomical structures. This template can ensure not only that mini-implants are placed at the correct depth inthe maxillary bone but also that multiple implants are parallelly placed. The use of CBCT is strictly recommended in all cases of impacted canines, laterally displaced lateral incisors, narrow maxilla, or anatomic abnormalities that may affect the correct insertion of the mini-implants. MAPA (Fig. 5) is designed to recreate the angle of insertion and prevent the mini-implants from penetrating beyond the required depth. Therefore, the 3D technological processes assure efficient, accurate, and predictable orthodontic planning, since they standardize the technique and reduce the risks.

Clinical Significance

Advantages Of Marpe

• MSE appliances transmit expansion force into the palatine bone and produced a more parallel-type and more consistent suture opening upon maxillary expansion. Widening of surrounding craniofacial structures including the zygoma and the nasal bone [2].
• Larger transverse skeletal expansion while lessening dental side effects such as dental tipping, vertical alveolar bone loss, and alveolar bending [1, 2].
• MARPE allows better vertical control, therefore, is also beneficial in young dolichofacial patients [2].
• MARPE surpasses conventional RME by a significantly decreasing excessive load on the buccal periodontal ligament of teeth to which they are anchored [1].
• Bone-anchored maxillary expansion is superior to the conventional RPE for OSA (obstructive sleep apnea) patients. For a post-adolescent OSA patient with Class II hyperdivergent pattern and maxillary constriction, MARPE can be useful. MSE appliances reduce upper airway resistance and increase intranasal capacity [31].
• BAME (bone-anchored maxillary expansion) allows full bonded orthodontic therapy at the same time as the expansion. This could shorten the total treatment time.
• A combination of MSE and Face mask can be a successful non-surgical orthopedic treatment modality for Class III adult patients [24].
• MARPE results in greater stability, reduced relapse [29].
• Choi et al [32] and Park et al. [33] reported a success rate for MARPE as 86.96% and 84.2% respectively.

Limitations Of MARPE

• The most frequent complication is the inflammation and hyperplasia of the mucosa around the mini-implant [6].
• In the tooth-bone-anchored design of MARPE appliance, a significant amount of dental tipping was reported in few studies due to the thickness of the connecting arms which is soldered to the molar bands [34].
• Unilateral expansion is not feasible in basic MARPE design, modifications are required [35].
• Reduced or absent bone thickness, contraindicates MARPE placement [29].
• Appliances present restricted to use with extreme maxillary atresia or palatal asymmetry [25].
• Systemic conditions like type II diabetes and habits like smoking should be carefully assessed and might contra-indicate the therapy [6].

Conclusion

MARPE represents a valid alternative to surgery in treating patients with a transverse maxillary deficiency with greater stability, safety, and fewer side effects.

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