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Mini-Screw Assisted Rapid Palatal Expansion - A New Horizon to Correct Transverse Dimensions

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Abstract: ***Rapid Palatal Expansion (RPE) is the treatment of choice to correct the maxillary transverse deficiency (MTD) [1]. However, expansion of maxilla in post pubertal patients might notbe feasible and might result in unwanted side effects such as limited skeletal movements, dentoalveolar tipping, root resorption, detrimental periodontal consequences, and lack of long-term stability [1]. Surgically Assisted Rapid Palatal Expansion (SARPE) was an invasive method, and the morbidity, risks and cost related to surgical treatment might discourage many adult patients. The use of Mini-screw Assisted Rapid Palatal Expansion (MARPE) appliance, being a minimal invasive procedure, is gaining popularity in treatment ofmaxillary transverse deficiency (MTD) in young adolescent patients. This article reviews about the MARPE appliance design, activation protocol and post treatment outcomes.***

Keywords: Rapid PalatalExpansion (RPE), maxillary transverse deficiency (MTD), Surgically Assisted Rapid Palatal Expansion (SARPE), Mini-screw Assisted Rapid Palatal Expansion (MARPE).

1. Introduction

Maxillary transverse deficiency is a prevalent malocclusion present in all age groups, with the prevalence of patients seeking orthodontic care, reaching up to23.3% [1] [2]. This, if not treated on time, can worsen to a more complex malocclusion, hindering facial growth and development [3]. Its multifactorialaetiology includes myofunctional disorders of the stomatognathic system, usually associated with deleterious habits such as thumb sucking [4] [5]. In these scenarios, the tongue may occupy an abnormally lower position, leaving room for the antagonist muscles to be the predominant forces and consequently constrict the maxillary arch. Depending on surrounding muscles activity and individual breathing pattern, intramembranousmaxillary bone formation may be affected [6] [7]. Along with these, genetic and hereditary factors also play major role in maxillary transverse deficiency. Posterior crossbites, crowding, wide buccal corridors, and some of sagittal Class II and Class III malocclusions may have maxillary transverse deficiency as the etiological factor [8].

The most serious consequence of maxillary transverse deficiency, might be the subsequent narrowing of the nasal cavity, which increases nasal air resistance and may be an etiological factor of obstructive sleep apnoea syndrome (OSAS) [9] [10].

The rapid maxillary expansion (RME) is the procedure to correct the skeletal transverse dimension in children and adolescents, by the combination of orthopaedic and dental effects [11] which consisting of biomechanical principle of separating the two maxillary halves by remodelling of the mid-palatal suture and intermaxillary sutures [12]. Treatment variables such as patient age, rate of expansion, magnitude of applied transverse force, appliance design, and retention protocol create a range of interactions which affect orthopaedic and orthodontic movements during maxillary expansion procedures [13].

Though, first RPE was done by Angell in 1860 [11], it was almost 100years later that Hass popularised and reported that, on maxillary expansion, there be increase in nasal width and arch perimeter [12]. This technique was soon approved by clinicians in patients with growth potential. However, the use of RME was less anticipated in patients over 15-years-old as this was a tooth-borne anchorage device [14] [15]. Literature evidences implies that expansion of maxilla in post pubertal patients are more dental than skeletal change due to dentoalveolar tipping and might also result in undesirable side effects such as, root resorption, detrimental periodontal consequences, and lack of long-term stability [16] [17] [18]. To moderate these effects, Brown proposed the concept of surgically assisted rapid palatal expansion (SARPE) in 1938 [19]. The advantages with SARPE procedure were predictable skeletal and dental changes and a low rate of relapse (5%~25%) [20]. However, despite its benefits, patients were discouraged due to invasive nature, risk, complications and cost of the treatment [21].

The introduction of the Mini-screw Assisted Rapid Palatal Expansion (MARPE) appliance byDr. Won Moon et al in 2008, provided a new alternative treatment modality for

clinicians and adolescent patients with maxillary transverse deficiency [22].

This article aims to review about MARPE appliance design, activation protocol and post treatment outcomes.

MARPE Appliance Design

Dr Won Moon proposed the original MARPE design [22] which was located at the centre of the palate with banded molars. Later Dr Kee Joon Lee modified the design by banding the first premolars along with first molars. This design provided with good anchorage and adaptation based on the topography of the palate for effective separation of the mid-palatal suture [23]. [FIGURE 1] Carlson et al modified the ConventionalHyrax Rapid Palatal Expander to derive the Maxillary Skeletal Expanders by incorporation of mini screws [22]. They claimed that this design produced more of a parallel expansion of maxillary bone and insignificant dental tipping.

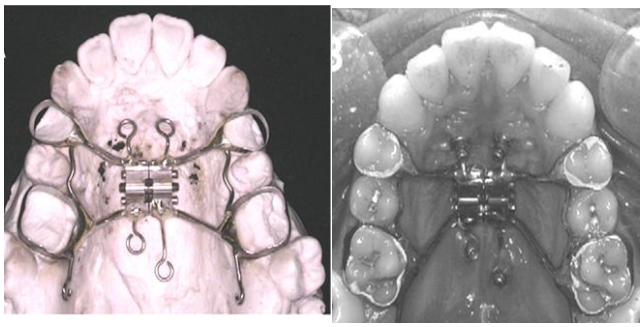

Figure 1 [adopted] [23]

Clinical Presentation of MARPE Appliance

MARPE technique consist of the insertion of four mini screws adjacent to the mid-palatal suture, two mesial and two distal to the expanding screw [23]. In tomographic mapping of hard palate and overlying mucosa, mean thickness of bone present in the regions mesial and distal to the expanding screw varies, respectively, from 3.77 to 3.88 mm and from 2.33 to 2.44 mm and soft tissue shows variation in thickness of 2.6 to 2.8 mm and 1.75 to 1.82 mm, respectively, at the regions mesial and distal to the expanding screw [24]. These variations in boneand soft tissue thickness, associated with the height of the fixation ring of the expander mini-screw and its distance in relation to the soft tissue, worsen the appropriate selection of the mini screw length.

The bicortical fixation of mini-screws is essential to aid the anchorage during expansion and to exceed the resistance of maxillary bones to separation. When the monocortical insertion of mini-screws is used in individuals with thick suture or with great resistance to maxillary separation, distortions may occur in the temporary anchorage device during activation of the expanding screw [25]. Therefore, an appropriate selection of mini-screw length should be done by analysing bone tissue thickness and height of midpalatal suture is relevant for the success of MARPE. These variables can be well assessed by Cone Beam Computed Tomography (CBCT).

Based on Lee's studies, the device consist of two anterior screws of diameter-1.5 1.8mm, length-11-13mm which could be varied according to the anatomical thickness of the patient's palate and two posterior screws of length 9mm [26].

Modified screw design in MSE— Hex head mini-screws (Medusa, FavAnchorTMSAS, India) are smooth and less bulky for a secure and precise insertion and are therefore more comfortable. They are available in 2 sizes-short (2X10mm) and long (2X12mm) based on requirements [27].

Based on the position of mini-screws and stress distribution various design types are classified. [Table1] [26]

Design Type	Miniscrew Placement	Stress Distribution
Type 1	Lateral to mid-palatal suture	Lateral to mid-palatal suture
Type 2	At the palatal slope	Low stresses evenly around the implants
Type 3	As in type 1 with additional conventional Hyrax arms	Largely on the MPS and around micro-implants and anchor teeth roots.

[adopted] [27]

The clinical procedure recommended to be followed [Table2] [26]

Visit	Clinical Procedure	Laboratory Procedure
1st	Separator is placed on maxillary permanent 1st molars	
2 nd	1) Separators are removed followed by prophylaxis and band placement on 1st molars. 3) separators were placed again on the molars. Then tubes and brackets are welded to the bands	2) Alginate impression is made and poured with regular plaster. 4) MSE is soldered to bands based on the curvature of the palate with 2mm separation from the palate
3rd	Separators are removed. Appliance cementation is done under topical anaesthesia after vertical positional assessment. • Self-drilling mini-implants are placed under local infiltrative anaesthesia. • Immediate expander activation is done using the appropriate key. • Hygiene and activation instructions with optional analgesic drug prescription for 2 days should be given. • Antibiotic coverage for good general health may not be required.	
Follow up	Mini-screw stability is checked with tweezers on every visit. The distance of the expander frommucosa is checked at all visits. If the mobility of Mini-screw is witnessed, treatment can still be continued carefully with one properMini-screw on each side.	
Removal	Removal is done by counter-clockwise rotation of jackscrew with the key.	

	Hydrogen peroxide dipped cotton pellet on MI removed site to promote asepsis. Oral Prophylaxis before removal is attempted to prevent plaque accumulation on MI head hinders	

Appliance Activation

Patient biotype and treatment objective should be considered while determining the activation protocol. According to Brunetto et al [26], the activation guidelines are as follows:

Age Group	Activation
Beginning of adolescence	3 to 4turns /week
End of adolescence	1turn /day
Young adults	2 turns /day
Older than 25 years	2 or more turns /day

The authors recommend giving the patient a form to control activations. The 8 mm MSE can do only maximum of 40 activations (0.2 mm per turn); the 10 mm MSE, 50 activations; and the 12 mm MSE, 60 activations. When activations reach its maximum limits, expander loses its rigidity and can create some deformations [26].

Improved method for better activation:-[28]

- In certain cases, patients unable to perform expander activation due to sutural resistance. This can be overcome by *corticopuncture method* before MARPE and mini-screw insertion.
- Eight bone perforations, called corticopunctures are placed along the mid palatal suture.
- Under greater palatine nerve block anaesthesia, shallow cortical bone is manually predrilled with 1.1mm diameter &4mm bur and contra angled screwdriver
- Corticopunctures o f5mm depth along mid palatine suture are made manually by inserting and removing a 9mm titanium alloy mini-screw (5mm double thread, 4mm neck of length&1.8mm diameter.) The distance between 2 perforations should be kept at 2mm
- Prescription of analgesics+ 0.12%CHX mouth rinse for 7days can be given after the procedure
- Corticopuncture method reduces the sutural resistance and accelerates bone formation.

2. Post Expansion Assessment

Skeletal and dental effects

The total expansion achieved is a combination of orthopaedic and orthodontic expansion which includes the alveolar bone bending and dental tipping. In conventional rapid palatal expanders, it is impossible to direct the force from the jackscrew through the center of resistance to produce pure bodily movement, as center of rotation of maxilla is much higher than the mini-screw placement position, leading to torque generation in two maxilla resulting in alveolar bone bending [29]. Even though, the relative position of anchored teeth has not changed, dental tipping could be observed due to alveolar bone bending. A more lateral translation of the complex could be achieved with reduced dental tipping, by exerting the expansion forces pointing closer to the maxilla's center of resistance [29]. The body of MARPE should be placed close to the junction of hard and soft palate since the greatest resistance against sutural opening is the pterygomaxillary complex. If the forces are applied to the center of resistance of maxilla through suitable mini-screw positioning using customized MARPE appliances, the force system becomes more favourable which would eliminate the inclined forces due to homogenous force dissipation on the posterior teeth facilitating more parallel mid palatal sutural opening coronally. Pterygoid plate separation with MARPE results in a parallel expansion in comparison to SARPE which gives a" V" expansion, as there is an absence of pterygoid plate separation at the mid palatal suture [30].

In children and adolescents, bony resistance during maxillary expansion would be less as their pterygomaxillary and zygomaticomaxillary sutures are less matured. In adult patients due to greater bony resistance, a substantial amount of orthopaedic force will be experienced on the anchor teeth resulting in dental tipping andalveolar bone bending [31]. The zygomatic bone exhibits a forward and lateral displacement. The forward displacement is negligible as a whole, whereas the lateral displacement is more near the zygomaticomaxillary suture and gradually decreases towards the temporal process of the zygomatic bone (zygomatic arch) and further decreases towards the frontozygomatic suture. In general, the zygoma rotates along with the zygomaticomaxillary complex with the frontozygomatic suture as the fulcrum [27].

Cantarella et al reported that there could be almost no displacement that could be seen above the frontozygomatic suture and a possibility for asymmetric expansion due to differences in densities and morphology of bones especiallythe zygomatic buttress and pyramidal process which may not be identical on both sides. He also proposed that the fulcrum of rotation of the maxilla will be more posterior and lateralinMARPE when compared to the tooth-borne appliance. Since the maxilla is located mediallyand anteriorly to the fulcrum of rotation, during expansion the maxilla tends to movelaterally and anteriorly. This movement helps in the disarticulation of pterygopalatinesutures. The pterygoid fossa and the infratemporal surface exhibits almost no displacement [30] [32].

MARPE exhibited minor buccal tipping of the maxillary molars, decrease in buccal bone thickness, and decrease in alveolar crest level on the maxillary first molar [31]. Less amount of periodontal effect (i. e., decrease in buccal alveolar bone thickness and loss of crestal bone) are expected compared with conventional RPE [33].

3. Stress distribution as per FEM studies

Several finite element method (FEM) studies were done to determine the most effective design of MARPE along with appropriate number, design, and placement of mini-screws [29] [34] [35] [36] [37]. MacGinnis et al [29] in their FEM study showed less propagation of stress to the buttresses in comparison to adjacent locations within the maxillary complex. In terms of stress distribution, a bone-borne RPE with mini-screws placed in the palatal slope exhibited the lowest stress concentrations without buccal tipping of

dentition compared with other types of RPE, including a bone-borne RPE with mini-screws placed near the mid-palatal suture, MARPE, and conventional RPE combined with surgery [34]. Seong et al. [35] in their FEM study reported that MARPE is better compared with conventional RPE and bone-borne RPE in terms of force delivery to the peri-maxillary sutures and stress to the buccal plate of the anchor teeth. Yoon et al. [36] examined various scenarios, including the length and position of mini-screws, position of the expander screw, and distance between the expander screw and mini-screws. Stress distribution was broader when four mini-screws supported MARPE in comparison to only twomini-screws supporting it. Their results showed no difference in stress distribution between monocortical and bicorticalmini-screws, which conflicts the FEM study of Lee et al., which showedthat bicortical mini-screws are superior to monocortical onesin palatal expansion [36] [37]. These differences might have occurred due to different study settings and designs of the palatal expander. Yoon et al. [36]constructed the MARPE design, whereas Lee et al. [37] used the bone-borne design.

A recent retrospective clinical study [38] analyse the monocortical and bicortical mini-screw design and showed that MSE with non-4-bicortical penetration produced less orthopaedic effects and more unwanted dentoalveolar side effects, whereas MSE with 2-rear-bicortical and 4-all-bicortical penetration produced similar skeletal effects, which means that 2-rear-bicortical penetrating mini-implants were critical to skeletal expansion.

Airway effects

Studies have shown that orthopaedic expansion alters the abnormal breathing patterns as it resolves the nasomaxillary deficiency [29]. Ina study by Hur et al, an increase in volume and decrease in airflow velocity and pressure in the nasopharynx and oropharynx after maxillary expansion with MARPE was reported in a patient having obstructive sleep apnoea [39]. Post expansion MARPE patients are incline more towards nasal breathing resulting in altering the tongue posture and muscular dynamics, indirectly increasing the nasopharyngeal airway which further enhances expiratory peak flow. Nasal inspiratory peak flow, an indicator for nasal and oral obstruction, can be increased immediately after expansion with stability maintained up to 5 months [40].

Advantages of MARPE

- Less treatment duration from one to four weeks of active expansion period
- Maximal skeletal displacement with minimal dental tipping effects.
- More stable

4. Limitations

- Forces applied from greater distance to the bone or implant interface leads to higher chances of mini-screw deformation [26].
- MARPE creates stress distribution around the anchor teeth and zygomaticomaxillary process extending along the external wall of the orbit, which can cause dizziness and stress around the bridge of the nose, eyes, and predominantly throughout the face. Therefore, in individuals who have very heavy sutural interdigitation and bone density expansion must resort to surgically assisted expansion [27].
- In cases where, multiple congenitally missing teeth often associated with craniofacial anomalies sutural expansion is difficult due to anchorage loss.

5. Conclusion

MARPE expands the vistas of orthodontics allowing non-surgical orthopaedic correction in young adult patients. The skeletal anchorage provided by the palatal expander offers unique mechanical possibilities for the treatment of a wide range of malocclusions.

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