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Research Article

Factors Affecting the Design of MARPE Appliance: A Scoping Review

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Abstract

Background: Treatment of transverse maxillary deficiency is of paramount importance. Though Rapid Palatal Expansion (RPE) and Surgically Assisted Palatal Expansion (SARPE) are established treatment modalities, treatment in adolescents and young adults can be accomplished using a more conservative approach like Mini-Implant Assisted Rapid Palatal Expansion (MARPE). Various factors affect the success of MARPE. This scoping review aims to list down the various factors affecting the success of MARPE appliance in treatment of transverse maxillary deficiency.

Methodology: The literature search was carried out on MEDLINE via Pubmed, Cochrane Library (Cochrane database of systematic reviews), Cochrane central register of controlled trials (CENTRAL), Google Scholar and ScienceDirect, for articles from 2010 to January 2023. Pertinent articles were selected based on inclusion and exclusion criteria. The results were tabulated based on number of cortices used as anchorage, number of implants used in the appliance, type of anchor support used, placement site of implant and positioning of the expander.

Results: The literature search resulted in 9 relevant articles. Among all the studies, two studies discussed monocortical versus bicortical placement of implants, one study assessed for positioning of the expander. Only one study compared for number of implants used whereas two studies assessed for site of implant placement. Three studies assessed for anchor support.

Conclusion: Due to heterogeneity in the literature, it is difficult to arrive at a definitive conclusion as to which design is the best for the treatment of transverse deficiency in adolescents and young adult patients. Design has to be customized as per the needs and requirements of the case.

Keywords: MARPE, Miniscrew Assisted Palatal Expansion; Bone Borne Expansion; Tooth-bone Borne Expansion; Palatal Expansion

Abbreviations

RPE: Rapid Palatal Expansion; RME: Rapid Maxillary Expansion; MARPE: Mini-Implant Assisted Rapid Palatal Expansion; SARPE: Surgically Assisted Rapid Palatal Expansion; MSE: Maxillary Skeletal Expander; MTD: Maxillary Transverse Deficiency; CVMI: Cervical Vertebral Maturation Index; TAME: Tooth Anchored Maxillary Expansion; BAME: Bone Anchored Maxillary Expansion; TADs: Temporary Anchorage Devices; 3D-Three Dimensional;

CBCT: Cone Beam Computed Tomography; RCT: Randomized Control Trial; MPS: Mid Palatal Suture; PNS: Posterior Nasal Spine; ANS: Anterior Nasal Spine

Introduction

Maxillary transverse deficiency is one of the prevalent malocclusions encountered by orthodontists on a routine basis. Prevalence rates was found to be 8% in deciduous dentition, 21% among the mixed dentition and less than 10% in adults [1]. Transverse deficiency could be real or relative. In a real transverse deficiency of maxilla, the maxillary bone is constricted whereas in relative maxillary deficiency could be due to a large mandible [2].

Transverse deficiency can cause functional and esthetic problems in patients. These problems include, crowding of anterior teeth, unilateral or bilateral crossbite, deviation of the mandible, V shaped palate, wide buccal corridors [3]. The early growth cessation in the transverse dimension is the most crucial factor influencing the treatment of these malocclusions. Therefore, early diagnosis and intervention is of paramount importance. The various treatment modalities include non-surgical correction using conventional Rapid Palatal Expansion (RPE), Slow Maxillary Expansion (SME), and Surgically assisted Rapid Palatal Expansion (SARPE) depending upon the growth status of the patient.

Traditional rapid maxillary expansion harnesses anchorage from the teeth and results in orthopedic effects in younger population while numerous studies have depicted undesirable dentoalveolar effects like buccal tipping, loss of alveolar bone height and thickness, fenestrations and dehiscence, periodontal loosening of teeth, in late adolescents and adult population [4,5]. Though surgical approach has the advantage of overcoming the resistance offered by the mid palatal suture it is highly invasive, also not to blindside the cost factor [6].

Advent of temporary anchorage devices in orthodontics has a great impact as a treatment modality. To overcome the unwarranted effects of RME in adolescents and adults, the mini-implant assisted RPE (MARPE) was introduced by Lee et al in 2010 following which Maxillary Skeletal Expander (MSE) was introduced by Dr. Won Moon as an alternative to the conventional RME [6,7].

MARPE is a modification of conventional RME which incorporates mini-implants for skeletal anchorage and produces a localized effect by concentrating the expansion forces over the palatal bone rather than the teeth, thus, minimizing the dentoalveolar side effects [6]. Various studies have compared the effectiveness of MARPE appliance over the tooth borne RME appliance [8-10], although other studies found comparable results with both appliances [11-13]. Studies have also concluded stable treatment outcomes following treatment with this appliance in late adolescent groups [14]. MARPE has also triumphed over SARPE since TADs placement is a simple procedure.

Even though the MARPE appliance has the above-mentioned advantages it tends to produce nasal discomfort, headache and heaviness over nasal and frontal regions due to high forces. It cannot be used in cases with single tooth crossbite, where multiple teeth are missing, in patients with poor oral hygiene with gingival hyperplasia (Dilantin medications), in cases with facial asymmetry, high mandibular plane angle and uncooperative patients [15]. Some of these shortcomings have been tried to overcome by modifying the appliance. Till date, numerous modifications have been introduced by various authors which differs in the site of expander position, number of implants used, placement of implant, cortices involved and anchorage units involved. However, no consensus has been attained to which all factors govern its effectiveness. This article aims to pen down the factors which makes the MARPE appliance more efficient.

Methodology

This review has been registered with Open Science Frameworks [16]. The literature search was carried out in MEDLINE via Pubmed, Cochrane Library (Cochrane database of systematic reviews), Cochrane central register of controlled trials (CENTRAL), Google Scholar and ScienceDirect, for articles from January 2010 to January 2023. Keywords used were MARPE, Miniscrew assisted palatal expansion, bone borne expansion, tooth-bone borne expansion, palatal expansion.

The titles and abstracts of the articles found were read to match the following inclusion criteria-

- Human/clinical studies that assessed various factors affecting MARPE appliance.
- The articles which assessed at least one of the following factors: number of implants, placement of implant site, expander position, anchor support and monocortical and bicortical implant insertion.
- Human studies which were conducted in subjects older than 11 years.
- Maxillary constriction with unilateral or bilateral posterior crossbite.

The exclusion criteria

- Reviews, narrative reviews, literature reviews and systematic reviews.
- Studies conducted on subjects with systemic conditions,
- Severe dentofacial anomalies (e.g. cleft lip and palate), and
- Articles in languages other than English.

Results

The search resulted in 956 articles. Removal of duplicates and the articles pertinent to the inclusion and exclusion criteria were evaluated. The search strategy and selection of articles based on PRISMA guidelines is depicted in figure 1.

A total of 13 articles, following the database search, were reviewed. The redundant articles were removed on basis of duplication and non-relevance to the topic. Nine studies were included wherein the patients were treated with MARPE appliance in various age groups. Table 1 describes the articles and its results.

Figure 1: Search strategy and methodology flowchart.

Study	Type of study	Sample size	Age group	Gender	Radiographic method used	Parameters assessed	groups	Implant size	Appliance design	Conclusion
MONOCORTICAL VS BICORTICAL										
Na Li, 2020	RETROSPECTIVE CLINICAL	48	G1: n = 17; aged 19.5 +/- 3.1 years G2: n = 17; aged 19.2 +/- 3.5 years G3: n = 14; aged 19.6 +/- 3.5 years	19 males 29 females	CBCT	Monocortical vs bicortical	3 1) G1 (4-all-bicortical), (2) G2 (2-rear-bicortical penetration;) (3) G3 (monocortical)	4 mini-implants 1.5 mm X 11 mm;	Tooth-bone borne expander with extension arms soldered to first molar	Monocortical group produced more dentoalveolar effects. Group1 and group 2 depicted similar results.
Oliviera 2020	Retrospective study	28	15- 37 years	10 men 18 women	CBCT	Monocortical vs bicortical	2	-	Tooth bone borne	Bicortical mini-implant anchorage had no correlation with MARPE success or any of the skeletal measures

EXPANDER POSITION										
Danielle Cantarella 2017	Observational	15	17.2 ± 4.2 years CS>4	6 M, 9 F	CBCT	Expander position	1	1.5 mm diameter	4 minis-crew and 1st molar	parallel opening of the MPS anteroposteriorly 53% of opening between lateral and medial pterygoid plates
NUMBER OF IMPLANTS										
Lagravere, 2010	RCT	62	14.21 +/- 1.32	19 males 43 females	CBCT SCAN	Number of implants	3 traditional hyrax tooth-borne expander, bone-anchored expander, and control	2 mini-screws (length, 12 mm; diameter, 1.5 mm)	traditional tooth-anchored maxillary expander (TAME) bone-anchored maxillary expander (BAME)	maxillary expansion-both TAME and BAME showed similar results that BAME can be considered as an a lternative choice for TAME
ANCHOR SUPPORT										
Canan et al 2017	RCT	47 TBG =16; BBG =16 HG= 15	TBG=12.63 +/- 1.36 yrs BBG= 12.92+/- 1.07 yrs HG=13.41+/-0.88 yrs	25 girls, 22 boys	3D dental digital models	Anchor support	1. tooth-borne group 2. bone-borne group 3. hybrid group	1.8x9 mm	tooth-borne appliance (hyrax) bone-borne appliance hybrid appliance.	similar dentoalveolar treatment effects were achieved in all groups
Mohamad Sarraj, 2021	Prospective study	34 G1= 16 G2= 18	G1:14.9 yrs G2:13.8 yrs	G1:10 females and 6 males G2: 16 females and 2 males	CBCT	Anchor support	group 1: MSE appliance, group 2: BAME appliance.	Four minis-screws 1.5-1.8 mm in diameter and 11 mm BAME: 1.8x9 mm	MSE- Teeth and bone borne Bone anchored	BAME appliance resulted in greater skeletal effects, less dental tipping, and less buccal bone reduction compared to MSE appliance
H Oh 2021	Retrospective study	102	G1: 14.2+/- 1.5 G2: 14.01 +/- 1.24 G3: 13.8 +/-	M:F 15:22 14:27 9:15	CBCT	Anchor support	Group 1: TAME Group 2: BAME Group 3:: tooth-bone anchored - MSE	2 mini-screws (length, 12 mm; diameter, 1.5 mm;	TAME BAME MSE:	MSE group much greater skeletal changes. Relatively parallel opening of suture

IMPLANT PLACEMENT										
Lu Lin, 2015,	clinical, retrospective study	28 female adolescent patients	BB: n = 15, age 18.1 +/- 4.4 years TB: hyrax, n = 13, age 17.4 +/- 3.4 years	28 F	CBCT	Implant placement	Group1: bone-borne Group 2: tooth-borne	1.8-mm diameter and 8.5-mm length	TSADs were connected to the expander through the hole of an acrylic resin cover.	For patients in late adolescence, bone-borne expanders produced greater orthopedic effects and fewer dentoalveolar side effects compared to the hyrax expanders.
Tugce Celenk-Koca, 2018	RCT	40	13.84 +/- 1.36	25 female 15 males	CBCT	Implant placement	Group 1(Conventional RME) Group 2 (Miniscrew-Supported RME)	Four miniscrews (1.8 mm X 9 mm	Hyrax-type and miniscrew-supported RME devices	bone-borne expansion in the adolescent population increased the extent of skeletal changes than that of tooth-borne expansion and did not result in any dental side effects.

Table 1

The age group in the studies ranged from 11-37 years.

Factors considered were:

- Monocortical and bicortical implants
- Number of implants
- Expander position
- Anchor support
- Placement site of implant

Out of nine articles, two articles discussed monocortical versus bicortical implant anchorage used in MARPE appliance, for maxillary expansion in young adults [17,18]. One study was in support of usage of bicortical implants whereas the other study found no statistically significant results with either monocortical or bicortical anchorage. Only one study fell under the category for positioning of the expander [19]. The study suggested more posterior positioning of the expander is beneficial in overcoming the ptergomaxillary resistance.

Two studies demonstrated the effects bone borne expansion using two implants instead of the four implants which is generally used, this was categorized under, number of implants used in the appliance design [12,20]. Three studies compared for anchor support i.e., Bone borne anchorage or tooth-bone borne anchorage [20-22]. Two studies were in favour of Tooth-Bone Borne anchorage support and one study suggested more skeletal effects with bone borne appliance. Two studies assessed the success of MARPE appliance with implant placement over the slopes of palate site [10,23].

Discussion

Monocortical and bicortical insertion

The monocortical implant which utilizes anchorage from palatal cortex only, experiences more shear forces at the implant bone interface which might result in inflammatory reaction and finally implant loosening. On the contrary, bicortical anchorage utilizes more surface contact area between cortical bone and mini-implant, allows for proportionate load distribution which helps in more transverse displacement. Nevertheless, bicortical anchorage can traumatize the mucosa of the nasal floor and cause nasal discomfort. A clinical study [17] supported the usage of bicortical anchorage system and found 68% skeletal effects with bicortical anchorage compared to 44% skeletal effects with monocortical anchorage. On the other hand, another clinical study [18] demonstrated bicortical mini-implant anchorage had no correlation with MARPE success or any of the skeletal measures. The highest success rate (80%) for suture opening was in cases with monocortical anchorage. The cases with four and two bicortical mini-implants had success rates of 70.5% and 66.6%, respectively [18]. These results could have been possibly due to factors such as bone density which may have influenced the results of this clinical study.

Expander position

The pterygoid buttress offers high resistance to mid palatal sutural opening. In order to overcome this resistance and to achieve a uniform parallel opening of the mid palatal suture, it is suggested to place the expander in a more posterior position closer to the center of resistance of maxilla which is located between first and second molars in the sagittal plane [24]. A CBCT study [19], observed 53% of opening between lateral and medial pterygoid plates, this was probably due to the use of four mini-implants in the MARPE positioned in the posterior part of the palate, medial to the zygomatic buttress bones. This allowed the separation force to be distributed along the entire suture length. The study also observed a more parallel split of the midpalatal suture in an antero-posterior direction. The borders of the midpalatal suture moved almost perfectly parallel to each other since the amount of split at PNS (4.3 mm) was 90% of that at ANS (4.8 mm) [19].

Number of implants

Some of the MARPE appliance design used two mini-implants whereas most of them used four. Many studies have depicted success of MARPE appliance using four mini-implants [25-27]. This might be since four implants have greater stability than the two implants as there is more implant to bone surface contact which helps the appliance to better resist the expansion forces. However, there are studies wherein the authors have found clinically acceptable results upon using two implants as well [12,20].

Anchor support

MARPE appliance can be categorized as tooth-bone borne (hybrid type) or purely bone borne. Loss of stability can be possibly anticipated with bone borne group as it harnesses support with mini-implants alone whereas the tooth-bone borne appliance are considered more stable as they have support with both teeth as well as the implants. Thus, it can act as a fail-safe mechanism in case the implants fail. A three-dimensional superimposition study of digital maxillary dental models depicted greater posterior expansion in tooth-bone borne than bone borne group, but tipping was observed more in tooth-bone borne than bone borne group [20]. This was probably due to the fact that the tooth-bone borne used the first molar support in addition to the implant support. The study observed fewer clinical complications with the tooth-bone borne MARPE group, probably due to the design of the tooth-bone borne appliance. A loss of stability in the bone borne MARPE device by tongue movements and pressure in the bone borne group was also noted.

On the contrary, two CBCT studies [21,22], found greater skeletal changes with bone borne group 81% and 83% respectively while the tooth- bone borne group depicted 73% and 56% of skeletal changes respectively. A definite parallel mid palatal sutural expansion, lower dental tipping and lower buccal bone reduction was also noted with the bone borne group. This could be due to direct transfer of the expansion forces to the basal bones and since no teeth were involved, no tipping or adverse periodontal effects were noted.

Placement site of implant

The implants can be either placed in the paramedian region or over the slopes of palate. This placement may be dictated either by the depth of the palate or arch constriction or governed by the clinician in order to be closer to the center of resistance of the maxilla. In several studies [7,8,14], the authors have used the design wherein the implant is placed in the paramedian region.

Two CBCT studies [10,23] placed the implants 8mm beneath the alveolar ridge of palatal slope. The anterior implants were placed between canine and first premolars in one study while the other study placed it between first and second premolars and the posterior implants were placed between second premolar and first molars [10,23]. Temporary skeletal anchorage devices TADs on the palatal slope showed minimal rotational movement of the dentoalveolar unit. Inconsistent protocols among the studies, especially with regard to the design of the bone-borne expander and the period of time between comparisons, make clinically useful conclusions difficult.

Scope for future research

More Randomized Controlled Trial's (RCTs) are required assessing skeletal as well as dento-alveolar effects of miniscrew-supported maxillary expanders. Studies comparing the effects of MARPE appliance with regards to following factors: number of incorporated anchor teeth, number and size of implants used and their placement site using reliable assessment methods such as CBCT and digital casts clinically. This can provide more reliable understanding of MARPE.

Conclusion

In the conclusion, MARPE has greater skeletal effects supporting its usage in adult patients. Various design features have been discussed in this article. Such modifications can be useful under the given clinical situations for better results. High anchorage cases require modifications such as bicortical implant placement and increasing the number of implants from two to four implants, as they would be able to resist the forces better.

Parallel expansion can be achieved with the expander positioned more posteriorly. Placing the implants on slopes of palate can possibly help in even distribution of stress as it is closer to the center of resistance of Maxilla. Use of both teeth and implants might be beneficial as fail-safe mechanism and for even stress distribution across the mid palatal suture. Keeping these modifications in mind we can strive towards a safe and effective tool to achieve expansion in the transverse dimension especially in young adults.

Standardization of a particular MARPE appliance design would be difficult due to the heterogeneity in the above-mentioned studies. Design should be customized as per the needs and requirements of the case. Hence, we warrant more RCT's and longitudinal studies comparing the effectiveness of the design factors on MARPE.

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