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Miniscrew-assisted rapid palatal expander (MARPE) therapeutic results: A review

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ABSTRACT

Background: One of the most common maxillary abnormalities is transverse deficiency, which can be a contributory factor in malocclusions. There are some evidence of successful non-surgical treatment of this type of discrepancy after puberty by using maxillary expansion techniques. The Miniscrew-assisted rapid palatal expander (MARPE) method is a newly introduced method that has attracted the interest of many orthodontists. This study aimed to evaluate the therapeutic results of this technique in a systematic review.

Materials and Methods: In this study, various databases including PubMed, Scopus, and ISI (Web of science) were queried with proper keywords, provided by PICO strategy of research, from 1980 to December 2020. Relevant articles were collected with restrictions on the English language. The full text of papers with all inclusion criteria was assessed. The therapeutic outcomes of MARPE were evaluated in the selected studies.

Results: A total of 14 studies were included in the systematic review. Totally, 5 case report studies, 8 retrospective studies, and 1 case series study were reviewed. Cone-beam computed tomography was used as an outcome measure in all studies. In all reviewed studies, maxillary expansion occurred with high success rates in patients. Moreover, respiratory characteristics were also assessed in two studies measuring respiratory muscle strength, airflow and nasal and nasopharyngeal airway volume, showing benefits of MARPE. A study also examined three-dimensional soft tissue stereophotogrammetry. Based on these studies, the indication for using this method was a maxillary transverse deficiency as well as upper and lower arches crowding. No serious complications were reported in any of the reviewed studies. However, most studies did not perform long-term follow-ups and the age range of the subjects was mainly between 12 and 24 years. MARPE has been suggested as a treatment modality for correction of maxillary transverse deficiency in young adults but patients under the age of 14 may also benefit from this treatment in special conditions.

Conclusion: A general review of the results of studies showed the high efficiency of MARPE technique in correcting maxillary transverse deficiency.

Keywords: Maxillary transverse deficiency; Crossbite; Miniscrew; Miniscrew-assisted rapid palatal expander (MARPE).

Introduction

Correction of dentofacial defects by surgery has undergone many advances since its invention in the late nineteenth century [1]. Dentofacial abnormalities are not a disease but in general, they can affect quality of life [2]. Resolving dental malocclusion results in improving function and esthetic of dentofacial complex,

which are the two important goals of orthodontic treatments [3]. Stability of the achieved results is the third goal of any orthodontic, orthopedic or orthognathic surgery treatment [4]. Malocclusions can have dental or skeletal components. Among the skeletal maxillomandibular discrepancies, maxillary deficiency in transverse dimension is one of the most prevalent ones [5].

Maxillary transverse deficiency is defined as the mismatch between the upper and lower widths of dental base arches [6]. Besides, malocclusion and the resulting aesthetic problems may lead to functional disorders such as low masticatory ability index (MAI) and fetal food intake ability (FIA) [7]. Habits such as thumb sucking or mouth breathing reported as the probable causing factors of this discrepancy [8]. In addition, differences in size or any disrupted development of basal skeletal structure due to muscle disorders, congenital syndromes or cleft palate can result in maxillary transverse abnormality [9-11]. Posterior crossbite as one of the indicators of maxillary transverse discrepancy is a relatively common malocclusion, and its prevalence is in the range of 7-17% [12]. Early loss of deciduous teeth, crowding, hereditary and genetic factors, abnormal tooth anatomy, tooth alignment, mouth breathing, and finger sucking habits are some of the most important causes of posterior crossbites [12]. In most cases, there is a background skeletal problem in patients with posterior crossbite. Researchers generally believe that one of the following combinations causes skeletal crossbites: 1) Small maxilla and normal mandible 2) Normal maxilla and large mandible 3) Small maxilla and large mandible [13].

In a study, Allen and colleagues compared the dental and skeletal characteristics of patients with posterior crossbites to those without posterior crossbites by dental casts, lateral and anteroposterior cephalograms. They found that patients with larger mandibular plane angles, longer lower face height, smaller maxillary to mandibular width ratio, smaller maxillary intermolecular and larger mandibular intermolar widths were significantly more likely to have posterior cross bite [14]. In a study of maxillary morphology in patients with obstructive sleep apnea (OSA), they concluded that the depth of the palate and posterior crossbites were greater comparing to the individuals without OSA [15]. Rapid palatal expansion (RPE) without anchor implant is one of the most popular techniques for non-surgical maxillary skeletal expansion [16]. This technique is unsuccessful in patients after adolescent growth spurt. In these patients, the expansion force is mainly concentrated in the posterior teeth and it subsequently leads to buccal tipping with minimal sutural expansion [17]. To compensate the complications of conventional maxillary expansion, Surgically Assisted Rapid Palatal Expansion (SARPE) was introduced [18]. This treatment involves a surgical procedure to divide the maxilla into halves, which follows with the rapid expansion of the suture. This method increases the success rate of treatment and reduces the side effects including dental tipping. However, hospitalization, general anesthesia, and high costs are among the major disadvantages of this technique [18].

Another alternative to increase the success of expansion as well as reduction of patient's risk is bone borne expansion technique using miniscrews (Miniscrew Rapid Palatal Expansion (MARPE)) [19]. The device is designed to use palatal bone as the main anchorage with minimal engagement of the teeth. The force is transmitted from the expander to the miniscrews to rupture the evolved mid palatal suture and move the maxillary structure further than the buccal tipping of teeth [20,21]. However, the use of miniscrews with expanders has only recently become more common, and therefore the success or failure factors of this treatment has not been sufficiently addressed yet. Patients' anatomical variations, including bone height, different stages of maturation and shape of the mid-palate suture, and in particular the miniscrew placement technique are the most important factors that can play role in the success or failure of the maxillary expansion with MARPE appliance [20,21].

Materials and Methods

The search strategy was developed based on the study questions. Study questions were asked based on the PICO (participants, interventions, comparisons, and outcomes) questions (as shown in supplemental table 1). Our main interest question of the study was "what are the MARPE intervention consequences?". Based on the PICO eligibility criteria of studies, we included the studies reporting various outcomes of MARPE intervention in young adults and all papers had to be in English and Full text. We did not restrict our search strategy to patients with maxillary transverse deficiency, Posterior crossbites, or any specific malocclusion classes to assess all possible indications of MARPE usage in literature. Studies that reported using MARPE were included. Therefore, a wide range of MARPE intervention outcomes was assessed in our study, and a wide range of study designs as well as case series, case reports, cohort, and clinical trials were con-

sidered eligible; while narrative reviews, editorial letters, editorial papers were not considered. No specific comparisons with control groups were required in our search strategy. The search keywords included "Micro-implant-assisted Rapid Palatal Expansion" or "MARPE' as the primary keyword and secondary keywords were based on the assessed outcomes. Searching the articles was conducted from 1950 to December 2020 at electronic databases of Wiley, PubMed, Embase, Springer, Cochrane library, Web of Science, and Clinical trils.gov. Grey literature was not included in our study. In the selection phase of the article, two independent researchers reviewed the abstracts. Then duplicated or irrelevant cases were excluded. Full text of studies was evaluated to extract data based on the checklist containing names of authors and publications, as well as the findings. Subsequently, the papers fulfilling the requirements for inclusion were included. Information on the sample size, participant ages, type of study design, detail of performing the intervention, outcomes, method of measuring outcomes, a period of testing, follow-up, and complications were extracted.

Results

In the present study, 14 articles were included in the systematic review (as shown in supplemental table 2). Five case reports, 8 retrospective studies, and one case series study were reviewed. Cone-beam computed tomography analysis was used as the outcome measure in 11 studies. However, respiratory characteristics were also assessed in two studies measuring respiratory muscle strength and airflow as well as nasal and nasopharyngeal airway volume. A study also examined three-dimensional soft tissue stereophotogrammetry. Based on the diagnosis in the included studies, the indication for using this method was maxillary transverse deficiency and upper and lower arches crowding. No serious complications were reported in any studies. However, most studies did not report the result of long-term follow-up of patients and re-examined the factors only after the procedure was completed. The age range of the subjects was often between 12 and 24 years. This procedure has been suggested as a treatment for maxillary transverse deficiency in young adult patients, but studies have shown that patients under 14 also can benefit from this treatment modality. In all reviewed studies, maxillary expansion occurred with high success rates in patients. In retrospective studies, there were various variables defined and measured in CBCT analysis, as shown in supplemental table 3. Zong et al. reported an average of 5.41±2.18mm maxillary expansion. Midpalatal suture expansion was reported in three studies. Shin et al. reported 0.9±0.81mm of midpalatal suture expansion. Storto et al. reported midpalatal suture expansion to be 4.7±1.49mm. Zong et al. reported midpalatal suture expansion to be 2.8±1.54mm. Three studies evaluated the nasal cavity width. Song et al. reported 0.9±0.3mm of nasal cavity width; While Park et al. reported1.4±1mm of nasal cavity width and Storto et al. reported nasal cavity width to be 3.47±2.7mm.

Participants	*Which patients are receiving MARPE? Which age ranges were receiving MARPE?*
Intervention	*How was the MARPE implanted in each study?*
Comparisons	*Was there any control or alternative intervention to compare results?*
Outcomes	*What consequences of the MARPE intervention was assessed? What are the MARPE intervention consequences*

Table 1. PICO questions for systematic review.

Study	Study design	Partici-pants	Diagnosis/ Inclusion criteria	Outcome assessment/ outcome measurement method	Treatment Results	Follow up period
Cunha et al. (24)	Case report	24Y, 1F	maxillary transverse deficiency; upper and lower arches crowding, Skeletal Cl I	CBCT, Photographs, Dental casts, Lateral Cepha-lometry	4.9 mm anterior, 3.6mm inter-mediate and 2.4mm posterior expansion achieved immediately after MARPE.	3 years
Lee et al. (25)	Case report	20Y, 1M	severe mandibular prognathous; Class III malocclusion; bilateral buccal crossbites; absolute transverse deficiency	Photographs, Dental casts, Lateral and PA cephalometry, Axial computed tomography 12 months after debonding	2.4 mm transverse increases in maxillary basal bone width and 2.5 mm in nasal width	18 months
Brunet-to et al. (26)	Case report	22Y, 1F	transverse maxillary deficiency; mild crowding of maxil-lary and moderate crowding of arches; edge-to-edge rela-tionship (Class II)	CBCT	Achieved Expansion was not report/ (AHI) reduced from 7.9 to 1.5	NA
Storto et al. (27)	Retrospective	17.1 Y, 13 F, 7 M	maxillary transverse deficiency/ Mouth breathing	CBCT, respiratory mus-cle strength and airflow	MIP improved 20%, MEP increased 10%, nasal inspiratory peak flow increased 30.28%, Oral expiratory peak improved between 20% and 40%,	5 months after expan-sion
Lim et al. (28)	retrospective	21.6 Y; 8M, 16F	maxillary constric-tion	CBCT	2.1mm and 1.56mm of increase in alveolar and nasal floor width, respectively.	1 year after comple-tion of expan-sion
Zong et al. (29)	retrospective	14.97 ± 6.16 Y; 11M, 11F	maxillary transverse deficiency	CBCT	A total expansion of 5.41mm (3.15mm skeletal and 2.27mm dental expansion)	NA
Song et al. (30)	retrospective	NA, 20 patients	maxillary transverse discrepancy	CBCT	6.86 mm incrase in nasal width base, 14.1% and 20.4% increase in na-sal cavity and the nasopharynx, respectively.	NA
Park et al. (31)	retrospective	20.1 Y; 9M, 5F	maxillary transverse discrepancy	CBCT	zygomatic arch , nasal cavity and the lateral contour of the maxillary alveolus were widened by 0.8 and 1.4 mm, and 2.0–3.2 mm, respectively	NA

Gholinia et al. (32)	case report	20 Y; F	class II canine and molar relationship, transverse maxillary deficiency, and bilateral posterior crossbites, transverse maxillary deficiency	CBCT	3.1mm and 2.2mm splitting of midpalatal suture in anterior and posterior parts, respectively	3 and 12 months after expansion
Lee et al. (33)	retrospective	20.46 Y; 12M, 8M	maxillary transverse discrepancy	three-dimensional stereo photogrammetry study	The alar base width, alar width, and alar curvature width increased by 1.214, 0.932, and 0.987 mm, respectively. The average volumetric change was 993.33 mm	NA
Rojas et al. (34)	Cohort (Retrospective observational)	.18.5Y; 3M, 6F	maxillary transverse discrepancy	CBCT, photographic records, posteroanterior and lateral teleradiographies and study models	Hyrax: Anterior expansion: 1.93mm, Posterior expansion: 1.94mm MARPE: Anterior:2.1mm Posterior: 2.41mm	NA
Lupini et al. (35)	case report	17Y; F	skeletal Class III tendency, constricted upper arch, severe upper and lower crowding	CBCT, photographic records, posteroanterior , lateral and Panoramic radiographies and study model	5mm , 4.8mm and 2.6mm increase in total arch length, upper 4-4 and upper 6-6 widths	NA
Shin et al. (36)	retrospective	22.52 Y; 31 patients	maxillary transverse discrepancy	CBCT	Age, palatal length, and midpalatal suture maturation stage can be predictors of the success/failure rate of midpalatal suture opening	NA
Kolge et al. (37)	case series	17Y; F 12Y; F 14Y; F	moderately crowded upper and lower anterior constricted maxillary arch constricted maxillary arch	Intraoral Photographs	5mm,5mm and 6mm increase in intermolar widths in Case 1,2 and 3, respectively	NA

Table 2. Study characteristics.

	Mean	STD
Midpalatal suture expansion, mm		
Shin	0.9	0.81
Storto	4.7	1.49
Zong	2.8	1.54
Alar base width, mm		
Park	1.4	1.7
Lee	1.24	0.507
Nasal cavity width, mm		
Song	0.9	0.3
Park	1.4	1
Storto	3.47	2.7
Maxillary expansion, mm		
Zong	5.41	2.18

Table 3. Some evaluated variables in CBCT analysis.

Discussion

Transverse Maxillary deficiency is one of the most common dentofacial anomalies [4]. The prevalence of maxillary transverse deficiency is reported to be 11.72% and between 8% and 18% in mixed and permanent dentition, respectively [22,23]. In the conventional treatment of maxillary transverse deficiency, patients should be treated while still growing. If the patient›s growth is complete, the midpalatal suture changes with the formation of calcium, which makes treatment more difficult, mainly due to the increased mechanical strength of the suture during expansion. Therefore, maxillary expansion treatment is related to the patient›s age and skeletal maturity [19]. MARPE technique was designed to have the anchored structure directly attached to bone without involvement to teeth in order to increase the age range of non-surgical treatment of maxillary deficiency.

The purpose of this study was to compare different studies conducted in this field and to evaluate the results of treatment with the MARPE method. Regarding MARPE treatment results, in a case report study, this method was performed for a 24-year-old woman with maxillary transverse deficiency. The patient also suffered from upper and lower arches crowding. Treatment results revealed 5mm increase in intermolar width as well as the crowding resolution [24]. Skeletal expansion of the maxilla in patients who needs orthognathic surgery for correction of anteroposterior maxillomandibular discrepancy is another indication for MARPE. This technique can prevent two-stage surgery in patients with maxillary constriction combined with severe anteroposterior discrepancy (SARPE followed by orthognathic surgery). In one study, a 20-year-old patient with severe Class III malocclusion and bilateral buccal crossbite associated with maxillary transverse deficiency was treated with MARPE followed by orthognathic surgery. The initial maxillary and mandibular intermolar widths were 42.0 and 44.5mm, respectively. After using MARPE method, expansion stability and periodontal status were desirable from clinical and radiological standpoints. This report proposes an effective corporation of orthodontic mini-screws for transverse correction before orthognathic surgery [25].

In another study, MARPE was used for a 22-year-old female patient. The patient had posterior crossbite and deficient breathing, especially during sleep. Post-expansion CT scan showed the opening of the palatal suture and an increase on the nasal cavity floor. Also, apnea/hypopnea index (AHI) reduced from 7.9 to 1.5 [26]. In another study, 20 patients underwent maximal inspiratory pressure (MIP) and maximum expiratory pressure (MEP), peak expiratory flow, and nasal flow after MARPE. The results showed that MARPE significantly increased the size of the airway. The skeletal changes caused by MARPE directly affect the volume of the airways, resulting in a significant improvement in muscle strength and peak nasal and oral flow [27]. In the study of Lim et al., patients who had undergone MARPE due to maxillary constriction were evaluated for the dental, alveolar, and skeletal changes one month and one year after completion of expansion. There were significant increases in dentoalveolar and skeletal measurements one year after MARPE, while buccal alveolar bone thickness and height at the first

premolar decreased. The results of the study showed stable outcomes one year after expansion [28]. Another study evaluated alveolar facial and dental bone changes in patients with mean age of 14.97 years immediately after expansion with MARPE. A total expansion of 5.4mm achieved in which near 60% was contributed by skeletal expansion. Moreover, 2.82mm expansion of the mid-palatal suture at the nasal floor level as well as 2.56 ° of buccal tipping of first molars were reported as the results of the MARPE treatment. The findings of this study showed that MARPE was an effective method for correcting maxillary transverse deficiency [29]. The study by Song et al. Showed that the effects of MARPE treatment included an increase in nasal and nasopharyngeal cavity volume, but there was no evidence that MARPE could increase oropharyngeal airway volume. The nasal cavity expands orthopedically with MARPE in a triangular manner in both frontal and transverse dimensions [30]. Park et al. reported that the zygomatic arch and nasal cavity were widened by 0.8 and 1.4mm, respectively, and the lateral contour of the maxillary alveolus exhibited an expansion of 2.0–3.2mm ($p<0.001$). While the zygomatic arch expanded less, the expansion of the nasal cavity was much more pronounced and therefore nasal breathing improved due to increased airflow. On the other hand, buccal tipping of maxillary teeth upon MARPE leads to the decrease in buccal alveolar bone thickness and crest height. Hence, by effectively increasing the volume of the nasal cavity, treatment with the MARPE device can improve the constricted airway but paying attention to inclination of the posterior teeth is necessary for success of treatment [31].

In one case report, a 20-year-old female patient underwent MARPE treatment. She had anterior open bite, severe crowding and increased lower anterior facial height. Skeletal and dental Class II relationship, transverse maxillary deficiency, and bilateral posterior crossbites were also diagnosed in the patient. Treatment plan included maxillary expansion by MARPE followed by orthognathic surgery. After MARPE treatment, transverse maxillary deficiency was eliminated by increasing the inter first molar and the first premolar widths by 6 and 9mm, respectively [32]. In a study by Lee, most of the soft tissue around the nasal area showed significant local changes after MARPE in adults. The nose tended to dilate and move forward and downward. The volume of the nose after treatment also increased significantly compared to the initial volume. Considering the amount of soft tissue changes following MARPE treatment, orthodontists should fully explain the predicted changes to the patients before starting MARPE treatment [33]. A cohort study was performed and nine patients (three males and six females) with a mean age of 18±5.5 years were included. Six patients were treated by Hyrax expander (tooth borne appliance) and 3 patients with MARPE (bone borne appliance). Both groups achieved an increase in posterior transverse width; however, those in MARPE group achieved a greater parallel and skeletal expansion. Posterior transverse dimension changes in patients treated with MARPE were significantly greater than Hyrax group. Also, significantly smaller molar inclination in the group of skeletal anchorage was observed [34].

In another case report, a17-year-old female patient with skeletal Class III tendency, constricted upper arch, severe upper and lower crowding received Haas-inspired miniscrew-assisted maxillary expander (HIMAME). HIMAME appliance has metal pads to cover the palate and a jackscreaw. The appliance is connected to the maxilla with four TADs inserted into the cortical bone of the palate and nasal floor. Patient had 21mm arch-width discrepancy before treatment. With 6mm expansion of HIMAME appliance, 5mm, 4.8mm and 2.6mm increase in total arch length, upper 4-4 and upper 6-6 widths could be achieved, respectively [36]. In a retrospective study, in 31 patients (mean age, 22.52 years) who underwent MARPE treatment, the midpalatal suture opening ratio showed statistically significant negative correlations with age, palate length, and midpalatal suture maturation stage. The findings of this study indicated that age, palatal length, and midpalatal suture maturation stage can be predictors of the success/failure rate of midpalatal suture opening by MARPE in young adults but midpalatal suture density (MPSD) ratio cannot be used in this regard [36].

Kolge performed a case series study and concluded that the skeletal maxillary expansion could effectively be accomplished using various designs of MARPE in all three patients who participated in the study. In all 3 cases, clinical observations suggested that MARPE can prevent many of the adverse effects of RPE although some amount of buccal tipping is inevitable [37].

Conclusion

This procedure has been suggested as a treatment option for maxillary transverse deficiency in young adult patients, but studies have shown that people under age 14 also benefit from this method. More skeletal expansion and less dental tipping can be expected with this treatment modality. However, orthodontists

should be aware of the soft and hard tissue side effects and explain them to the patient before starting treatment.

Conflict of Interest

There is no conflict of interest to declare.

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