Journal of Research in Medical and Dental Science
2022, Volume 10, Issue 10, Page No: 23-32

Available Online at: www.jrmds.in
eISSN No. 2347-2367: pISSN No. 2347-2545

Maxillary Skeletal Expansion as a Reliable Technique for Correction of Transverse Deficiencies in Adults: A Concise Review

Allam Amira[1], Basaruddin Ahmed[2], Norma Ab Rahman[3*]

[1]School of Dental Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia
[2]Biostatistic and Dental Public Health Unit, School of Dental Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan Malaysia
[3]Orthodontic Unit, School of Dental Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia

ABSTRACT

Introduction: Maxillary expansion in adults is considered as a challenging treatment modality for the correction of transverse maxillary deficiency in such a mature skeleton. Surgical intervention was the only treatment option for those cases until the development of maxillary skeletal expanders (MSEs).

Aim: This comprehensive review aims to identify the extent and nature of the previous studies about non-surgical maxillary expansion techniques in adults, disadvantages of conventional procedures and advancement of MSEs in respect to their mechanism, appliance design, activation protocols, different effects, stability, and limitations.

Methods: PubMed, Google Scholar, Web of Science, EPSCO host, and Cochran library were used to search for literature in electronic databases. The following were the eligibility criteria: 1) Studies on human samples or human dry skulls, 2) published in English, 3) young adults or late adult ages with no additional treatments in progress that could affect the RME treatment. Studies included SARME, and MSE studies done on animal samples were excluded.

Results: Sixty (60) published papers based on the inclusion criteria was included and the findings was summarizes based on the study aims.

Conclusion: The skeletal effects of conventional RME in adults varies from failure to a very limited horizontal effect according to patient maturation. However, RME almost induced similar dentoalveolar, skeletal, nasal, and airway effects, which considered being a better treatment modality in situations of transverse maxillary deficiency in adults.

Key words: Maxillary expansion, Transverse deficiency, Adult orthodontics

HOW TO CITE THIS ARTICLE: Allam Amira, Basaruddin Ahmed, Norma Ab Rahman, Maxillary Skeletal Expansion as a Reliable Technique for Correction of Transverse Deficiencies in Adults: A Concise Review, J Res Med Dent Sci, 2022, 10 (10):23-32.

Corresponding author: Norma Ab Rahman

e-mail✉: drnorma@usm.my

Received: 27-Sep-2022, Manuscript No. JRMDS-22-76033;

Editor assigned: 29-Sep-2022, PreQC No. JRMDS-22-76033(PQ);

Reviewed: 13-Oct-2022, QC No. JRMDS-22-76033(Q);

Revised: 18-Oct-2022, Manuscript No. JRMDS-22-76033(R);

Published: 25-Oct-2022

INTRODUCTION

Maxillary expansion is a regular treatment of transverse maxillary deficiency, and posterior cross bite either unilateral, or bilateral. It can also be used to widen the perimeter of an arch to relieve crowding and can even be used to appropriate arch forms to enable for non-extraction therapy. Various equipment and therapy approaches have been created and utilized successfully in children and adolescents; however adults with maxillary insufficiency have faced a difficult treatment alternative. The most common operation was rapid maxillary expansion (RME) with a tooth-anchored expander like Hyrax. There are few drawbacks that have been discussed which were age-dependent on a regular basis. A maxillary skeletal expander (MSE), either a bone-born or a tooth-bone-anchored (Hybrid) expander, might be anchored directly to the palatal surface of the maxilla using mini-screws as an alternative to this method (Figure 1). They apply forces directly to the maxillary bones or distribute it among the bone and the anchored teeth in hybrid anchorage device. The MSE, overcome the limitations of traditional tooth-born RME appliances with minimum invasiveness. In adults, it is less expensive than the previously required surgically assisted rapid maxillary expansion (SARME) [1]. Literature presented different MSE appliances, with

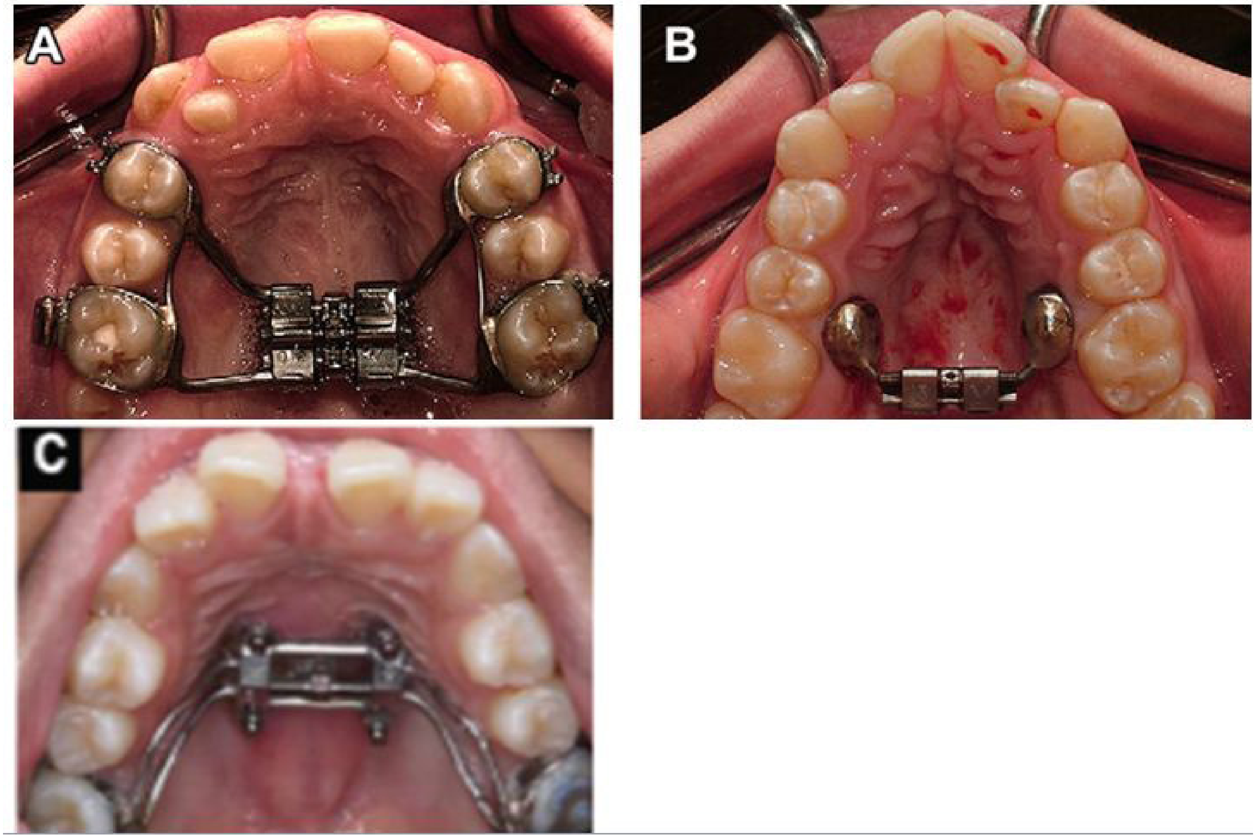

Figure 1: A: rapid maxillary expansion (RME) with a tooth-anchor expander. B: A bone-born maxillary skeletal expander (MSE), C: A tooth-bone-anchored MSE.

different designs, number of anchor teeth, and mini-screws with different positions, size, and number. All serving the same purpose, which is producing sufficient maxillary expansion in non-growing adolescent ages.

MATERIALS AND METHODS

PubMed, Google Scholar, Web of Science, EPSCO host, and Cochran library were used to search for literature in electronic databases. The following were the eligibility criteria: 1) Studies on human samples or human dry skulls, 2) Published in English, 3) Young adults or late adult ages with no additional treatments in progress that could affect the RME treatment. Studies included SARME, and MSE studies done on animal samples were excluded.

RESULTS

Conventional RME in adults

During development, craniofacial suture especially the mid-palatal suture, become increasingly calcified and interdigitated [2]. Anchor teeth's amount of buccal tipping was related to the patient's age and skeletal maturity [3]. In young adults, the operation becomes more complicated. Although studies have shown that tooth-born growth is successful in this age range [4-6]. However, no well-designed clinical trials, according to the authors, have characterized its success rate. As a result, this procedure can be classified as unexpected, risky, and linked to a higher risk of poor outcomes such as loss of alveolar bone thickness and height, bone dehiscence, and gingival recession [5]. Various RME appliances, like tooth-borne Hyrax, tooth-tissue-borne Haas, or bonded RME appliances, have been frequently used in teenagers with narrow maxillary arches for a long period [3,7-10]. The traditional appliances of RME work by splitting the mid-palatal suture to increase the maxillary arch. In addition to the desired orthopedic impact, RME unavoidably created a dental consequence of buccal movement (tipping) of the anchored teeth [11]. This tipping, as well as posterior tooth extrusion and alveolar bending, all help to expand the bite and rotate the jaw posteriorly. Due to the resistance from the surrounding structure, it also raises the likelihood of relapse [11]. When the pressures are concentrated at the dentoalveolar area, tooth-born (banded) expanders have been shown to produce iatrogenic effects on periodontal tissues, including root resorption, buccal dehiscence, and gingival recession [11,12]. The inclusion of an acrylic palatal covering to support the appliance resulted in increased body movement and reduced dental tipping, according to Haas [13]. In literature, both tooth-tissue-born (Haas) and bonded RME appliances were found to reduce the negative effects of tooth-borne devices while having minimal effects on the basal bone, resulting in more dental tipping and a high relapse rate [14]. As a result, different research investigations demonstrated that tooth-anchored palatal expansion in adults has different effects. Some people refer to them as skeletal expansion, alveolar expansion, or tooth bending or tipping [2,15]. And other people believe they range from failure to a four-millimeter horizontal increase [11,16,17]. The patient's skeletal maturity has been linked to failure. When relapse of horizontal measures is identified, and the maxilla later restores its primary position after its rotation downward, variation in the transverse measuring results is dependent on post-treatment time when data were taken, after acceptable retention periods; when the horizontal measures relapse is identified, the maxilla later restores its primary position after its rotation downward [18].

The development of MSE devices

In face of all dento-alveolar side effects of tooth-born RME, some authors have suggested that orthodontic alternatives be used as bone anchorage devices to optimize the application of expansion pressures to circum-maxillary sutures, hence reducing the need for surgical osteotomies [19]. This procedure was carried out to ensure that the underlying basal bone expanded and that the aforementioned concerns were avoided. Wehrbein, et al. [20], firstly introduced the use of mini-screws in palatal area. While the first who used mini-screws in maxillary expansion was Mommaerts, et al. [21], with a trans-palatal distractor, which was considered to be the first bone-borne surgically assisted RME. The newly developed distractor was applied for maxillary expansion following osteotomy of the lateral walls of the maxillary sinuses and the mid-palatal suture. Previously, conventional devices used for SARME were all tooth-born. Dental fixation, on the other hand, has a number of potential downsides, including anchoring loss, skeletal relapse both during and after the growth period, cortical fenestration, and buccal root resorption [21]. Despite of the significant increase in inter-canine distance, widening of the anterior and posterior dental arch widths and although the values were found to be largely constant [22,23]. It's still an intrusive procedure with a high price tag and the danger of root damage and infection [14]. For delivering direct stresses to the maxillary bone, implant-supported and aided expansion devices have lately emerged as a feasible alternative to invasive surgical procedures [24-27]. Maxillary skeletal expander is the name given to them (MSE). They apply stresses to the micro-screws, which were designed with a jackscrew anchored to the palatal vault simply (bone-borne MSE in implant-supported expansion) or in conjunction with bone-tooth anchorage (Hybrid anchorage expansion or mini-screw assisted rapid palatal expansion (MARPE).

Stress distribution with MSE

Rather of alveolar remodeling or tilting, maxillary growth is accompanied with sutural changes in remote places as people get older [28] as the sutures are no longer patent and also the expansion forces are all now blocked by the established buttresses of the mid-facial skeleton [29]. Although conventional appliances have the ability to expand teeth in grownups, deformations are less significant in the structures in the anterior region and along the midline, with more anterior expansion than posterior, and minimal displacement but high stress in the posterior and lateral structures, particularly in the buccal cortical area of anchored teeth [28]. When Hartono, et al. [30] used MSE to assess stress distribution, he found that stress was centered on the mini-screws, which served as absolute anchoring for the study's expansion. The palatal bone was directly expanded using mini-screws, resulting in skeletal mobility. Their occlusal examination showed a suture that stretched from posterior to anterior in a straight line. MSE led in a more parallel opening of the sutures than standard RME, which resulted in a wedge-shaped opening, according to Lin, et al. [31]. The greatest stress value was localized around the mini-screws in the Seong, et al. study [32] with MARPE, but the stress value was significantly lower than it was with mini-screw assisted expansion (bone-born). The stress was distributed uniformly throughout the mid-palatal suture and then fell towards the buccal plate of the anchor teeth. They hypothesized that the insertion of mini-screws altered the expansion force's resulting vector closer to the basal bone's resistance center [33]. MARPE, according to Seong, et al. [32] achieved significant buccal extension of the anchor teeth with much less buccal tilting than bone-born.

Mechanism of MSE in adult ages

Previous research has shown that the true bone of the mid-palatal obliteration suture in radiographs does not correspond with chronological age [34], and that people aged 10 to 30 years can have essentially comparable histology results [35].

Lin observed the bone-anchored RME had better orthopaedic benefits and less dentoalveolar adverse effects in late adolescents than conventional RME in their study [31], (mean age of twenty-two years). However, even the tooth-borne RME group experienced skeletal transverse expansion, but it was considerably less than the bone-borne group. Despite radiographs showing complete ossification, only the front section of the suture was ossified in persons beyond the age of 70, according to a recent histological investigation [36] Boryor, et al. [36] demonstrated that the intermaxillary suture can be opened with a very minimal transverse force. To open the fused sutured in the seventy-three-year-old female specimen, a minimal force (80 to 90 N) was required. During RME, this force is similar to that of youths with non-fused sutures. The posterior regions of those samples showed connective tissue. The idea that the suture of mid palatal is the only cranial suture that does not fully ossify due to the constant mechanical stress it undergoes, which was supported by this research [5]. Choi, et al. [37], who conducted a similar study on late teenage age group and discovered, corroborated this evidence. The sixty-nine participants in the study failure of maxillary expansion utilizing MARPE were identified in nine of them. As a result, suture split and diastema occurred in 86.9% of the cases. In the Park et al research [38], only three of the 19 patients treated with MARPE failed to open the mid-palatal suture and were eliminated, yielding in an 84.2 percent success rate. It's still unclear why certain MARPE cases fail, but Brunetto, et al. believes he knows why [5] that craniofacial architecture (high resistance), and the discrepancies in the mid-palatal suture's calcification patterns, are contributing factors. Choi, et al. [37] agreed with Lee's, et al. [27] notion that adult expansion failure is caused by variances in the obliteration of suture with resistance from craniofacial characteristics. As a result, they concluded that the zygomatic buttress's effect and pterygopalatine junction resistance were to blame for the failure of their nine cases. Even though, skeletal expansion was successfully achieved in the majority of the cases. However, they considered the craniofacial structural resistance playing the main role in subsequent relapse [37]. Liu looked at publications with ages ranging from 5 to 20 years in their systematic review [39]. The mid-palatal suture was divided even though the sample in two studies [10,40] was much older than 18 years. Korbmacher, et al. [41] used computed tomography (CT) to divide human palatal tissues into three age groups, ranging from 14 to 71 years old (25, 25 till 30, and 30 years). Only bone density showed significant changes between age groups. The oldest and youngest age groups had considerably reduced the density of bone, while the group of middle-aged already had greatest bone density (53.2%). The degree of interdigitation of the mid-palatal suture and the mean obliteration index were not observed to be associated to chronological age in this study. Sutural density of bone seems to be the trait limiting conservative RME, according to Liu et al [39].

Influence of different designs of MSE

Lee treated a twenty-year-old patient in a pilot experiment in 2010 with the first expansion device fastened to the palate utilizing minis-crews [27]. (Bone-born expansion). After retention, clinical and radiographic testing confirmed that the expansion was successful with minimum injury to the teeth and periodontium, and that the staple outcomes were validated by use of a clinical and radiographic examination It was discovered by the authors that it is an excellent therapy strategy for transverse palatal correction in adult patients with craniofacial abnormalities, eliminating the need for surgical operations. To secure the mini-screws to the turn-key, Lee et al. employed metal extensions soldered to expansion screw and bonded with the light-curing epoxy. Moon [42] and MacGinnis et al [43] utilized Lee's results to include four mini-screws parallel to the mid-palatal and linked to one anchored tooth on each side into the expansion screw body. Introducing a novel advancement to the maxillary skeletal expander (tooth-bone born - MARPE). Suzuki et al [18] improved the design of the MARPE appliance after finding that in previous studies, (bone-born [27] and MARPE [42,43], Moving the mini-screws away from the mid-palatal suture raised the chance of perforating underlying systems such nerves and canals in each of the posterior and anterior locations, in addition on the lateral sides, What's more, it's even more harmful. Mini-screws placed apart from the body of the screw allow for greater growth, as they stated. However, the mini-screws were designed to be inserted more evenly parallel to the suture of the palatal [18], allowing for higher engagement of thicker bone surfaces and adequate stress propagation to the nasomaxillary complex. They reasoned that mini-screws should be used in orthopedic and orthodontic therapy, along with wires and elastics, and that they would be useful as anchorage units where they were likely to be positioned. Park et al. [38] in their research, MARPE was used on fourteen individuals with a mean age of 20.1 years. This time, the MARPE device was constructed by modifying a regular hyrax-type RME device (Figure 2). They soldered four robust connectors made of stainless-steel wire with helical hooks onto the base of a standard hyrax screw body. The rugae area received two anterior hooks, and the para-midsagittal area received two posterior hooks. Each helical hook was then fitted with four mini-screws in the centre. Later on, the same appliance design was employed in many experiments [44-47]. Lim, et al. [44] used this method to investigate the variations in dental, alveolar, and skeletal measurements of twenty-four individuals (mean age, 21.6 years), they confirmed the results of previous studies about the success of MARPE on adult patients. Two other studies used the same appliance design; the first was to evaluate its effect stability in sixty-nine adult patients [37]. And the other was a case report illustrated the treatment of a transverse maxillary deficiency in a twenty-four-years old woman [45]. Both investigations found that MARPE is a successful treatment technique for adult patients with arch-perimeter deficiencies caused by maxillary transverse discrepancies, with Choi, et al. [37] describing it as a stable therapy modality.

In a study by Cantarella, et al. [46], the appliance was secured to the palatal bones with four micro-implants, and only two extended arms fused and soldered to the first molar. This MARPE was given to fifteen people with an average age of 17.2 years. Results revealed that, regarding the magnitude of mid-palatal suture opening; it was virtually exactly parallel antero-posteriorly with this appliance design and position. The same authors in 2018, published another article [47] using another appliance design. The MARPE device this time consisted of an extension jackscrew with four holes for palatal mini-screws and bilateral arms attached to molar bands. They found that after treatment with MARPE, the maxillary and bones of zygomatic, as well as the entire zygomatic arch, were considerably shifted in a lateral direction in the horizontal plane. And that the zygomaticomaxillary complex's center of rotation was towards the proximal section of the temporal bone's zygomatic process, which is more laterally and posteriorly than what has previously been described in the literature. Another article [5] discussed Dr. Won Moon's MARPE design [42], which detailed all of the

Figure 2: Mini-screw assisted rapid palatal expansion (MARPE) design.

therapy progress and outcomes. Following the surgery, the patient in this study experienced significant occlusal and pulmonary advantages without having any surgical intervention. The MARPE appliance was designed in the same way as a standard Hyrax expander. But this time, the expander's body was positioned as far back as possible, near to the confluence of the hard and soft palates (Figure 3). Even in the instance of narrow high arched palates, removal of MARPE's anterior wire segments was required to improve the appliance's vertical fit posteriorly. The authors indicated that this position is owing to the greatest resistance to suture opening, which is positioned between the pterygoid plates and the maxilla. To overcome this initial resistance and induce a more parallel opening of the mid-palatal suture, pressures should be given more posteriorly. In their investigation, Zong, et al. [48] used a device consisting of a central expansion screw soldered to four tubes that functioned as micro-implant placement guides. The micro-implants had a diameter of 1.8 mm and a length of 11 mm. The longer the length of micro-implants, the greater the bi-cortical contact of the palatal and nasal floor, which reduces the force sent to the attached teeth during expansion, according to the authors. The main disadvantages of MSE in literature, were considered to be due to lack of skill and improper application according to Brunetto et al. To avoid perforation of the nasal cortical bone, a minimum of six millimeters of bone is required to maintain good primary stability of the mini-screw [5]. In his study [1], Montigny underlined that, in addition to the area chosen for placement, the positioning of any mini-implant is heavily influenced by this element.

A mini-implant placed too far anteriorly may cause harm to the naso-palatal canal, which contains nerves and arteries. While too posteriorly toward the hard palate could affect the small salivary glands in this area causing mucus retention complications. Moreover, the risk of damaging the roots of maxillary teeth is pronounced at the posterior region, at the level of the maxillary molars' palatal roots One of the reasons why the dental anchor was adopted in later stages was because of this [42,43]. Selection of the appropriate mini-screws was discussed by Nojaima, et al. [49], who presented a systematized protocol for its selection, CBCT was used to help. In this paper, variables relating to bone and soft tissue thickness in the palate regions of interest, as well as the fixation rings of the palatal expander's mini-screws, were all evaluated and discussed.

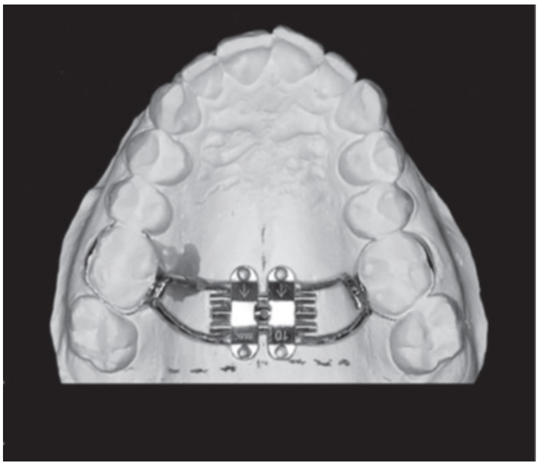

Figure 3: The body of the expander was placed as posterior as possible, close to the junction of hard and soft palate.

The activation rates of MSE

Brunetto [5] presented a table suggesting some activation rates according to age, with a device expansion 0.2 mm per turn. The mostly used expansion rate in different studies [5,14,46, 47, 50-53] was two turns per day (0.2mm per turn) with overall 4-5 mm expansion per day. The same amount of expansion was applied by Zong, et al. [48] and Oh-Heeso, et al. [54], but with different screw width (1.3mm per turn) which required four activations per day. Other studies [31,38,44,45,55], used one turn (2mm) expansion per day. Hourfar, et al. [56] used a rapid expansion protocol (three turns) with 6mm expansion per day. On the other hand, Lagravere, et al. [26] and Choi, et al. [37] in their studies, used slow expansion Every other day, (one rotation 0.2 mm) to reduce tissue damage, inflammation, and discomfort, as explained by Choi et al. The initial activations after immediate placement of the appliance differ in literature according to the clinical procedures and appliance used in each study. Most studies neglected the initial activation. Some used three immediate activations [5], some initiated expansion the day after placement of the MARPE appliance [38, 55]. Others waited a healing period of one week [26] and two weeks [48] before activation of the expander. Lin, et al. [31] when used a 10-mm palate split-screw, with a nickel-titanium spring in the screw bed, it was activated over 7 mm immediately after placement. The continuation of the expansion protocol either being the same after interincisal diastema appearance or decreased to half the initial rate (46-48) or decreased to once in every three days [14] as suggested by Işeri, et al. [57].

Influence of MSE on respiration

The impact of MARPE on variations in airflows in the upper airway of an adult patient with obstructive sleep apnea syndrome was investigated using computational fluid dynamics and fluid-structure interaction analysis (OSAS) [58]. 3D upper airway models were created using CBCT images. At maximum inspiration, rest, and maximum expiration, changes in cross-sectional area, airflow pressure and velocity node movement, and total resistance were all examined. They came to the conclusion that MARPE increased airflow and decreased resistance in the upper airway. An analogue manometer, an expiratory peak flow meter, and a nasal inspiratory peak flow meter were utilized in a 2019 study [53] to look at changes in respiratory muscle strength, inspiratory and expiratory peak flow. A total of twenty adult patients took part in the study. The data showed that MARPE enhanced airway capacity considerably because skeletal changes had a direct effect on airways volume, leading to significant increases in the muscle strength, nasal & oral peak flow [45]. Two more investigations [52,55] assessed nasal airway volume, cross-sectional area, and upper airway volume using CBCT quantitative analysis. They both agreed that the volume of the nasal cavity had increased significantly, although Kavand, et al. [52] indicated an increase in nasopharynx volume with no effect on oropharynx or maxillary sinus volumes. In spite of the findings of a recent systematic review [59] that showed that the short-term airway volumetric changes after MARPE were not significant, and the effects of MARPE on breathing is still not clear, Brunetto, et al. [60] in 2022 had different opinion. In their multi-center prospective controlled trial. They examined the effects of MARPE on adult obstructive sleep apnea (OSA) and quality of life and observed important daytime sleepiness and OSA-related quality of life improvement, as well as the improvement achieved in apnea/hypopnea index, oxygen saturation and snoring duration.

Influence of MSE on facial soft tissue

Several studies have established the dental and skeletal effects of RME in adults, but just a handful has documented alterations in the underlying soft tissue after nonsurgical RME [61]. This could be owing to the belief that it will be minor or obscured by other developmental changes, making it difficult to assess. Greater non-growing individuals may now be skeletally harmed as a result of MSE, prompting more in-depth investigation into the consequences of expansion on soft tissue. According to Abedini, et al. [62], effects on the soft tissue during MSE expansion may be easily examined by combining the excellent technology of the 3dMD Face Device, which

Table 1: Studies evaluated and compared different non-surgical expansion techniques.

The study	Tooth born	Bone burn	Tooth born born	Samples	Tools	Compared effects
Lagravere, et al. [26]	Banded Hyrax	Mini-screw supported		N=62 1 control group M age =13.8	CBCT	Transverse, vertical, and anteroposterior skeletal and dental changes and long-term stability
Lin, et al. (31)	Banded Hyrax	Acrylic appliance connected to the screw heads		N=28 M age =18.2± 4.5	CBCT	Transverse skeletal and dentoalveolar changes
Yilmaz, et al. [14]	Banded Hyrax Bonded Hyrax	Acrylic appliance connected to the screw heads		N=42 M age =13.2± 2.1	Cephalometric, posteroanterior radiographs, and dental casts	Dentoskeletal effects
Hourfar, et al. [56]	Conventional, banded design		Molar banded, hybrid design	N=100, M age =13.04 ± 4.82	Cephalometric radiographs	Cephalometric changes in the maxilla and mandible
Celenek-Coca, et al. [50]	Hyrax- type expander	Mini-screw supported		N=40 M age =13.84± 1.36	CBCT	Dentoskeletal effects
Hartono, et al, [30]	Conventional RPE		MSE		A dry skull, CBCT and FEM	Stress distribution
Seong et al. [32]	Conventional RPE	Mini-screw supported	MARPE		A dry skull, CT and FEM	Stress distribution
Kavand, et al. [52]	Banded Hyrax	Mini-screw supported		N=36 M age=14.5	CBCT	Changes in upper airway volume and dentoskeletal effects
Oh-Heesoo, et al. [54]	Banded Hyrax		MARPE	N=102 M age=14.2±1.5	CBCT	Dentoskeletal effects
N=Number of samples						
M age=Mean age						
CT=Computerized tomography						
FEM=Finite element method						

is a very quick stereo photogrammetry system, with a newly developed method of 3D quantification. In their Study [60], They studied and quantified MSE-induced soft tissue face alterations in twenty-five subjects with an average age of 21.3 years. 3D facial photos (3dMD) were used to obtain face scans in order to produce 3D soft tissue meshes. After MSE, there were significant alterations in the Paranasal, upper lip, and both cheeks, with the latter having a greater amplitude.

Comparative studies among different non-surgical expansion techniques

Studies evaluated and compared different non-surgical expansion techniques are illustrated in Table 1.

In Lagravere's, et al. study [26], each of the expanders showed the same results. The transverse dimension experienced the most modifications, while the anteroposterior and vertical dimensions experienced minimal changes. In their investigation, dental expansion was likewise bigger than skeletal expansion. Lin et al [31] discovered that bone-born expanders had greater orthopedic results and less dentoalveolar side effects than that of the hyrax tooth-born expanders. Even with an activation of one-quarter turn per day (0.25-mm widening), the difference in maxillary width between the bone-born group and the other conventional RME groups was significant, indicating that the bone-born group had more skeletal expansion. According to Yilmaz [14], the banded and bonded Hyrax groups' maxillary molars had significant buccal tipping, whereas the bone-born group's molars had lingual tipping. In all the groups they used a semi-rapid activation protocol; twice a day in the first 7-10 days till a central diastema occur, then continued once in every 3 days. When Celenek-Coca, et al. [50] compared the two procedures, they discovered that bonded expansion was a better option, especially for individuals with vertical growth patterns and those who lacked anchorage teeth. With really no dental side effects, bone-born growth in the adolescence raised the degree of skeletal alterations by 1.5 to 2.8 times than that tooth-born expansion. In recent research of the upper airway, Kavand, et al. [52] agreed with Celenek-dentoskeletal Coca's findings, finding that only tooth-born expanders produced considerable buccal tilting of maxillary anchored molars, as well as an increase in nasal cavity and nasopharynx volume. In Hourfar's study [56], hybrid appliances exerted a more pronounced skeletal effect on the maxilla than other appliances. In their investigation of stress distribution in tooth-born versus tooth-bone born expansions, Hartono et al [30] agreed with most of the comparative studies when they discovered the stress distribution in tooth-born versus tooth-bone born expansions. the first molar palatal side (M1), the palatal alveolar mesial side of M1, the M1 pulp chamber, and the inferior cortex of palatine sutures were all part of the tooth-born group. The disto-palatal cusp of M1, the palatal side of M1's palatal alveolar, and the superior and inferior cortex of palatine sutures received the most stress in the hybrid tooth-bone born group. Both groups had their zygomatico-temporal sutures stressed, however the anterior mini-screws and the surrounding bones palatal side were only stressed in the mini-screws. The stress distribution of the three non-surgical expansion techniques [32] was subjected to another finite element analysis. Traditional RME was found to create the most stress in the frontal process of the maxilla and along the connected teeth, followed by the suture area. Although the stress region within the suture was limited, bone-born RME caused the most stress surrounding the mini-screws. When compared to other appliances, MARPE induced an equitable distribution of strain, with much less tension just on buccal plate of the linked teeth and less tipping. In retrospective research, Oh-Heesoo, et al. [54] examined the same three procedures. They found that the MARPE group showed more skeletal changes than the tooth-anchored and bone-anchored groups, especially at the nasal floor, maxillary base width, and palatal suture opening. Seventy-two to seventy-eight percent of suture opening took place at the PNS, indicating slightly more anterior than posterior opening; nonetheless, it was determined to be more parallel than expected.

Evaluation of stability after MSE

In a study of adolescents, Lagravere, et al. [26] looked at the short- and long-term effects of tooth-borne and bone-anchored expanders. The first molar of the maxillary crown and root apex, first premolar crown and root, alveolus in the first molar and premolar areas and central incisor root all showed considerable long-term extension in both treatment groups. While tooth-born expansion resulted in significantly more long-term growth at the maxillary premolar crown and root than bone-born expansion, tooth-born expansion resulted in significantly more long-term expansion at the maxillary premolar crown and root. Choi in their study [37] examined postero-anterior cephalometric records and dental casts which were obtained in a post-treatment follow-up after a mean period (30.2 ± 13.2 months). As none of the patients had such a posterior cross bite relapse or edge to edge bite, they considered MARPE to be a clinically appropriate and stable treatment approach for this age group (mean age 20.9 2.9). Lim et al. [44] looked at changes in dental, alveolar, and skeletal markers one year after MARPE in 24 patients (mean age, 21.6 years). Despite some relapses throughout therapy, MARPE resulted in significant improvements in most metrics, with generally consistent results. Kim et al. [55] discovered that volume and cross-sectional area of the nasal cavity rose and remained steady one year following expansion when they employed MARPE to test the stability of modifications in the nasal airway in fourteen patients (mean age: 22.7 years). In their soft tissue analysis following MSE in late adolescent ages, Abedini, et al. [62] discovered alterations in Paranasal, upper lip, and each cheek, which did not recur after a one-year retention period.

CONCLUSIONS

The skeletal effects of conventional RME in adults vary from failure to very limited horizontal effects according to patient maturation. In addition of being unpredictable, risky, and of higher rate of side effects. MSE (bone supported and bone assisted) were presented in literature with different designs in respect to the number and length of mini-screws, number of anchored teeth, and in the position of the appliance along the palate. However, they almost induced similar dentoalveolar, skeletal, nasal, and airway effects, which considered being a better treatment modality in situations of transverse maxillary deficiency in adults. In comparison studies, the benefit of MARPE was proven in their even stress distribution, which reduced stress on the attached teeth buccal plate and reduced tipping. They also proved to be with stable dent skeletal, respiratory, and soft tissue facial changes outcomes one year after expansion. The scarcity of articles evaluated soft tissue changes after MSE, calls for more in-depth studies especially after the advancement of the 3dMD Face System technology.

ACKNOWLEDGEMENT

Grant supported from External Agencies KPS Dental Care Team Sdn Bhd (RT 304 PPSG.6150250.K161).

REFERENCES

1. Montigny M. Mini-implant assisted rapid palatal expansion: New perspectives. J Dentofac Anom Orthod 2017; 20:405.
2. Garrett BJ, Caruso JM, Rungcharassaeng K, et al. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofac Orthop 2008; 134:8-9.
3. Garib DG, Henriques JF, Janson G, et al. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: A computed tomography evaluation. Am J Orthod Dentofac Orthop 2006; 129:749-758.
4. Handelman CS, Wang L, BeGole EA, et al. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. Angle Orthod 2000; 70:129-144.
5. Brunetto DP, Sant'Anna EF, Machado AW, et al. Non-surgical treatment of transverse deficiency in adults using Microimplant-assisted Rapid Palatal Expansion (MARPE). Dent Press J of Orthod 2017; 22:110-125.
6. Stuart DA, Wiltshire WA. Rapid palatal expansion in the young adult: Time for a paradigm shift? J Can Dent Assoc 2003; 69:374-377.
7. Christie KF, Boucher N, Chung CH. Effects of bonded rapid palatal expansion on the transverse dimensions of the maxilla: A cone-beam computed tomography study. Am J of Orthod and Dentofac Orthoped 2010; 137:79–85.
8. Asanza S, Cisneros GJ, Nieberg LG. Comparison of Hyrax and bonded expansion appliances. Angle Orthod 1997; 67:15–22.
9. Akkaya S, Lorenzon S, Uçem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. Europ J of Orthod 1999; 21:175–180.
10. Davidovitch M, Efstathiou S, Sarne O, et al. Skeletal and dental response to rapid maxillary expansion with 2-versus 4-band appliances. Am J of Orthod and Dentofac Orthoped 2005; 127: 483–492.
11. Wertz RA. Skeletal and dental changes accompanying rapid mid-palatal suture opening. Am J of Orthod 1970; 58:41–66.
12. Odenrick L, Karlander EL, Pierce A, et al. Surface resorption following two forms of rapid maxillary expansion. Euro J of Orthod 1991; 13:264–270.
13. Hass AJ. The treatment of maxillary deficiency by opening the mid-palatal suture. Angle Orthod 1965; 35:200–217.
14. Yılmaz A, Arman-Özçırpıcı A, Erken S, et al. Comparison of short-term effects of mini-implant-supported maxillary expansion appliance with two conventional expansion protocols. Euro J of Orthod 2015; 37:556-564.
15. Mosleh MI, Kaddah MA, Abdou F, et al. Comparison of transverse changes during maxillary expansion with 4-point bone-borne and tooth-borne maxillary expanders. Am J Orthod Dentofac Orthop 2015; 148:599–607.
16. Capelozza Filho L, Cardoso Neto J, Silva Filho OG, et al. Non-surgically assisted rapid maxillary expansion in adults. Int J Adult Orthod Orthog Surg 1996; 11:57-66.
17. Haas AJ. Palatal expansion: Just the beginning of dentofacial orthopedics. Am J Orthod 1970; 57:219-255.
18. Suzuki H, Moon W, Previdente LH, et al. Miniscrew-assisted rapid palatal expander (MARPE): the quest for pure orthopedic movement. Dent Press J of Orthod 2016; 21:17-23.
19. Carlson C, Sung J, McComb RW, et al. Micro-implant-assisted rapid palatal expansion appliance to orthopedically correct transverse maxillary deficiency in an adult. Am J Orthod Dentofac Orthop 2016; 149:716-728.
20. Wehrbein H, Glatzmaier J, Mundwiller U, et al. The orthosystem–a new implant system for orthodontic anchorage in palate. J Orofac Orthop 1996; 57:142–153.
21. Mommaerts MY. Transpalatal distraction as a method of maxillary expansion. British J of Oral Maxillofac Surg 1999; 37:268–272.
22. Matteini C, Mommaerts MY. Posterior transpalatal distraction with pterygoid disjunction: A short-term model study. Am J of Orthods Dentofac Orthop 2001; 120:498–502.
23. Gerlach KL, Zahl C. Transversal palatal expansion using a palatal distractor. J of Orofac Orthoped 2003; 64:443–449.
24. Tausche E, Hansen L, Hietschold V, et al. Three-dimensional evaluation of surgically assisted implant bone-borne rapid maxillary expansion: a pilot study. Am J of Orthod Dentofac Orthop 2007; 131:92–99.
25. Garib DG, Navarro R, Francischone CE, et al. Rapid

maxillary expansion using palatal implants. J Clin Orthod 2008; 42:665–671.

26. Lagravére MO, Carey J, Heo G, et al. Transverse, vertical, and anteroposterior changes from bone anchored maxillary expansion vs traditional rapid maxillary expansion: A randomized clinical trial. Am J of Orthod and Dentofac Orthop 2010; 137:304–312.
27. Lee KJ, Park YC, Park JY, et al. Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism. Am J Orthod Dentofacial Orthop 2010; 137:830-839.
28. Baldawa RS, Bhad WA. Stress distribution analysis during an intermaxillary dysjunction: A 3-D FEM study of an adult human skull. Ann Maxillofac Surg 2011; 1:19-25.
29. Festila D, Enache M, Ghergie M. Treatment modalities of skeletal maxillary deficiency: A review. Rom J of Stomat 2018; 64:172-178.
30. Hortono N, Seogiharto BM, Widayati R. The difference of stress distribution of maxillary expansion using rapid maxillary expander (RME) and maxillary skeletal expander (MSE): A finite element analysis. Prog Orthod 2018; 19:33.
31. Lin L, Ahn HW, Kim SJ, et al. Tooth-borne *vs.* bone-borne rapid maxillary expanders in late adolescence. Angle Orthod 2015; 85:253–262.
32. Seong EH, Choi SH, Kim HJ, et al. Evaluation of the effects of miniscrew incorporation in palatal expanders for young adults using finite element analysis. Korean J Orthod 2018; 48:81-89.
33. Koo YJ, Choi SH, Keum BT, et al. Maxillomandibular arch width differences at estimated centers of resistance: comparison between normal occlusion and skeletal class III malocclusion. Korean J Orthod 2017; 47:167-175.
34. Persson M, Thilander B. Palatal suture closure in man from 15 to 35 years of age. Am J Orthod 1977; 72:42–52.
35. Knaup B, Yildizhan F, Wehrbein H. Age-related changes in the midpalatal suture. A histomorphometric study. J Orofac Orthop 2004; 65:467–474.
36. Boryor A, Hum B, Hohmann A, et al. Use of a modified expander during rapid maxillary expansion in adults: An *in vitro* and finite element study. Int J Oral Maxillofac Implants 2013; 28:11–16.
37. Choi SH, Shi KK, Cha JY, et al. Nonsurgical miniscrew-assisted rapid maxillary expansion results in acceptable stability in young adults. Angle Orthod 2016; 86:713–720.
38. Park JJ, Park YC, Lee KJ, et al. Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion in young adults: A cone-beam computed tomography study. Korean J Orthod 2017; 47:77-86.
39. Liu SY, Xu TM, Zou W. Effects of rapid maxillary expansion on the mid-palatal suture: A systematic review. Euro J of Orthod 2015; 37:6.
40. Baydas B, Yavuz I, Uslu H, et alI. Nonsurgical rapid maxillary expansion effects on craniofacial structures in young adult females: A bone scintigraphy study. Angle Orthod 2006; 76:759–767.
41. Korbmacher H, Schilling A, Puschel K, et al. Age-dependent three-dimensional microcomputed tomography analysis of the human midpalatal suture. J Orofac Orthop 2007; 68:364–376.
42. Moon W, Machado A. Interview with won moon. Dental Press J Orthod 2013; 18:12-28.
43. MacGinnis M, Chu H, Youssef G, et al. The effects of micro-implant assisted rapid palatal expansion (MARPE) on the nasomaxillary complex–a finite element method (FEM) analysis. Prog Orthod 2014; 29:15:52.
44. Lim HM, Park YC, Lee KJ, et al. Stability of dental, alveolar, and skeletal changes after miniscrew-assisted rapid palatal expansion. Korean J Orthod 2017; 47:313-322.
45. Cunha AC, Lee H, Nojima LI, et al. Miniscrew-assisted rapid palatal expansion for managing arch perimeter in an adult patient. Dent Press J Orthod 2017; 22:97-108.
46. Cantarella D, Dominguez-Mompell R, Mallya SM, et al. Changes in the midpalatal and pterygopalatine sutures induced by micro-implant-supported skeletal expander, analyzed with a novel 3D method based on CBCT imaging. Prog in Orthod 2017; 18:34.
47. Cantarella D, Dominguez-Mompell R, Moschik C, et al. Zygomaticomaxillary modifications in the horizontal plane induced by micro-implant-supported skeletal expander, analyzed with CBCT images. Prog in Orthod 2018; 19:41.
48. Zong C, Tang B, Hua F, et al. Skeletal and dentoalveolar changes in the transverse dimension using microimplant-assisted rapid palatal expansion (MARPE) appliances. Seminars Orthod 2019; 25:46-59.
49. Nojima LI, Nojima MCG, Cunha AC, et al. Mini-implant selection protocol applied to MARPE. Dental Press J Orthod 2018; 23:93-101.
50. Celenk-Koca T, Erdinc AE, Hazara S, et al. Evaluation of miniscrew-supported rapid maxillary expansion in adolescents: A prospective randomized clinical trial. Angle Orthod 2018; 88:702-709.
51. Lombardo L, Carlucci A, Maino BG, et al. Class III malocclusion and bilateral cross-bite in an adult patient treated with miniscrew-assisted rapid palatal expander and aligners. Angle Orthod 2018; 88:649–664.
52. Kavand G, Lagravere M, Kula K, et al. Retrospective CBCT analysis of airway volume changes after bone-borne vs tooth-borne rapid maxillary expansion. Angle Orthod 2019; 89:566-574.
53. Storto CJ, Garcez AS, Suzuki H, et al. Assessment of respiratory muscle strength and airflow before and after microimplant-assisted rapid palatal expansion. Angle Orthod 2019; 89:713-720.
54. Oh H, Park J, Lagravere-Vich MO. Comparison of traditional RPE with two types of micro-implant assisted RPE: CBCT study. Seminars Orthod 2019; 25:60-68.
55. Kim SY, Park YC, Lee KJ, et al. Assessment of changes in the nasal airway after nonsurgical miniscrew-assisted

rapid maxillary expansion in young adults. Angle Orthod 2018; 88:435-441.

56. Hourfar J, Kinzinger GSM, Ludwig B, et al. Differential treatment effects of two anchorage systems for rapid maxillary expansion: A retrospective cephalometric study. J Orofac Orthop 2016; 77:314-324.
57. Işeri H, Ozsoy S. Semirapid maxillary expansion–a study of long-term transverse effects in older adolescents and adults. Angle Orthod 2004; 74:71–78.
58. Hur JS, Kim HH, Choi JY, et al. Investigation of the effects of miniscrew-assisted rapid palatal expansion on airflow in the upper airway of an adult patient with obstructive sleep apnea syndrome using computational fluid structure interaction analysis. Korean J Orthod 2017; 47:353-364.
59. Abu Arqub S, Mehta S, Iverson MG, et al. Does Mini Screw Assisted Rapid Palatal Expansion (MARPE) have an influence on airway and breathing in middle-aged children and adolescents? A systematic review. Int Orthod 2021; 19:37-50.
60. Brunetto DP, Moschik CE, Dominguez-Mompell R, et al. Mini-implant assisted rapid palatal expansion (MARPE) effects on adult obstructive sleep apnea (OSA) and quality of life: A multi-center prospective controlled trial. Progress Orthod 2022; 23:3.
61. Huang J, Li C, Jiang J. Facial soft tissue changes after nonsurgical rapid maxillary expansion: A systematic review and meta-analysis. Head Face Med 2018; 14:6.
62. Abedini S, Elkenawy I, Kim E, et al. Three-dimensional soft tissue analysis of the face following micro-implant-supported maxillary skeletal expansion. Prog Orthod 2018; 19:46.