Al-Rafidain Dental Journal, Vol. 24, No. 1, 2024 (248-259)

Al-Rafidain Dental Journal

rden.mosuljournals.com

Impact of Skeletal Expansion on the Soft Tissue of the Mid-face: A Prospective Study.

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Article information

Received: 21 November 2022
Accepted: 21 December 2022
Available online: 10 May 2024

Keywords
Maxillary expansion
Midpalatal suture
Maxillary skeletal expander (MSE)

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Abstract

Aims: The study aimed to assess the midfacial soft and hard tissue changes of males and females following maxillary skeletal expansion in young adults. **Materials and methods:** 24 patients, 11 males, and 13 females (mean age, 19.54 years; between 17 to 27) with maxillary transverse deficiency treated with MSE. CBCT scans taken before and after expansion were used to measure the changes in soft and hard tissue landmarks. Paired t-tests were used for statistical analyses. **Results:** Hard tissue lower interzygomatic distance increased by (3.41mm in males, and 2.97mm in females), intermolar distance increased by (5.84mm in males, and 5.51mm in females), the palatal separation anteriorly was (4.14mm in males, and 3.76mm in females), posteriorly was (3.24 mm in males, and 3.25 mm in females), however nasal width increased by (3.49mm in males, and 3.29mm in females). Soft tissue average lateral movement of the alar curvature points was (2.1mm in males, and 1.98mm in females). the nasolabial fold width was (3.54mm in males, and 2.55mm in females). and interzygomatic width was (2.27mm in males, and 1.85mm in females). **Conclusions:** Maxillary expansion using MSE resulted in an almost parallel expansion with significant lateral movements of the soft tissues of the cheek and alar curvature points on both sides in young adults and it was correlated with the hard tissue changes.

تأثير توسيع الهيكل العظمى على الأنسجة الرخوة فى منتصف الوجه: دراسة مستقبلية

الملخص

الأهداف: هدفت الدراسة إلى تقييم تغيرات الأنسجة الرخوة والصلبة في منتصف الوجه بين الذكور والإناث بعد توسيع الهيكل العظمي للفك العلوي عند الشباب. **المواد وطرائق العمل**: 24 مريضا، 11 ذكور، 13 إناث (متوسط العمر، 19.54 سنة؛ الأعمار هي من 17 الى 27) مع عوز عرضي للفك العلوي عولجوا بـ .MSE مع استخدام فحوصات CBCTالتي تم إجراؤها قبل وبعد التوسيع لقياس التغييرات في معالم الأنسجة الرخوة والصلبة. التحليلات الإحصائية باستخدام اختبارات t المزدوجة. **النتائج**: زادت المسافة السفلية للأنسجة الصلبة للعظم الوجني بمقدار (3.41 ملم ذكر، 2.97 ملم أنثى)، زادت المسافة بين الاضراس بمقدار (5.84 ملم ذكر، 5.51 ملم أنثى)، كان مقدار الانفصال الحنكي في الأمام (4.14 ملم ذكر، 3.76 ملم إناث)، في الخلف كان (ذكر 3.24 ملم، 3.25 ملم أنثى)، إلا أن عرض الأنف زاد بمقدار (ذكر 3.49 ملم، 3.29 ملم أنثى). بلغ متوسط الحركة الجانبية لنقاط الانحناء الانفية (2.1 ملم ذكر، 1.98 ملم أنثى). كان ازدياد عرض الطية الأنفية الشفوية (3.54 ملم ذكر، 2.55 ملم أنثى). وكان ازدياد العرض بين الوجنتين (2.27 ملم ذكر، 1.85 ملم أنثى). **الاستنتاجات**: أدى توسيع الفك العلوي باستخدام MSE إلى توسع متوازي تقريبًا مع حركات جانبية ملحوظة للأنسجة الرخوة للخد ونقاط الانحناء العلوية على كلا الجانبين عند البالغين الصغار وكانت مرتبطاً بكمية الفتح في الفك العلوي.

DOI: 10.33899/RDENJ.2022.137001.1180, © Authors, 2024, College of Dentistry, University of Mosul

INTRODUCTION

In daily orthodontic practice, the maxillary transverse deficit is a common issue [1]. The maxillary mandibular transverse disparity can be corrected using a variety of therapeutic approaches. Orthodontic braces, orthopedic non-surgery, and surgical correction are available as treatments. Rapid palatal expansion (RPE) is traditionally used by orthodontists to treat transverse maxillary deficiency in young patients. However, after puberty, interlocking of the palatal suture can have unintended side effects, including dental tipping and alveolar bone bending, which limit skeletal movement and lead to poor long-term stability [2]. Surgically assisted rapid palatal expansion (SARPE), is frequently used on older patients, nevertheless, surgical morbidity should be taken into account. SARPE also involves expensive and complicated treatment procedures. To minimize unpleasant side effects and complexity, orthodontists invented mini-implant-assisted rapid palatal expansion (MARPE) in recent years [3].

The maxillary skeletal expander (MSE), a specific type of MARPE, became a treatment choice for transverse maxillary deficient patients, especially in adult patients as it has four mini-implants placed in the palate and nasal cortical bones [4] in the posterior part of the maxilla between the zygomatic buttress bones these are unique characteristics that define the MSE from other types of MARPE. Generally speaking, tooth-borne expanders result in a V-shaped expansion with larger apertures in the front region [5]. But MSE, on the other hand, can increase the posterior expansion [6]. Cone beam computerized tomography (CBCT) technology with computer software has made it possible to accurately examine the craniofacial complex and its alterations through the reconstruction of the skull and the development of multiplane views for the precise assessment of changes to both hard and soft tissues [3]. The current study aimed to assess the midfacial soft and hard tissue changes brought by the use of MSE in young adults, using CBCT scan, and analyse the zygomaticomaxillary modifications, with separate results for males and females.

MATERIALS AND METHODS

This prospective study was performed at the University of Duhok, College of Dentistry. The pre and 3-week post-expansion CBCT scans were obtained from 24 adult patients (11 males, and 13 females) with a mean age of 19.54 years, ranging from (17 to 27). The sample size was calculated using a statistical power of 80% and a level of significance of 5%, for detecting an effect size of 0.62 between pairs, using an online sample size calculator (https://statulator.com/SampleSize/ss2PM.html).

All selected patients were treated with maxillary skeletal expander type 2 (MSE II) (Biomaterials Korea, Seoul, Korea). **All patients were treated at the dental clinic of the College of Dentistry, after obtaining consent from the patient, and the Research ethics committee (approval code:10112021-11-15, on 10 Nov. 2021)**. The inclusion criteria were the following: 1. An Adult who presents with inter-palatal molar width less than 35 mm, then the case is identified as constricted maxillary arch [7 & 8], with one or more of the clinical signs of transverse maxillary deficiency such as dental crossbite, moderate to severely crowded teeth [9], accompanied with clinical nasal constriction as the patient has narrowing of nasal nostrils and mouth breathing: 2. No previous tonsillar, nasal, adenoid, head, or neck surgery, and no craniofacial deformity with the absence of any previous mid-facial trauma; 3. No previous orthodontic treatment; 4. The patient needs treatment with a maxillary skeletal expander (MSE II) as part of the overall treatment plan. The exclusion criteria were the following; 1. Failure to open the mid-palatal suture post-expansion; 2. Pregnant patients to avoid pain and stress from expansion and the radiation dose of CBCT.

The materials and instruments used

The Maxillary skeletal expander type 2 (MSE II) device as shown in Figure 1, it has a jackscrew unit, 8 mm maximum opening capacity, with four parallel holes (1.8mm in diameter) for mini-implant insertion and two soft supporting arms on each side which are soldered to the molar bands for stabilizing the device during insertion and further support during the expansion the device came with Four mini implants (1.8mm in diameter, 11mm or 13mm in length) were inserted through the palatal bone, bi-cortically using special mandrill, also the appliance slots work as a surgical guide. The chosen length of the mini-implants depended on the palatal depth and palatal bone thickness. The body of MSE II is positioned between the first maxillary molars on the mid-palatal suture at the zygomatic buttress bone level, Figure (1) [10].

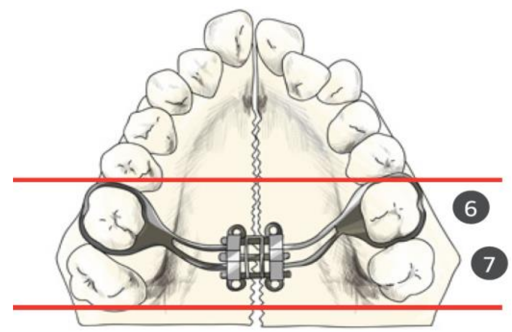

Figure 1: The body of Mid-facial skeletal expander type II is positioned between the first maxillary molars on the mid palatal suture at the zygomatic buttress bone level.

An X-ray machine (KAVO: OP3D Pro) was used for all patients, with a 13x15cm field of view, with a standard voxel size of 0.5 mm. The CBCT scan time is 18 seconds with 90 kV. We use an automated exposure control system to detect the patient's anatomic density and adjust the mill amperes accordingly [11].

The CBCT scans were obtained before and after 3 weeks of the expansion. The rate of expansion as the manufacturer's instruction for the adult patient is 4 activation turns per day (0.13 mm per turn) until a diastema appears then the expansion rate become 2 activation turns per day. The activation continued until around 60 activation turns [10], Figure (2).

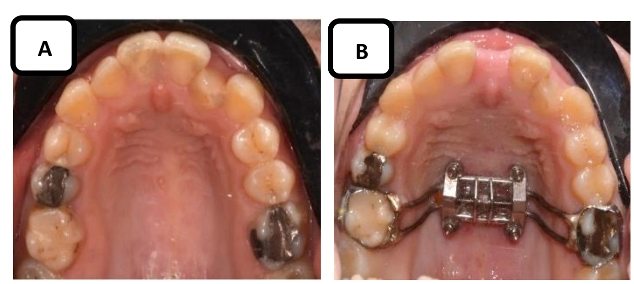

Figure 2: A MSE fixation, B after 3 weeks of the expansion.

Methods of Measurements

Evaluation of the midface's skeletal alterations

The head orientation was established using the Frankfurt horizontal plane (sagittal view), midsagittal plane (axial view), and coronal plane (coronal view) for the analysis. A multiplanar reconstruction was used to measure the dimensions. 0.5-mm slice thickness to assess the transverse changes Skeletal linear measurements included the upper interzygomatic distance, which is the distance between the most external points of the right and left frontozygomatic sutures, and the lower interzygomatic distance, which is the distance between the most external points of the right and left zygomaticomaxillary sutures Figure (3) [12].

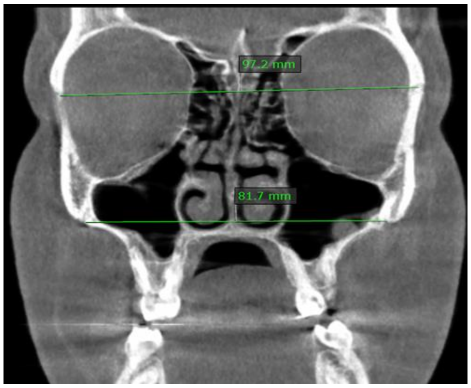

Figure 3: Upper interzygomatic distance (UID) and lower interzygomatic distance (LID) were measured in the coronal zygomatic portion of slice 147.

The axial view showed the exact amount of skeletal expansion by determining the distance of mid-palatal suture separation at anterior nasal supine (ANS) and posterior nasal supine (PNS) after rapid palatal expansion using the MSE II device as seen in Figure (4) [8].

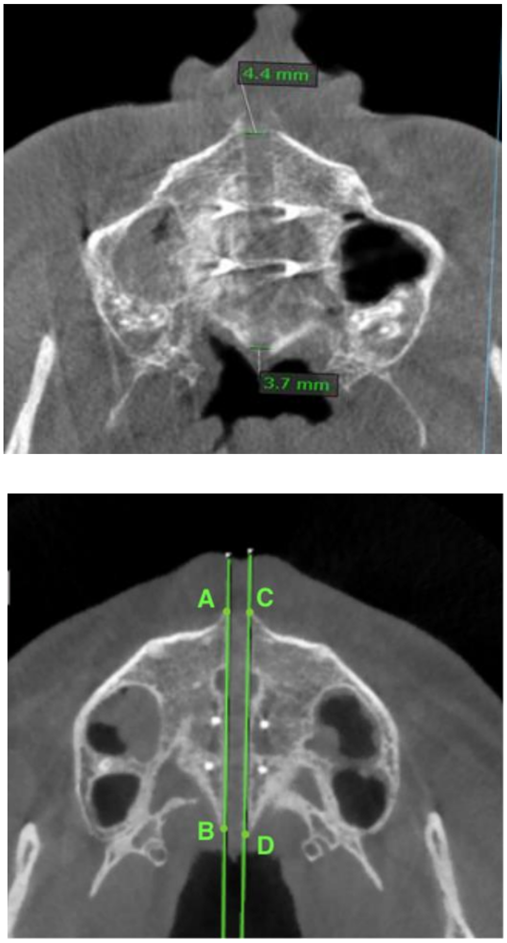

Figure 4: On axial slice 170 the anterior and posterior mid-palatal suture separation at anterior nasal supine and posterior nasal supine after rapid palatal expansion using the MSE II device.

The 3D reconstruction model of the skull was used to determine the anterior inter-maxillary distance and the nasal width at the widest point of the nasal cavity opening as shown in Figure (5) and all the landmarks are in Table (1) below.

Patients in this study answered a questionnaire to offer a subjective evaluation of nasal breathing improvements.

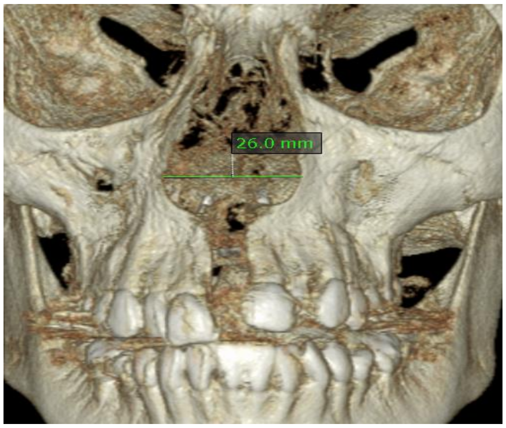

Figure 5: On 3D reconstruction skeletal linear measurements: the anterior inter-maxillary distance and nasal width at the widest point of nasal opening.

Table 1: Description of Measurements of Skeletal landmark.

Measurement	Landmark
Inter molar distant	The distance between mesio-palatal cusp tips of right and left maxillary first molar.
Palatal separation Anterior and Posterior	The expansion of the mid palatal suture at the anterior nasal spine and posterior nasal spine.
Interzygomatic distant Upper and Lower	The distance between the left and right zigmatico-frontal suture. Distance between left and right zygomaticomaxillary suture.
Nasal width	The nasal cavity opening width at it is the widest point.

Evaluation of the midface's soft tissue alterations

The following points on the soft tissue of the face were chosen as landmarks for linear measurements to detect any changes that occurred in the midfacial complex post-expansion: The inner intercanthal width, the outer intercanthal width, the interzygomatic width, the alar curvature point, the alar base point, and the nasolabial folds. These measurements are shown and defined in Table (2) and Figure (6). The landmarks were measured in millimeters on CBCT scans using OnDemand 3D Dental Viewer software [8].

Table 2: Description of measurements of soft tissue landmarks.

Number	Measurement	Landmark
1	Inner intercanthal width	From the right and left lateral canthus of eyes.
2	Outer intercanthal width	From the right and left medial canthus of eyes.
3	Interzygomatic width	At the level of the ala of the nose extending from right to left at the corner of the face at most anterolateral points.
4	Alar curvature point width	The point is located at the most lateral in the curved line of each ala towards the cheek.
5	Alar base point width	The point is located at the facial insertion of the alar base.
6	Nasolabial fold	Creases in the skin extend from both sides of the nose to the corners of the mouth.

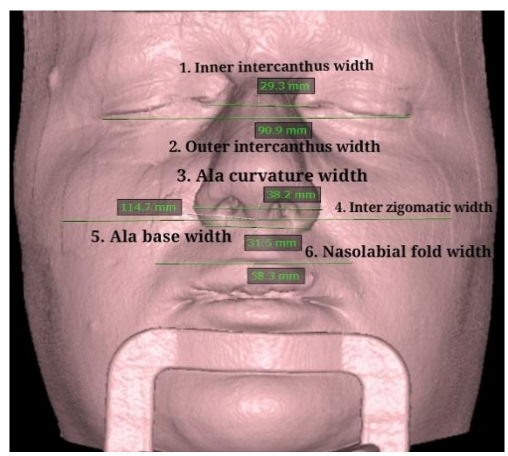

Figure 6: Soft tissue linear measurements in this study; 1. the inner canthus width is 29.3 mm, 2. the outer canthus width is 90.9mm, 3. Alar curvature points 38.2 mm (right and left), 4. the interzygomatic width is 114.7 mm. 5. Alar base point width 31.5 mm (right and left), 6. The nasolabial fold width is 58.3 mm.

Reliability tests

1- For the intraexaminer reliability in this study, the examiner re-analysed ten randomly selected measurements within a 2-week interval for each patient and the difference was non-significant for all measurements (using paired t-test, all *p*-values > 0.05). Two examiners performed all the measurements (the researcher and a radiology specialist), to determine the interexaminer reliability. All sample measurements and landmarks have been checked by a radiology specialist.

2- The accuracy of 3D landmark position on CBCT scans: To determine the accuracy of 3D landmark position on CBCT scans, the same examiner reanalyzes ten randomly selected landmarks in the 3D manner (X, Y, Z) using the ITK-SNAP software package within a 2-weeks interval for each patient to determine the 3D landmarking accuracy error, the mean of the mean difference between the landmark position was 0.804 slice. Paired t-tests to determine the *P*–value difference between the measurements, were statistically not significant for all measurements (all *p*-values > 0.05), except the molar tip at the apex of the left palatal root on the Z slice was slightly significant (*P*-value 0.049).

Statistical analysis

Comparisons of the changes in hard and soft tissue in each of the sexes were made using paired t-tests. *P*-values ≤ 0.05 were considered statistically significant. All statistical analyses were performed using Microsoft excel software, version 2013 (Microsoft campus, Redmond, Washington, USA).

RESULTS

The results of this study showed considerable changes in different parts of the craniofacial skeletal, dental, and soft tissue structures, following the maxillary skeletal expansion using MSE in both genders. The result of the questionnaire involved in this research showed an 87.5 % improvement in the airway and nasal breathing after the expansion. The results of the CBCT assessment could be summarized in the following points.

Cone beam computed tomography skeletal changes after expansion

The midfacial skeletal different changes between gender after maxillary skeletal expansion using MSE as shown in the CBCT scans with male and female different results are listed below.

All of the males said that their airway and nasal breathing improved after the expansion. The intermolar width increased by 5.845 mm, while the midpalatal separation was 4.145 mm at the anterior nasal supine and 3.245 mm at the posterior nasal spine. However, the nasal cavity width increased by 3.49 mm. The interzygomatic width also increased by 0.52 mm at the upper but 3.41 mm at the lower. All of the changes were statistically significant, as Table (3) shows. Seventy-seven percent of females said that their airway and nasal breathing improved after the expansion. The intermolar width increased by 5.51 mm while the midpalatal separation was 3.76 mm at the anterior nasal supine and 3.25 mm at the posterior nasal spine. However, the nasal cavity width increased by 3.29 mm. The interzygomatic width also increased by 0.69 mm at the upper but 2.97 mm at the lower. All of the changes were statistically significant, as Table (4) shows.

Table 3: Hard tissue changes of males after maxillary skeletal expansion using paired t-test.

Hard tissue landmarks			Mean	SD	*P*-value	Difference	%
Nasal width		Before	22.86mm	1.88	7.20749E-08**	3.49mm	15.27%
		After	26.35mm	1.99			
Interzygomatic width	Upper	Before	95.92mm	2.9	0.006781029**	0.52mm	0.54%
		After	96.44mm	3.06			
	Lower	Before	85.16mm	3.31	4.53128E-07**	3.41mm	4.00%
		After	88.57mm	2.90			
Palatal separation	Anterior	Before	0mm	0.56	2.65486E-10**	4.145mm	
		After	4.145mm				
	Posterior	Before	0mm	0.56	5.76522E-09**	3.245mm	
		After	3.245mm				
Inter molar distant		Before	37.863mm	3.89	9.54501E-08**	5.845mm	15.44%
		After	43.709mm	3.75			

* Significant at p≤0.05 ** Highly Significant at p≤0.01.

Table 4: Hard tissue changes of females after maxillary skeletal expansion, using paired t-test.

Hard tissue landmarks			Mean	SD	*P*-value	Difference	%
Nasal width		Before	23.15mm	1.60	1.01765E-07**	3.29mm	14.22%
		After	26.44mm	1.55			
Interzygomatic width	Upper	Before	92.44mm	2.88	0.00010414**	0.69mm	0.75%
		After	93.13mm	2.88			
	Lower	Before	82.95mm	3.17	7.30329E-09**	2.97mm	3.58%
		After	85.92mm	3.41			
Palatal separation	Anterior	Before	3.76mm	1.18	7.96844E-08**	3.76mm	
	Posterior	Before	3.25mm	1.08	1.52517E-07**	3.25mm	
Intermolar distance width		Before	35.98mm	4.34	5.24338E-07**	5.51mm	15.33%
		After	41.49mm	3.85			

* Significant at p≤0.05 ** Highly Significant at p≤0.01.

Changes at the Soft tissue level:

The CBCT scans of the males' midfacial soft tissue after maxillary skeletal expansion showed that the Alar curvature point width increased by 2.1 mm and the alar base point width increased by 2.53 mm. However, the inner intercanthus width increased by 0.64 mm, while the outer intercanthus width was reduced by 0.32 mm. Also, the interzygomatic width increased by 2.27 mm. All changes were significant, except the outer intercanthus width, as Table (5) shows.

Table 5: Male soft tissue changes after maxillary skeletal expansion using paired t-test.

Landmarks soft tissue		Mean	SD	*P*-value	Difference	%
Alar curvature point width	Before	36.39mm	2.40	0.00058953**	2.1mm	5.77%
	After	38.49mm	2.99			
Alar base point width	Before	30.12mm	2.32	0.00095358**	2.53mm	8.4%
	After	32.65mm	2.91			
Inner intercanthus width	Before	31.69mm	3.06	0.003348783**	0.64mm	2.01%
	After	32.33mm	3.03			
Outer intercanthus width	before	92.62mm	2.93	0.60878534	-0.32mm	-0.34%
	After	92.3mm	2.57			
Nasolabial fold width	Before	66.13mm	3.63	3.18516E-06**	3.54mm	5.35%
	After	69.66mm	3.89			
Interzygomatic width	Before	109.86mm	9.25	6.21405E-06**	2.27mm	2.07%
	After	112.14mm	9.38			

* Significant at $p \leq 0.05$ ** Highly Significant at $p \leq 0.01$.

The CBCT scans of the females' midfacial soft tissue after maxillary skeletal expansion showed the alar curvature point width increased by 1.98 mm and the alar base point width increased by 2.44 mm. However, the inner intercanthus width increased by 0.35 mm, while the outer intercanthus width reduced by 0.07 mm. While the nasolabial fold width increased by 2.55 mm, also the interzygomatic width increased by 1.85 mm. All of the changes were significant except the inner intercanthus width and outer intercanthus width, as Table (6) showed.

Table 6: Female soft tissue changes after maxillary skeletal expansion using paired t-test

Landmarks soft tissue		Mean	SD	*P*-value	Difference	%
Alar curvature point width	Before	34.77mm	2.51	8.84356E-06**	1.98mm	5.69%
	After	36.75mm	2.25			
Alar base point width	Before	28.23mm	2.55	3.335E-03**	2.44mm	8.64%
	After	30.67mm	2.28			
Inner intercanthus width	Before	31.71mm	2.61	0.09278455	0.35mm	1.12%
	After	32.06mm	2.92			
Outer intercanthus width	before	92.14mm	5.08	0.73798645	0.07mm	0.08%
	After	92.21mm	5.09			
Nasolabial fold width	Before	61.02mm	3.79	1.07259E-08**	2.55mm	4.17%
	After	63.57mm	3.43			
Interzygomatic width	Before	110.16mm	7.13	4.32358E-05**	1.85mm	1.68%
	After	112.02mm	6.96			

* Significant at $p \leq 0.05$ ** Highly Significant at $p \leq 0.01$.

DISCUSSION

In this study, there was an average of 3.17 mm increase in the lower interzygomatic distance. According to clinical research, zygomatic bone lateral displacements caused by tooth-borne expanders are insignificant, as the Haas appliance causes increases in bizygomatic width of 0.4 and 0.3mm in early-treated patients [(13)]. Due to the differing force delivery involved in the 2 types of appliances. When using tooth-borne expanders, some of the force generated by the jackscrew is lost in the buccal dentoalveolar tipping of the supporting teeth [(14)], but with MARPE, the force is transmitted directly to the maxilla, creating a pressure that can laterally displace the zygomatic bone. The zygomatic bone tends to rotate around the weaker frontozygomatic suture with a pyramidal expansion pattern as the upper interzygomatic distance rose by 0.59mm, indicating the underlying maxilla is pushing the zygomatic bone laterally. This significant zygomatic bone displacement suggests that MARPE can provide more midfacial orthopedic change [(12)].

The zygomaticomaxillary complex's rotational movement may be the cause of the molar crowns' greater movement as compared to the jackscrew activation. Because of points farther from the rotating fulcrum (such as molar crowns) experience more linear movements than points closer to the fulcrum (such as maxillary basal bone) for the same amount of angular rotation [(12)]. This rotational movement may account for the disparity between the increase in intermolar distance (5.67 mm) and the amount of maxillary expansion (3.38mm).

According to this study's results, all patients who used MARPE had their midpalatal sutures effectively separated. About 82.49% of the ANS's mean separation was present at the PNS. The ANS had 3.94 mm, and the PNS had 3.25 mm of bone separation at the midpalatal suture caused by the MSE in this study, despite the fact that suture interdigitation gets stronger during the teenage stage, it was found that the midpalatal suture's opening angle was extremely near to 0° (0.81°), indicating that the suture practically divided parallel to the palatal ridge [(15)]. In most cases, patients used MSE had palatal suture opening angles of less than 1°. Referring to the data published by Oh, expansion by a MARPE caused a substantially larger suture opening than the conventional RPE [(11)].

For many years, a variety of research articles discussed maxillary expansion procedures and their beneficial impact on nasal breathing. After employing the MSE in this investigation, the nasal cavity width was enlarged by 3.38 mm. In 1961, Haas described the effect of RME in opening the midpalatal suture and dislodging the nasal cavity walls laterally and away from the nasal septum after using the Haas appliance on patients under the age of 16 years. Alveolar processes tilt laterally, and the free edges of the horizontal palatal process are moved inferiorly, expanding the floor of the nasal cavity. The intranasal area and dimensions would rise as a result [(16)]. According to research on patients aged 11 years, RME treatment increased the mean nasal cavity width by 2.2 mm over the long term when compared to the control group [(17)]. This result may lessen nasal airway resistance (NAR) [(16)]. The questionnaires revealed that more than 87.5% of patients who undergo maxillary expansion experience better nasal breathing [18].

The soft tissue change was similar to hard tissue displacement in the lateral directions following RPE this result has also been seen in a prior study that used 3D face scanning [19]. In contrast to a prior study, the significant rise in soft tissue nasal width seen in this investigation was consistent in a 71% ratio with the increases in skeletal width [20] this could be the result of soft tissue compression. But the nasolabial fold width increased by 3.07 mm more than another soft tissue landmark because the soft tissue in this area is thin and highly reflects the amount of alveolar bone expansion [8]. Even if 3D face pictures or CBCT are quickly recorded, it found that due to eyelid movement, there may be alterations in the soft tissues surrounding the eye which may lead to changes in intercanthal width [21].

The rise in nasal width and nasolabial fold width following expansion was the study's most clinically important finding. In this study, nasal base width increased by (mean: 2.42 mm) and nasal width (mean: 2.07 mm) while the nasolabial fold width increased by (mean: 3 mm) all showed statistically significant increases. Alar width following RME increased on average by 1.34 mm according to Pangrazio-Kulbersch *et al*. in 2012 [22], which is consistent with our findings. Johnson *et al*. in 2010 observed that nasal base and alar cartilage width changed by less than 1.5 mm using direct measurements with an average of 7 mm of appliance expansion [23].

This gap may be caused by the age differences between research samples, the factor of development age, and the ethnic group studied leading to different outcomes from the same therapy as the soft tissue alterations may be influenced by other factors in addition to the size and direction of the skeletal movement, such as the tonicity of the surrounding muscles and tissues, skin elasticity, face type, and weight change. As a result, some patients may have an improvement while others would experience a decline in the facial aesthetic.

CONCLUSIONS

The MSE produced skeletal maxillary expansion with a nearly parallel expansion of the midpalatal suture. Maxillary intermolar, and palatal width increased in the short term after expansion. The midfacial soft tissue landmarks, specifically the cheek and alar curvature points on both sides, were displaced in the lateral directions following expansion.

Significant changes in the nasal width and mid-facial region were found after RPE. So, patients with narrow and constrained noses may benefit from these soft-tissue changes.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript

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