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Evaluation of skeletal changes after mini-implant assisted rapid maxillary expansion in young adults: CBCT study

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Abstract
Objectives: to evaluate the skeletal alterations in young adult patients with maxillary transverse deficiency by maxillary skeletal expander (MSE) appliance, using Cone Beam Computed Tomography (CBCT).
Methods: Twenty-four patients (12 females and 12 males) with transverse maxillary deficiency were treated with the MSE II (Biomaterials Korea, Inc., Seoul, Korea). Their ages ranged from 17 to 22 years, The MSE II device consists of a central expansion screw welded to four tubes that acted as guides for the mini-implants. The mini-implants have a diameter of 1.8 mm and a length of 13 mm. The appliance activation varied according to the patient's chronological age. CBCT scans were captured before treatment (T_1) and immediately post-expansion (T_2). Measurements were performed to evaluate the skeletal expansion.
Results: within the limits of this study, the mid-palatal suture was separated successfully in 21 of the patients there is a highzly significant between measurements before and after the expansion treatment. The change of nasal cavity width (N-N) was also significantly different before and after expansion treatment by miniscrew-assisted rated perceived exertion (MARPE), however, the study shows there is no significant difference between males and females in the result for measurements after expansion.
Conclusion: MARPE appliances, such as the MSE II, can be used to manage transverse maxillary deficiency in young adult patients.

Keywords: CBCT, MARPE, skeletal expansion, transverse maxillary deficiency

Introduction
Maxillary transverse deficiency, which is observed in 21% of children and 10% of adults, is a common orthodontic finding [1]. Rated perceived exertion (RPE) is a successful orthodontic technique for expanding the maxilla and correcting the transverse discrepancy in children. The mid-palatal suture is disrupted and separated when a rapid transverse force is applied to the maxillary teeth. This increased cellular activity causes bone remodelling along the sutural areas [2]. The response to palatal expansion by RPE is less effective in adults because of the maturity of the midpalatal sutures and resistance from the zygomatic buttress. The response to palatal expansion by RPE is less effective in adults because of the maturity of the midpalatal sutures and resistance from the zygomatic buttress the widening of the maxillary width results from alveolar bone bending and dental tipping in adult patients [3]. The RPE can cause unwanted side effects including arch expansion failure, bone dehiscence, root resorption, marginal bone loss, and inability to produce complete skeletal expansion in adults [4].
Surgically assisted rated perceived exertion (SARPE) is a therapeutic method that helps to overcome greater resistance from the bony plates and zygomatic buttress in adults [5]. Nevertheless, SARPE has been documented to have several limitations, including surgical morbidity, high cost, and periodontal problems [6].
Adults with maxillary constriction are now able to be treated using miniscrew-assisted rated perceived exertion (MARPE) appliances, which can localize lateral forces to the midpalatal suture by utilizing mini-implants for anchorage.[7] A bone-borne expander that is entirely skeletally attached and without alveolar and dental side effects has been used to achieve pure skeletal expansion in adults [8].

Interesting research contrasted a traditional tooth-anchored RPE with a surgically assisted, bone-anchored RPE. It was determined that the RPE that is bone-anchored results in greater skeletal than dentoalveolar changes [9].

These devices have been reported to create a more skeletal expansion, resulting in less alveolar/dental tipping, while also providing more stability increasing the skeletal expansion through skeletal anchorage enhancement by engaging both the palatal and nasal cortices, Simultaneously, a support wire connected to the maxillary first molars improves the stability. This is a relatively new concept, and such expanders are known as maxillary skeleton expanders maxillary skeletal expander (MSE) [10].

The MSE is a MARPE appliance design that has been reported in the literature since 2014 [11-13]. In recent years, there have been several studies on the use and success of MSE in adult patients. Cantarella describes the zygomaticomaxillary complex moving downward and outward in the coronal plane, with the fulcrum located slightly above the frontozygomatic suture [14]. This pilot study aimed to evaluate the skeletal alterations in young adult patients with maxillary transverse deficiency by (MSE) appliance, using Cone Bean Computed Tomography (CBCT).

Materials and Methods

A total of 24 patients were enrolled in this prospective, uncontrolled intervention study were collected from the Department of Orthodontics at Al-Ramadi specialist dental center in Anbar City/Iraq (12 females and 12 males). All the patients had transverse maxillary deficiency when they were diagnosed by an orthodontist in a specialist dental center and all of them would undergo maxillary expansion by MARPE between April 2022 and February 2023. CBCT images were captured before treatment (T_1) and immediately after maxillary expansion (T_2). In both (T_1) and (T_2), the same CBCT device and technician were used.

The inclusion criteria: The inclusion criteria include

1. Young adult patient ages ranged from 17 to 22 years (males and females)
2. Maxillary transverse deficiency depends on Andrews's analysis of six elements.[15]
3. Absence of craniofacial syndromes.
4. No prior orthodontic treatment.

The excluded criteria

1. Patient with cleft lip and palate.
2. Patient with developmental deformity.
3. Patients with co-existence of medical comorbidities such as congestive heart disease, pulmonary disease, and neurological disorders.
4. Patient with a history of nasal surgery.

Appliance design

The expansion device that was used is MSE type II (Bio Materials, Korea) as shown in Figure 1. The MSE appliance consists of a central expansion jackscrew which is available in three sizes (8mm,10mm, 12mm), and four arms soldered to orthodontic bands on the anchor teeth to facilitate it placing the appliance in position. Also has four parallel holes welded to the jackscrew (1.8 mm in diameter) These holes serve as guides for the placement of the mini-implants these 4 mini-implants were Ø1.8 mm in diameter and 13 mm in length. The longer mini-implant to enabling bicortical engagement between the palatal and nasal floor also, to reduce the force transferred to the anchored teeth during an expansion (OAS-$T_1$511, Biomaterials Korea Inc.) [12].

Fig 1: The MSE II appliance consists of (1) Ratchet Wrench Driver, (2) an MSE expander, (3) Mini Hand Driver, (4) Short Engine Blade (Shaft), (5) Micro Implant (M.I.), (6) Activation Key, (7) Safety Leashes.

CBCT machine

The cone beam computed tomography apparatus used was Vatech i3D Co., Ltd, Korea. The scanning was at single jaw used for all patients at 90 kV, 10mA, with voxel size 0.5mm, and the exposure time was 10 seconds. The software used for picture capture was (Acquisition Interface), which was built and developed, especially for the Vatech i3D.

The treatment procedure and laboratory Fabrication

First visit: A thorough explanation of the procedures to the patient, including all detailed information and technical limitations, and a reminder that the procedure may fail. Separator elastics are placed on the permanent maxillary first.

On the second visit: the separators were removed, and bands were put on the first molars. A traditional alginate transfer impression was made, and regular plaster was poured. Separator elastics were placed back on the molars. Also, Oral hygiene improvement.

Laboratory procedures: At first, choosing the appropriate size of MSE II (8, 10, or 12 mm) based on the width of the palate, the maximum size that could be accommodated in the palatal vault while still allowing for close adaptation to the surface of the tissue was used to determine the size of the expander that was used. The appliance was placed between the maxillary first molars, this position allowed lateral force against the pterygomaxillary buttress bone which is the major resistance during a skeletal maxillary expansion.[16] The lateral arms were formed to match the curve of the palatal shelves and soldered to molar bands. The central jackscrew expander was tight with the palate and the arm that supports it had 2 mm away from the side wall of the palate then finishing and polishing [12].

Third visit: Separators are removed, topical anaesthetics are placed on the palate, the appliance is cemented by GIC

(Takayama, Japan), and the vertical position in relation to the palate is checked. Local infiltrative anesthesia, self-drilling mini implant placement using a manual ratchet key for precise assessment of torque levels (Biomaterials Korea®, Seoul, South Korea), Before beginning the activation protocol, a CBCT was performed (T_1), instructions about hygiene and activation, prescription of analgesic drug of choice for two days (optional), and no need for an antibiotic if the patient has good general health (Figure 2).

Fig 2: (A) Before and (B) After 3 weeks of expansion, the mid-palatal suture has opened successfully and diastema appears.

CBCT image: Prior begun with activation each patient was asked to take CBCT (T_1) Image acquisition. The patient stood inside the CBCT unit and bit on the bite block presented with the machine, which was also covered by new, clear protective sheaths. The head position is adjusted from the positioning panel such that the region of interest is centered in the beam (the patient midline will coincide with the machine midline). The head of the patient was stabilized with head and chin rest in position so that the Frankfort horizontal plane (which is the plane coinciding with the highest point of the external auditory canal to the lowest point of the lower margin of the orbit) is parallel to the floor. After that adjustment, the required field of view by the technician from acquisition interference software (upper jaw 5*5 cm, parameters were selected of 90 Kv,10 mA and exposure time 10 sec.)

The patient has been told that the machine would rotate during the scan, and this is a normal thing.

Activation protocol: The activation protocol varied depending on the patient's chronological age, as recommended by Lee *et al*. (2017) [13], (Table 1).

Table 1: Activation protocol according to chronological age as recommended by Prof. Won Moon

Early teens	**6X/week (0.80 mm /week**
Late teens	2X /day (0.27 mm/day)
Early to mid-20's	4~6 X /day (0.53 ~ 0.80 mm /day)
Older	Min. 4~6X /day
After Diastema	2X /day (0.27 mm/day)
* 6 Turns = 0.8mm (1 revolution)	

CBCT analysis

The CBCT images were analyzed by using the Ez3D-i-3D software program. To decrease measurement errors resulting from nonstandard head positions, all images were oriented using a standardized procedure. The horizontal axis parallels the palatal plane (Anterior Nasal Spine-Posterior Nasal Spine), as seen in Figure (3A), and the vertical axis was aligned parallel to the nasal septum, as shown in Figure (3B). The angle of slicing would be changed as a result [17]. Landmarks for evaluation are tabulated in Table 2.

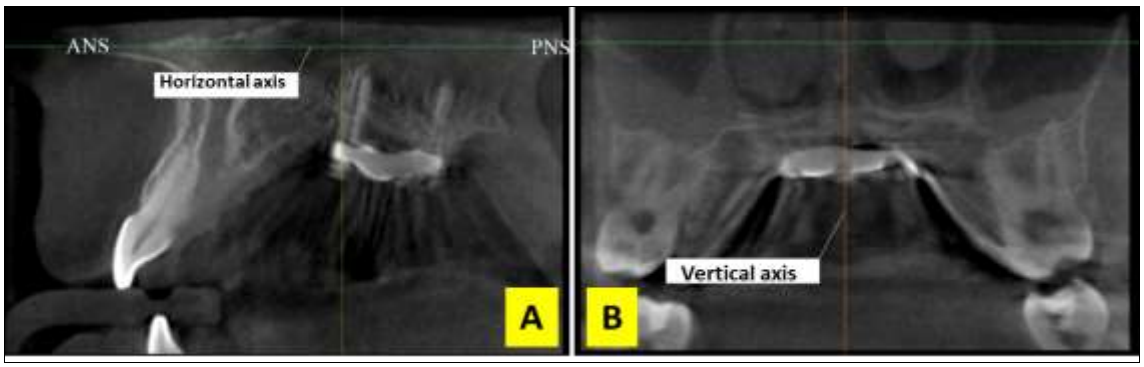

Fig 3: CBCT images of the tested model (A) Axial cross-section shows (Ai) (DPSA)Distance of mid-palatal suture separation before expansion, (Aii) (DPSA) Distance of mid-palatal suture separation after expansion.(B) coronal cross-section shows (Bi) Distance between N-N before expansion. (Bii) Distance between N-N after expansion.

CBCT measurement

Distance of mid-palatal suture separation: One horizontal slice in the axial cross-section plane was selected for measurement when the mid-palatal suture was clearly visible. An extended distance was measured anteriorly and posteriorly between the left and right micro-implants in this slice, as shown in Figure (4A). The value is considered to represent a real skeleton horizontal expansion. The anterior and posterior extended distances were similar for the most of subjects. As a consequence, it is possible to consider the mid-palatal suture's expansion pattern as parallel or somewhat "V" shaped.[18]

Distance between landmark nasal cavity width (N-N): The landmark N represents the lateral most border of the nasal cavity in the coronal slice as shown in Figure (4B).[19]

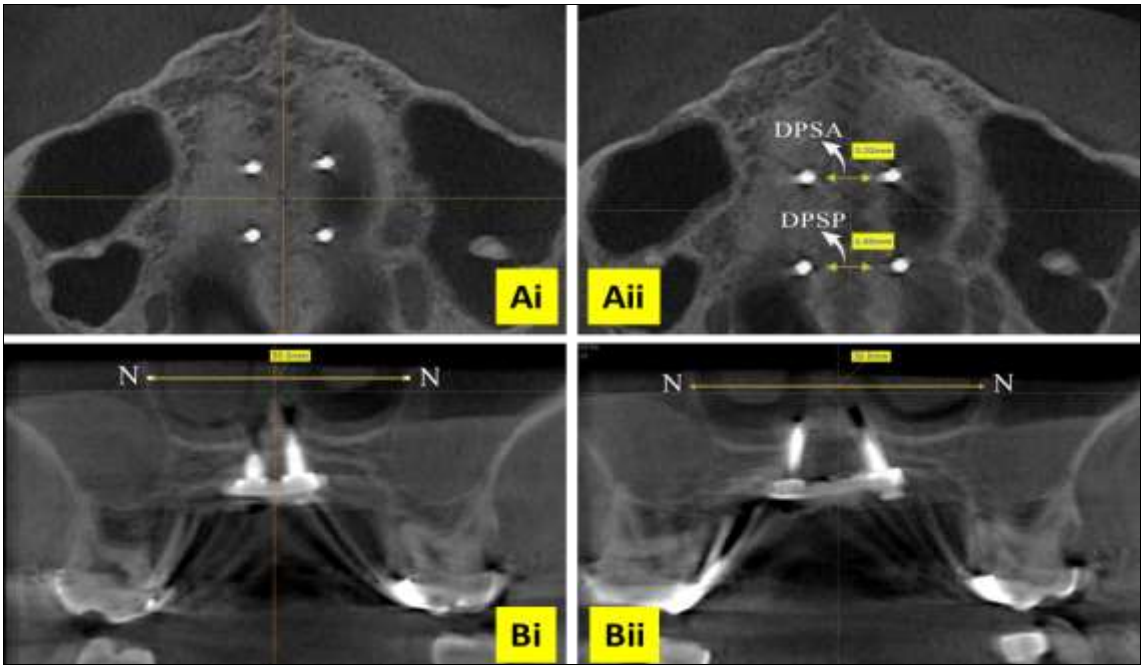

Fig 4: comparison between measured parameters, comparison between DPSA before and after treatment, comparison between DPSP before and after treatment, comparison between N-N before and after treatment.

Reliability of Measurement: Intra-examiner reliability was tested by comparing all measurements for 5 patients recorded from the first examination with the second examination repeated after 2 weeks by the researcher himself.

After that, the method error was tested statistically by using the intraclass correlation coefficient as shown in Table (3), which was .0.95 for all variables measured in this study.

Statistical analysis: All measurements were tabulated in groups, and the statistical analysis was performed using the SPSS software program (version 20, SPSS Inc., Chicago, IL, USA)

1. Shapiro-Wilk test proved that the data was normally distributed.
2. Descriptive statistical analysis for all measurements (Before & After).
3. Paired sample t-test was used to compare all the measurements before and After.

Table 2: Landmarks Evaluation in CBCT and its Description:

Landmark	Description
ANS	Anterior Nasal Spine
PNS	Posterior Nasal Spine
DPSA	Distance of mid-Palatal suture Separation Anteriorly
DPSP	Distance of mid-Palatal suture Separation Posteriorly
N	Lateral most border of the nasal cavity
N-N	Nasal cavity width

Table 3: Intra-examiner reliability by using Intraclass correlation coefficient test.

	Before (T_1)	**After (T_2)**
	Interclass correlation	Interclass correlation
DPSA	0	0.960
DPSP	0	0.985
N-N	0.969	0.965
Intraclass correlation (ICC) for intra-examiner reliability shows that all Skeletal and dental measurements before and after were greater than 0.99 (95% CI). This means an absolute difference in all measurements before and after treatment.		

Results

Among 24 patients treated by MARPE in the present study, three of them were excluded from the study as two patients exhibited failure of the opening of the midpalatal suture, and one of them suffer from severe inflammation around the mini-implant due to poor oral hygiene.

The Test of Normality Distribution for the Data: The normality test for all measurements (DPSA, DPSP, N-N) before and after treatment is performed and shown in Table (4).

The Descriptive statistic for the data: The descriptive statistic for all measurements (DPSA, DPSP, N-N) before and after treatment is performed and shown in Table (5). The Comparison Between the Before and the After for all data: The comparison between the before and after for all measurements by using paired samples t-test is shown in Table (6, 7, 8) and Figures (5).

Table 4: The Tests of Normality for all measurements (DPSA, DPSP, N-N) before and after treatment

Test	Paired Test	Sample	Statistic	df	p value
DPSA	Before	Male	0.001	11	.
		Female	0.001	10	.
	After	Male	0.244	11	0.066
		Female	0.257	10	0.061
DPSP	Before	Male	0.001	11	.
		Female	0.001	10	.
	After	Male	0.203	11	0.148
		Female	0.209	10	0.128
N-N	Before	Male	0.121	11	0.200
		Female	0.176	10	0.200
	After	Male	0.219	11	0.211
		Female	0.185	10	0.200

Table 5: The Descriptive statistic for all the data (DPSA, DPSP, N-N) before and after

Test	Paired Test	N	Minimum	Maximum	Mean	SE
DPS A	Before	21	0.001	0.001	0.0001	0.00001
	After	21	0.001	4.34	3.0876	1.14684
DPS P	Before	21	0.001	.00	0.0000	0.000001
	After	21	0.001	4.37	3.0857	1.14428
N-N	Before	21	31	38.20	34.2429	1.75971
	After	21	32.80	41.10	36.9095	2.12389

Table 6: The Comparison Between Before & After for all the measurements (Mean, N, SD, and SE)

		Mean	N	SD	SE
DPSA	Before	0.0001	21	0.00001	0.00001
	After	3.0876	21	1.14684	0.25026
DPSP	Before	0.0001	21	0.00000	0.00001
	After	3.0857	21	1.14428	0.2497
N-N	Before	34.2429	21	1.75971	0.384
	After	36.9095	21	2.12389	0.46347

Table 7: the correlation between all measurements (DPSA, DPSB, N-N) before and after treatment

		N	Correlation	Sig.
DPSA	Before & After	21	.	.
DPSP	Before & After	21	.	.
N-N	Before & After	21	0.851	0.0001**
** Highly Significant at P ≤ 0.01.				

Table 8: Paired sample test for the measurements (DPSA, DPSP, N-N)

		Paired Differences			t	P value
		Mean	95% CI			
			Lower	Upper		
DPSA	Before & After	-3.087	-3.609	-2.565	12.338	0.0001**
DPSP	Before & After	-3.085	-3.606	-2.564	12.358	0.0001**
N-N	Before & After	-2.666	-3.175	-2.157	10.933	0.0001**
** Highly Significant at P ≤ 0.01						

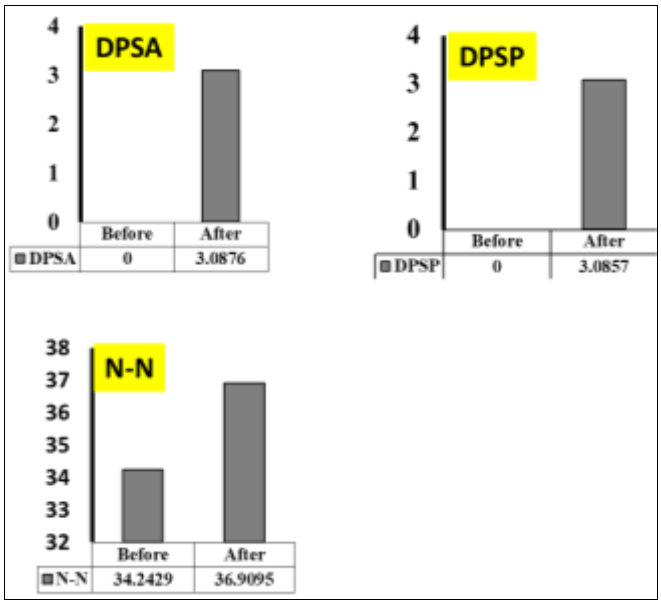

Fig 5: Comparison between measured parameters, comparison between DPSA before and after treatment, comparison between DPSP before and after treatment, comparison between N-N before and after treatment.

Discussion

Distance of mid-palatal suture separation: According to the results of this study, mini-implant-assisted rapid palatal expansion (MARPE) can successfully separate the midpalatal suture and correct maxillary transverse discrepancies in young adult patients. The horizontal slice of CBCT showed that the mean extended distance of the mid-palatal suture was 3.09±1.25 mm. The authors of previous studies on MARPE agree with this conclusion [20, 21] however, the opening of the midpalatal suture in our study showed successful maxillary expansion in 21 patients.

Previously, the authors believed that expansion treatment applied before the pubertal growth peak would result in the greater skeletal separation of both maxillary components [22]. Our study has shown that MARPE successfully provides skeletal expansion of the maxilla in post-pubertal patients compared to the outcomes of previous reports on the use of conventional RPE in younger patients. Obtaining maxillary skeletal expansion without surgical intervention in these types of patients was previously considered to be impossible or would lead to serious problems [23,, 24].

Distance between landmarks N-N

In the current study, The MSE appliance caused the significant orthopaedic separation of the mid-palatal sutures. In this study found a substantial difference in pre-treatment and immediately post-treatment N-N. These findings agree with prior research by Smith *et al.* (2012), Kavand *et al.* (2019), and Yi *et al.* (2020), who have observed a considerable increase in nasopharyngeal volume (8.48%) in recent research [25-27]. With regard to the effects of Traditional RME have been shown in studies to expand the nasal cavity's width and volume [28, 29]. The N-N increased following MARPE treatment with a significant statistical difference. According to Clement & Krishnaswamy N-N increased by 2.6mm with MARPE therapy [30] which is comparable to our results Tausche *et al.* (2009), who have studied the changes in nasal volume after surgical-assisted RPE and found that the greatest percent change happened anteriorly at the level of the nasal floor, which corresponded to the "V"-shaped opening of the mid-palatal suture. Since the soft-tissue anatomy is closely related to the skeletal structure, it is expected that the pattern of nasal expansion is correlated with a form of the mid-palatal suture opening. With a tendency toward more parallel sutural separating with the mini-screw-assisted expansion jackscrew,[5] this study supported the hypothesis that the nasal cavity separation tended to be more parallel too.

Conclusion

The MARPE is a clinically successful technique for treating transverse maxillary discrepancies in young adult patients through the separation of the midpalatal suture. There were statistically significant improvements in nasal cavity width and improved breathing after expansion (T_2).

Conflict of Interest

Not available

Financial Support

Not available

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