https://doi.org/10.48047/AFJBS.6.12.2024.6245-6260

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Nasal Changes of Monocortical Versus Bicortical Miniscrews Assisted Palatal Expansion

Badr Abdelghani[1], Wael M. Refai[2], Kareem M. Mohamed[3]

[1] Research fellow, Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Minia University, Egypt

[2] Professor of Orthodontics, Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Minia University, Egypt

[3] Associate professor of orthodontics, Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Minia University, Egypt

Corresponding author: Badr Abdelghani

Email: Badrabdelghani902@gmail.com

Article History

Volume 6, Issue 12, 2024

Received:25 June 2024

Accepted: 4August 2024

doi:

10.48047/AFJBS.6.12.2024.6245-6260

Abstract:

Objectives: To evaluate nasal changes of monocortical versus bicortical miniscrews assisted palatal Expansion (MARPE) by Cone Beam Computed Tomography.

Materials and Methods: The sample included 20 Patients (10 patients for each group) were randomly assigned to either group from the outpatient clinic of Department of Orthodontics, Faculty of Dentistry, Minia University. This prospective clinical trial formed of two groups, the 1st group was bicortical MARPE were the miniscrews used penetrated both nasal and palatal cortices and the 2nd group the miniscrews only penetrated the palatal cortex. Each patient did pre-expansion CBCT (T1) and post CBCT (T2) after expansion, time period T1 to T2 was 3 months. Soft tissue alar width, nasal height, nasal length (Sn-Pn). Skeletal pyriform height (PHT), Posterior nasal cavity width, nasal floor width and nasal septal deviation angle were evaluated.

Results: The bi-cortical group was associated with significantly larger increase in AW (mean increase: 2mm vs. 1.4mm; p-value: <0.001), larger increase in PNCW (mean increase: 2.4mm vs. 1.5mm; p-value: <0.001), and larger increase in NF (median increase: 5.3mm vs. 3mm; p-value: <0.001). Additionally, the decrease in NSDA was significantly smaller in the bi-cortical group (median decrease: -1.5 °vs. -0.3°; p-value: <0.001).

Conclusion: Both bi and monocortical expansions led to a significant increase in alar width and nasal floor in the short term with more increase in the bicortical group. Posterior nasal cavity width increased significantly in bicortical group. Nasal septal angle decreased significantly after expansion in bicortical group.

Keywords:Nasal changes, Skeletal expansion, crossbite

1. Introduction

Transverse discrepancy of the maxilla is common problem encountered in population and results in posterior crossbite development either unilaterally or bilaterally. [19]In all age groups, from primary to permanent dentition, maxillary transverse narrowing is a relatively prevalent malocclusion. It can progress to a more complex malocclusion if not treated in a timely manner, affecting the growth and development of the face. With the accompanying nasal constriction, the deficit can also result in airway issues in addition to the occlusal effects.[6]

Adolescent orthodontic patients with transverse maxillary constriction are usually treated with rapid palatal expansion (RPE), which corrects the posterior crossbite but Rapid palatal expansion (MARPE) with a mini-screw gives more effective alternative to traditional RPE. Mini-implants are used to anchor the MARPE appliance to the palatal bone, as opposed to a tooth-borne expander that was used in the RPE design.[3,10]

The enormous separation forces produced during rapid maxillary expansion are transferred to palatine shelves with the help of temporary skeletal anchorage devices like (mini-screws), which are fixed to the palatal bones resulting in fewer dental complications. When the palatal suture is interdigitated and the maxilla achieves its adult size, as in the case of adolescent or adult patients who require maxillary expansion, this is regarded to be of special interest.[15]

The effect of MARPE and traditional RPE has been assessed in different studies skeletally and dentally as well.[22,32] In order to produce stronger orthopedic effects and more parallel expansion in the coronal plane, Won Moon suggested adopting bicortical mini-implant anchoring. [9]

The mini-implants to enter either the monocortically or the bicortically extending to nasal cortex was not studied enough. In terms of expansion aided by mini-implants, the issue needs to be recognized that whether single or double cortical anchorage affect the same way the nasal structures.

Cone-beam computed tomography (CBCT) provides a clear minimally-distorted image of bone structures and enables imaging at comparatively low radiation dosages.[24] Thus, quantitative three-dimensional (3D) changes in the maxillofacial complex following MARPE can be precisely evaluated by CBCT, beside changes in dental and alveolus previously studied in literatures. The effects of MARPE on the nasal cavity structures associated with expansion appliances were also assessed in literature.[4,25,31]

From all the previously mentioned, the study of the nasal changes of monocortical versus bicortical miniscrews assisted expansion was found to be a point of worthy investigation. Accordingly, this study will be conducted to highlight this aim.

MATERIALS AND METHODS

This prospective randomized clinical trial was approved by ethical committee of faculty of dentistry MINIA University. 20 Patients (12 females and 8 males) with age 14-21 were recruited from the Outpatient Clinic of Department of Orthodontics, Faculty of Dentistry Minia University and randomly assigned into two groups; 10 in each group the bicortical hybrid expander group and the monocortical hybrid expander group.

Standard informed consent was signed by patients or their guardians. All steps were explained to the patients prior to any procedure. The inclusion criteria were constricted maxilla with posterior cross-bite either unilateral or bilateral, no history of previous orthodontic treatment, free from systemic diseases and syndromes. All patients were in adolescences or young adults.

Both groups were treated by miniscrew supported hyrax expander. The miniscrews were planned to be either bicortical supported anchorage (1^{st} group) or monocortical (2^{nd} group). The mono cortical means that miniscrews penetrated only the palatal cortical bone and the bicortical means that miniscrews penetrated the both palatal and nasal cortices.

For all patients who underwent maxillary expansion, a pre-insertion CBCT scan was obtained (T1). A second CBCT (T2) was required after the expansion.

To reach the desired miniscrew position in terms of cortical penetration. This was guided by digitally designed surgical guides. Intraoral scans were superimposed with the initial CBCT with the aid blue sky bio software *(Blue sky plan version 4.9.4 software, by BlueSky bio. LLC).* (Fig 1)

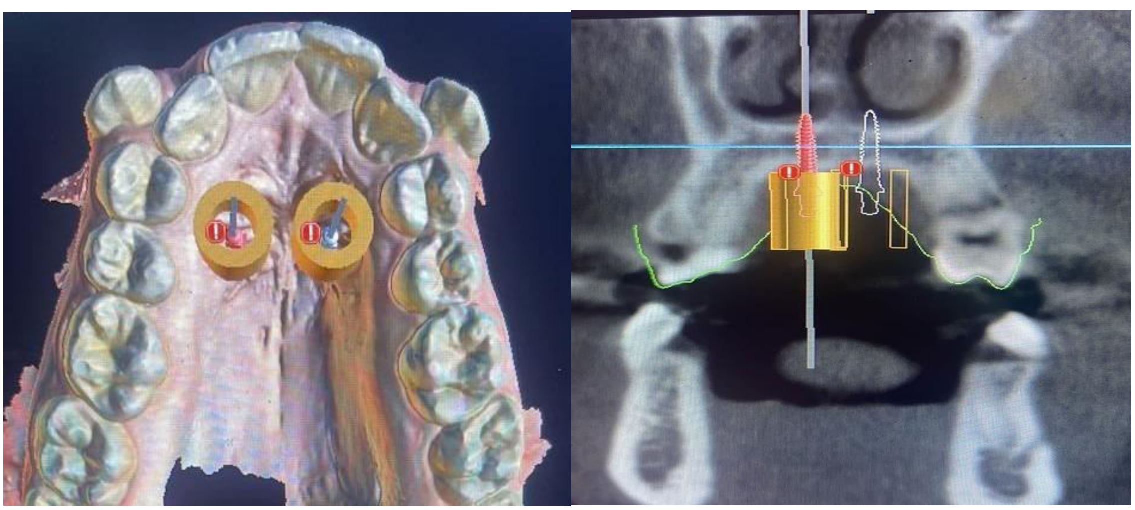


Figure 1. Guide planning for Miniscrews with BlueSky bio software

All digital planning had the objective of gaining either bicorticalism or monocorticalism according to the group that patient randomly assigned in, thus could choose the corresponding correct miniscrew length. Miniscrews used in the present study varied between 8 mm and 10 mm in length, while the diameter was 1.6 mm for all patients *(Tomas® temporary anchorage system, DENTAURUM Gmbh&Co, Germany).* The screws were designed to be placed in the premolar area lateral to the midpalatal sutures. For each patient, insertion guides were designed and then printed *(3D SG guide resin SENERTEK, TURKEY)*, including 2 sleeves allowing the insertion of miniscrews. Following an oral rinse with chlorhexidine gluconate, a preliminary guide fitting assessment was carried out, and local anesthetic was then administered in accordance with the palatal insertion sites. All the miniscrew placement site were preceded by pilot drill used for decortication. Miniscrews were inserted with a low-speed handpiece. (Fig 2).

Figure 2. Digital planned guide used for miniscrews insertion.

After the guide removal, in order to set he hybrid expander in its desired position 2 Transfer caps *(Dentaurum Tomas transfer cap)* were placed over the miniscrew heads, bands selected and fitted onto the upper first permanent molars and impressions of the upper jaw and palate were taken using a rubber base impression material. The whole assembly (impression + caps) was sent to the dental lab to construct the hybrid appliance were the abutments *(Dentaurum Tomas abutments)* were soldered to the hyrax and then to be fitted in its place in patient's mouth. The hybrid expander used for the study includes 2 miniscrew abutments that fit to miniscrew installed, 2 bands on the first molars. (Fig 3).

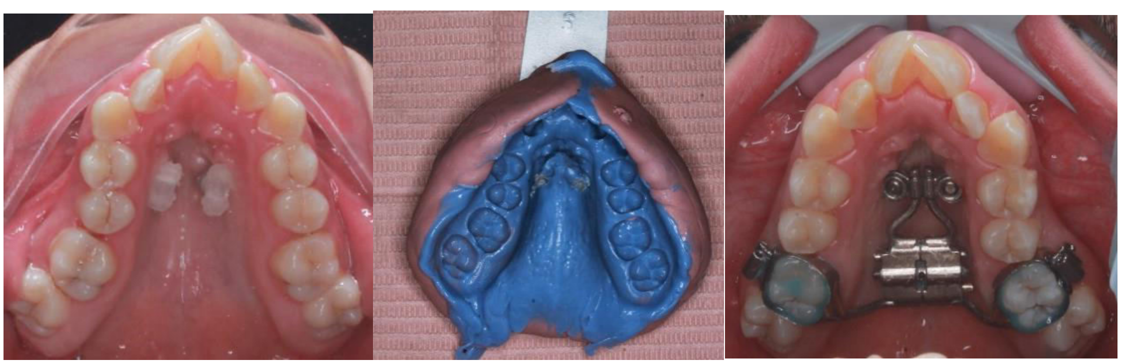


Figure 3. Hybrid MARPE customization and fitting

The activation protocol of the expansion appliance was two turns per day (0.25 mm twice daily, 0.5 mm per day) until posterior crossbite correction was achieved. After expansion completed close the screw appliance with resin to prevent rewinding. (Fig 4).

Figure 4. After expansion

All CBCT scans were taken with the same machine *(Scanora® 3Dx (soredex, Helsinki, Finland)* pre and post expansion with 90 kvp, 10 mA, and a field of view (FOV) of 180×165 mm 0.3 mm. The initial CBCT was recorded at pre-treatment (T1). The second CBCT was recorded at post expansion after 3 months after the initial CBCT in (T2). The patients or their guardians were informed about radiation exposure with CBCT. The potential risks from radiation exposure with recorded CBCT were minimal. The radiation dosage of CBCT scans could be as low as 50 µSv and this is much lower than the yearly limit of different radiation.[12]

Parameters

The CBCTs were reconstructed by Planmeca Romexis *(V6.4.2.49, Finland)* and were oriented in a standardized manner. From the frontal and lateral perspectives, orientation was finished in three spatial planes. Fig 5.

The inferior orbital rims were positioned equally and parallel to the floor from the frontal. The soft tissue nasion, the pronasale, and the middle of the chin were all considered to be the locations of the midsagittal line. The inferior border of the orbital rim to porion as the Frankfort horizontal line, was parallel to the floor when viewed from the side views. The coronal line was positioned directly behind the condyle. [33]The landmarks were measured on the CBCTs in three dimensions with the use Romexis Imaging. They are shown and defined in Tables 1 and 2 and Figures 6,7.8

Nasal soft tissue height (NHT), nasal length (NL), pyriform height (PHT), and alar width (AW). Changes in nasal septal deviation angle (NSDA) were measured as well, changes of posterior nasal cavity width (PNCW) and nasal floor (NF) were also evaluated. One investigator performed all measurements. The same investigator analysed ten randomly selected CBCTs after 2 weeks for intrarater reliability and another one for interrater reliability.

Table 1. Definition of Soft and Hard Tissue Landmarks

Landmark	**Description**
Soft tissue landmarks	
Alar point	The most lateral point on contour of the nostril
Nasion a (Na)	The soft tissue nasion on the anterior soft tissue aspect of frontonasal suture
Pronasale (Pn)	Most anterior point of the nose soft tissue down the midsagittal plane
Subnasale (Sn)	The intersection point between the base of the nose and upper lip in the midsagittal plane
Hard tissue landmarks	
Nasion	Most anterior aspect of the frontonasal suture
Superior pyriform aperture (SPA)	Most superior point of the bony anterior limitation of the nasal skeletal down the midsagittal plane
Inferior pyriform aperture (IPA)	Most inferior point of the bony anterior limitation of the nasal skeletal down the midsagittal plane
Posterior pyriform aperture (PPA)	The lateral most point on the pyriform aperture identified on the coronal slice passing through the furcation of maxillary right first molar either left or right

Table 2. Description of Measurements

Parameter	Description
Nasal height (NH)	The measurement of the distance from soft tissue nasion to subnasale
Nasal length (NL)	The measurement of the distance from pronasale to subnasale
Alar width (AW)	Alar width right–alar width left
Pyriform height (PHT)	Superior pyriform aperture–inferior pyriform aperture
Posterior nasal cavity width (PNCW)	The width of nasal cavity measured on the coronal slice passing through the furcation of maxillary right first molar from LPPA to RPPA
Nasal floor (NF)	Indicates the maxillary width tangent to the nasal floor at its most inferior level.
Nasal septal deviation angle (NSDA)	The angle between the line drawn from maxillary spine to crista-galli and another line from crista-galli to the apex of septal deviation

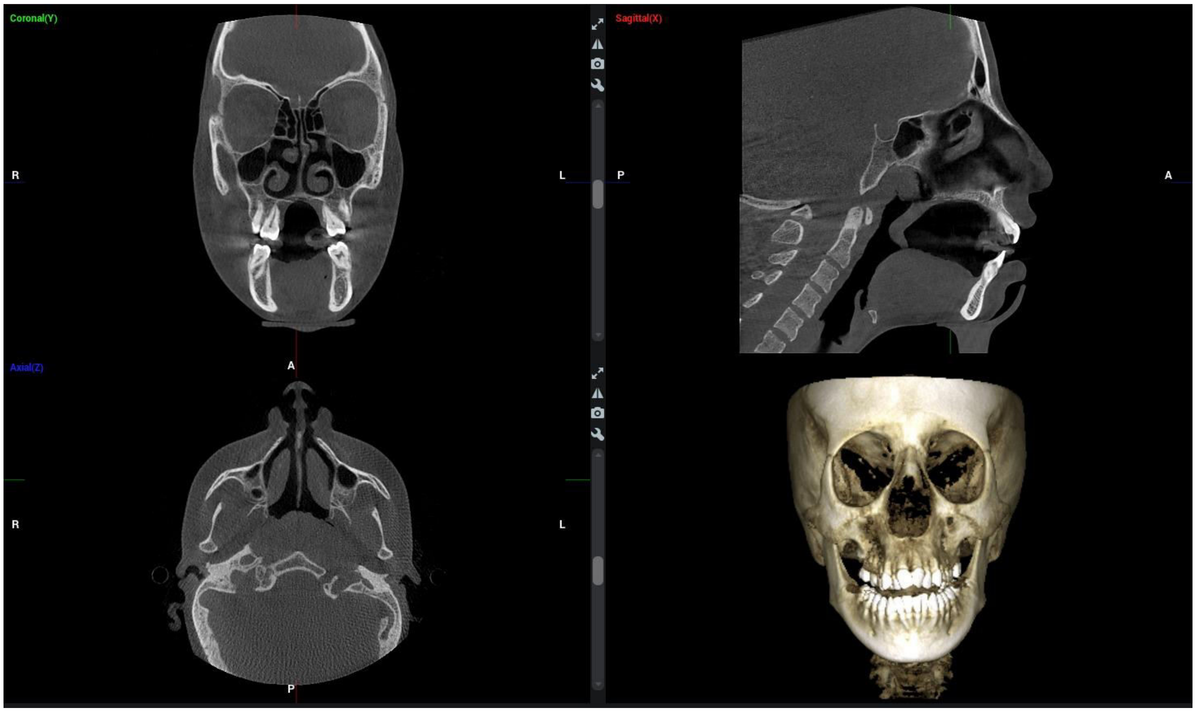
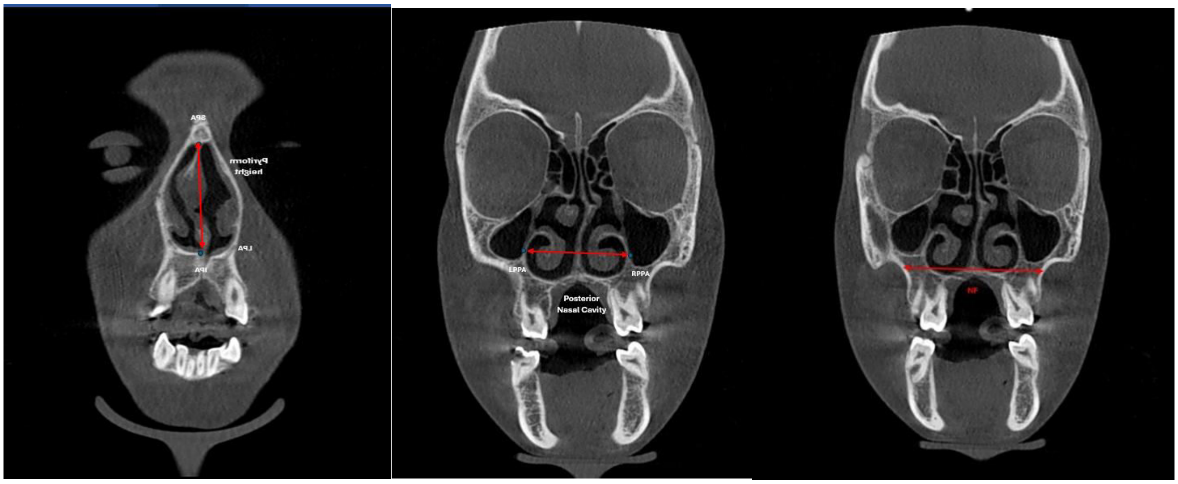


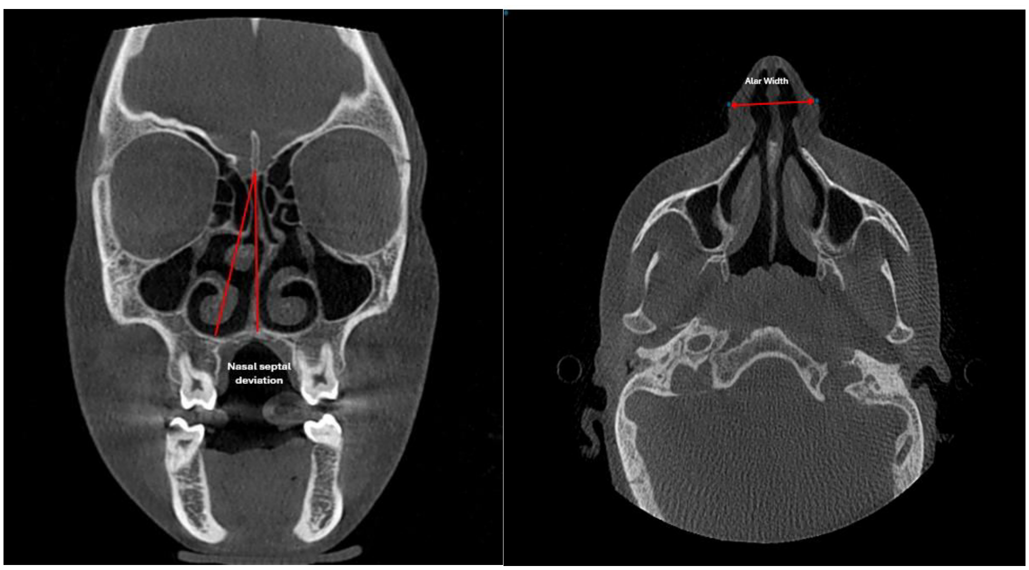
Figure 5. Orientation of CBCT

Figure 6. Landmarks: Na, soft tissue nasion; Pn, pronasale; Sn, subnasale. Parameters: nasal height, nasal length



(A) (B) (C)

Figure 7. Landmarks: A) Landmarks: SPA, superior pyriform aperture; IPA, inferior pyriform aperture; Parameter: pyriform height. (B) Landmarks: LPPA, left posterior pyriform aperture; RPPA, right posterior pyriform aperture. Parameters: posterior nasal cavity width. (C) Nasal floor.



(A) (B)

Figure 8. (A) Nasal septal deviation angle. (B) Alar width

Statistical Analysis

Categorical variables were shown in counts and frequencies, while numerical variables were described mean and standard deviation (SD), or median and inter-quartile range (IQR), depending on the distribution of each variable. Comparisons were made using the Chi-square test of independence (for categorical variables) and the two-sample t-test (for numerical variables).

Non-parametric alternatives were utilized when indicated. A significance level (α) of 0.05 was set to determine statistical significance. The statistical analysis was strictly bound to pre-specified study protocol and no p-value adjustment was required. Data handling and statistical analysis was done using the R programming language for statistical computing version 4.2.1.*(R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/*

Results

Table 3:*Descriptive statistics of the pre-operative measurements per group (n: 20).*

Among Bi-cortical group			
Term	**Avg (SD)**	**Median (IQR)**	**Range: Min-Max**
Alar width (AW) pre	32.74 (1.22)	32.73 (0.84)	30.7 - 34.47
Nasal height soft tissue (N-Sn) pre	48.91 (1.62)	49.37 (1.88)	45.85 - 50.57
Nasal length (Sn-Pn) pre	19.96 (1.35)	19.84 (1.83)	17.83 - 22.02
Pyriform height (PHT) pre	38.54 (1.24)	38.49 (1.78)	36.65 - 40.31
Posterior nasal cavity width (PNCW) pre	28.81 (1.66)	28.47 (1.74)	27.02 - 32.34
Nasal floor Width (NF) pre	57.52 (1.61)	57.94 (2.29)	55.11 - 59.8
Nasal septal deviation angle (NSDA) pre	14.19 (0.67)	14.11 (0.87)	13.42 - 15.42
Among Mono-cortical group			
Term	**Avg (SD)**	**Median (IQR)**	**Range: Min-Max**
Alar width (AW) pre	30.78 (0.63)	30.84 (0.34)	29.5 - 31.85
Nasal height soft tissue (N-Sn) pre	50.32 (2.2)	50.7 (1.84)	46.61 - 53.35
nasal length (Sn-Pn) pre	20.85 (1.23)	20.63 (1.13)	19.64 - 23.83
Pyriform height (PHT) pre	40.81 (1.91)	41.12 (2.4)	37.08 - 43.31
Posterior nasal cavity width (PNCW) pre	29.05 (2.18)	29.82 (3.61)	25.93 - 32.03
Nasal floor Width (NF) pre	57.48 (2.1)	57.52 (3.18)	54.11 - 60.16
Nasal septal deviation angle (NSDA) pre	14.02 (0.68)	14.18 (1.13)	12.91 - 14.8

Table 4:*Descriptive statistics of the post-operative measurements per group (n: 20).*

Among Bi-cortical group			
Term	**Avg (SD)**	**Median (IQR)**	**Range: Min-Max**
Alar width (AW) post	34.74 (1.2)	34.83 (1.07)	32.64 - 36.19
Nasal height soft tissue (N-Sn) post	49.18 (1.63)	49.65 (1.94)	46.16 - 50.87
nasal length (Sn-Pn) post	20.25 (1.35)	20.22 (1.91)	18.06 - 22.23
Pyriform height (PHT) post	38.84 (1.23)	38.73 (1.74)	37.01 - 40.6
Posterior nasal cavity width (PNCW) post	31.16 (1.71)	30.98 (1.99)	29.43 - 34.51
Nasal floor Width (NF) post	62.82 (1.58)	63.41 (2.14)	60.32 – 65
Nasal septal deviation angle (NSDA) post	12.69 (0.74)	12.57 (0.61)	11.74 - 14.42

Among Mono-cortical group			
Term	**Avg (SD)**	**Median (IQR)**	**Range: Min-Max**
Alar width (AW) post	32.15 (0.83)	32.32 (0.74)	30.5 - 33.44
Nasal height soft tissue (N-Sn) post	50.59 (2.19)	51.01 (1.8)	46.95 - 53.55
nasal length (Sn-Pn) post	21.17 (1.29)	20.85 (1.32)	19.79 - 24.25
Pyriform height (PHT) post	41.16 (1.9)	41.44 (2.4)	37.47 - 43.64
Posterior nasal cavity width (PNCW) post	30.54 (2.04)	31.12 (3.48)	27.66 - 33.5
Nasal floor Width (NF) post	60.48 (2.04)	60.07 (3.01)	57.44 - 64.16
Nasal septal deviation angle (NSDA) post	13.71 (0.68)	13.95 (1.06)	12.53 - 14.49

Table 5:*Comparing pre- and post-intervention measurements among the bi-cortical group (n: 10).*

Among bi-cortical group			
Term	**Pre**	**Post**	**p-value**
Alar width (AW)	32.7 (1.2)	34.7 (1.2)	**t: 0.0017****
Nasal height soft tissue (N-Sn)	49.4 (1.9)	49.6 (1.9)	U: 0.5288
nasal length (Sn-Pn)	20 (1.3)	20.2 (1.4)	t: 0.6471
Pyriform height (PHT)	38.5 (1.2)	38.8 (1.2)	t: 0.5923
Posterior nasal cavity width (PNCW)	28.8 (1.7)	31.2 (1.7)	**t: 0.0059****
Nasal floor Width (NF)	57.5 (1.6)	62.8 (1.6)	**t: <0.001*****
Nasal septal deviation angle (NSDA)	14.2 (0.7)	12.7 (0.7)	**t: <0.001*****
α = 0.05. p < 0.05*, p < 0.01, p < 0.001*****			
P-values obtained from two-sample t-test (t) or Mann-Whitney test (U)			

Table 5 shows that, among the bi-cortical group, AW increased significantly from a mean value of 32.7mm to 34.7mm after intervention (p-value: 0.001). Similarly, the PNCW increased from 28.8mm to 31.2mm on average (p-value: 0.005), mean NF increased from 57.5mm to 62.8mm (p-value: <0.001), and NSDA decreased from mean value of 14.2 ° to 12.7°.

Table 6:*Comparing pre- and post-intervention measurements among the mono-cortical group (n: 10).*

Among mono-cortical group			
Term	**Pre**	**Post**	**p-value**
Alar width (AW)	30.8 (0.6)	32.2 (0.8)	**t: <0.001*****
Nasal height soft tissue (N-Sn)	50.3 (2.2)	50.6 (2.2)	t: 0.7830
nasal length (Sn-Pn)	20.6 (1.1)	20.9 (1.3)	U: 0.4813
Pyriform height (PHT)	40.8 (1.9)	41.2 (1.9)	t: 0.6857
Posterior nasal cavity width (PNCW)	29 (2.2)	30.5 (2)	t: 0.1295
Nasal floor Width (NF)	57.5 (2.1)	60.5 (2)	**t: 0.0045****
Nasal septal deviation angle (NSDA)	14 (0.7)	13.7 (0.7)	t: 0.3339
α = 0.05. p < 0.05*, p < 0.01, p < 0.001*****			
P-values obtained from two-sample t-test (t) or Mann-Whitney test (U)			

Table 6 shows that, among the mono-cortical group, significant changes in our measurement between the pre- and post-operative measurements were only noted in AW and NF. Mean AW increased from 30.8mm to 32.2mm (p-value: <0.001) while NF increased from 57.5mm to 60.5mm (p-value: 0.004)

Table 7:*Comparing pre-post difference per group (n: 20).*

Term	Group		p-value
	Bi-cortical	Mono-cortical	
Alar width (AW) difference	2 (0.3)	1.4 (0.3)	**t: <0.001*** **
Nasal height soft tissue (N-Sn) difference	0.3 (0)	0.3 (0.1)	t: 0.9422
nasal length (Sn-Pn) difference	0.3 (0.1)	0.3 (0.1)	t: 0.5115
Pyriform height (PHT) difference	0.3 (0.1)	0.3 (0)	t: 0.0597
Posterior nasal cavity width (PNCW) difference	2.4 (0.4)	1.5 (0.2)	**t: <0.001*** **
Nasal floor Width (NF) difference	5.3 (0.3)	3 (1)	**U: <0.001*** **
Nasal septal deviation angle (NSDA) difference	-1.5 (0.5)	-0.3 (0.1)	**U: <0.001*** **
α = 0.05. p < 0.05*, p < 0.01, p < 0.001*** **			
P-values obtained from two-sample t-test (t) or Mann-Whitney test (U)			

Table 7 compares the difference in the study parameters between the two groups. The bi-cortical group was associated with significantly larger increase in AW (mean increase: 2mm vs. 1.4mm; p-value: <0.001), larger increase in PNCW (mean increase: 2.4mm vs. 1.5mm; p-value: <0.001), and larger increase in NF (median increase: 5.3mm vs. 3mm; p-value: <0.001). Additionally, the decrease in NSDA was significantly smaller in the bi-cortical group (median decrease: -1.5 °vs. -0.3°; p-value: <0.001)

DISCUSSION

The nasal cavity has been shown to be affected by expansion of the maxilla as the close anatomical relationship between nasal and maxillary structures. Past studies discussed the effect of RPE on nasal structures.[4]

Although, a lot of these studies were based on two-dimensional radiographic assessment.[8,11] Being two-dimensional, magnification errors and in ability to give accurate data, caution should be taken when dealing with data of studies. Vast majority of the recent research are three dimensional.[5,16,28,29]

CBCT is that it is a regarded as a trusted technique for assessing changes in the soft tissues of the face as well as the skeletal ones.[20] Our current study also used CBCT in assessment of both soft and hard tissues. There are a small number of literatures on addressing MARPE on the nasal cavity changes.[18]

During the study period, there were significant changes in the skeletal and soft-tissue nasal characteristics. In bicortical group, there was a significant increase in the PNCW and NF from T2 to T1 with higher increase in bicortical than monocortical group in skeletal parameters, the PNCW increased but insignificantly in monocortical group. One possible explanation for these results could be that MARPE generally was associated with a greater degree of skeletal expansion.[7] In agreement with previous work that stated that for better skeletal expansion, mini-implants needed to penetrate the bicortical bone at least.[21] In our study, we found that going bicortical gave more skeletal expansion. The increase in pyriform height in our study was not significant in both groups (Table 7).

Treatment outcomes in soft tissue associated with orthodontics, such as nasal proportions, are thought to have a significant impact on patients' overall macro-aesthetic look.[30] Some authors say that an increased nose width has been shown to have a negative impact on face aesthetics. The soft tissue nasal width is a crucial component of facial aesthetics.[17]

Other’s opinion that it's hard to say how the increase might look to the patient from an aesthetic perspective. The literature lacks threshold values for determining how a layperson would perceive differences in nasal width.[27] AS the same treatment may yield variable outcomes in different people, with one patient experiencing worsening while another has benefits.[23] MARPE was reported to increase soft tissue nasal width in the short term. [25]

In the current study, there was a significant increase in AW with MARPE both bi and monocortical with bicortcal more expressed (Table 7). However, there is need for assessment of changes of AW in the long term. To know if the expansion appliances do not adversely affect aesthetics of the nose in the long term.

When the groups were compared, it was found that the increases in the alar width (AW) were also found in the bi and monocortical groups in the T2 to T1 period at 2 mm and 1.4 mm respectively. No significant changes were found with nasal height and nasal length in both groups.

One essential anatomical component of the nasal assembly is the nasal septum. Variable degrees of nasal obstruction, issues with nasal breathing, and changes in the maxillary sinus volume can all be caused by deviations in the nasal septum.[13] Few studies have mentioned the effects of expansion on the deviation of nasal septum.[2]

The current study showed that there was a significant decrease in the NSDA in in the bi-cortical group with 1.5 degree and there is decrease in monocortical group by .3 degree but not significant. Previous reports showed correction of the deviated nasal septum with RPE and MARPE.[14]

A different study, however, disproved these assertions and found no effect of RPE on the deviated nasal septum.[1] We are still in need for further studies to spot light on nasal septal deviation with different expansion appliance as it still controversial.

Conclusion

Both bi and monocortical expansions led to a significant increase in alar width and nasal floor in the short term with more increase in the bicortical group.

Posterior nasal cavity width increased significantly in bicortical group.

Nasal septal angle decreased significantly after expansion in bicortical group.

References

1. Altug-Atac, A. T., et al. (2010). "Changes in nasal structures following orthopaedic and surgically assisted rapid maxillary expansion." International Journal of Oral and Maxillofacial Surgery**39**(2): 129-135.
2. Aziz, T., et al. (2015). Effect of non-surgical maxillary expansion on the nasal septum deviation: a systematic review. Prog Orthod, Springer Berlin Heidelberg. **16**.
3. Baccetti, T., et al. (2001). Treatment Timing for Rapid Maxillary Expansion. Angle Orthodontist. **71**.
4. Badreddine, F. R., et al. (2018). "Rapid maxillary expansion in mouth breathers: a short-term skeletal and soft-tissue effect on the nose." Braz J Otorhinolaryngol**84**(2): 196-205.
5. Bouserhal, J., et al. (2014). "Three-dimensional changes of the naso-maxillary complex following rapid maxillary expansion." Angle Orthodontist**84**(1): 88-95.
6. Brunetto, D. P., et al. (2017). "Non-surgical treatment of transverse deficiency in adults using microimplant-assisted rapid palatal expansion (MARPE)." Dental Press J Orthod**22**(1): 110-125.
7. Cantarella, D., et al. (2017). "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 Orthod**18**(1).
8. Cappellette, M., et al. (2017). "Skeletal effects of RME in the transverse and vertical dimensions of the nasal cavity in mouth-breathing growing children." Dental Press J Orthod**22**(4): 61-69.
9. Carlson, C., et al. (2016). "Microimplant-assisted rapid palatal expansion appliance to orthopedically correct transverse maxillary deficiency in an adult." American Journal of Orthodontics and Dentofacial Orthopedics**149**: 716-728.
10. Choi, S. H., et al. (2016). "Nonsurgical miniscrew-Assisted rapid maxillary expansion results in acceptable stability in young adults." Angle Orthodontist**86**(5): 713-720.
11. Cross, D. and J. McDonald (2000). "Effect of rapid maxillary expansion on skeletal, dental, and nasal structures: A postero-anterior cephalometric study." European journal of orthodontics**22**: 519-528.
12. Danforth, R., et al. (2003). "3-D Volume Imaging for Dentistry: A New Dimension." Journal of the California Dental Association**31**: 817-823.
13. Flint, P. W. and C. W. Cummings Cummings otolaryngology head & neck surgery.Fifth edition.
14. Gray, L. P. (1975). "Results-of-310-cases-of-rapid-maxillary-expansion-selected-for-medical-reasons." Laryngol otol**89**: 601-614.

15. Hammad, Y. M., et al. (2016). "AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES Rapid maxillary expansion using bone anchored Hybrid Hyrax appliance in adolescent females." Australian Journal of Basic and Applied Sciences**10**(18): 152-161.
16. Haralambidis, A., et al. (2009). "Morphologic changes of the nasal cavity induced by rapid maxillary expansion: A study on 3-dimensional computed tomography models." Am J Orthod Dentofacial Orthop**136**: 815-821.
17. Jagadish Chandra, H., et al. (2012). "Standards of Facial Esthetics: An Anthropometric Study." J Maxillofac Oral Surg**11**(4): 384-389.
18. Kayalar, E., et al. (2019). "Nasal soft- and hard-tissue changes following tooth-borne and hybrid surgically assisted rapid maxillary expansion: A randomized clinical cone-beam computed tomography study." Journal of Cranio-Maxillofacial Surgery**47**(8): 1190-1197.
19. Kutin, G. and R. R. Hawes (1969). "Posterior cross-bites in the deciduous and mixed dentitions." American Journal of Orthodontics**56**(5): 491-504.
20. Lee, K. and M. Perrino (2017). Alar width changes due to surgically-assisted rapid palatal expansion: A meta-analysis. J Orthod Sci, Wolters Kluwer Medknow Publications. **6:** 115-122.
21. Li, N., et al. (2020). "Skeletal effects of monocortical and bicortical mini-implant anchorage on maxillary expansion using cone-beam computed tomography in young adults." American Journal of Orthodontics and Dentofacial Orthopedics**157**(5): 651-661.
22. Lin, L., et al. (2015). "Tooth-borne vs bone-borne rapid maxillary expanders in late adolescence." Angle Orthodontist**85**(2): 253-262.
23. Magnusson, A., et al. (2013). "Three-dimensional computed tomographic analysis of changes to the external features of the nose after surgically assisted rapid maxillary expansion and orthodontic treatment: A prospective longitudinal study." American Journal of Orthodontics and Dentofacial Orthopedics**144**(3): 404-413.
24. Mah, J., et al. (2003). "Radiation absorbed in maxillofacial imaging with a new dental computed tomography device." Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics**96**: 508-513.
25. Mehta, S., et al. (2022). "Long-term assessment of conventional and mini-screw-assisted rapid palatal expansion on the nasal cavity." Angle Orthodontist**93**(2): 315-323.
26. Moura, C., et al. (2005). Rapid maxillary expansion and nasal patency in children with Down syndrome. Rhinology.
27. Nada, R. M., et al. (2013). "Volumetric changes of the nose and nasal airway 2 years after tooth-borne and bone-borne surgically assisted rapid maxillary expansion." Eur J Oral Sci**121**(5): 450-456.
28. Oliveira De Felippe, N. L., et al. (2008). "Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: Short- and long-term effects." American Journal of Orthodontics and Dentofacial Orthopedics**134**(3): 370-382.
29. Pangrazio-Kulbersh, V., et al. (2011). "Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders." Angle Orthod**82**: 448-457.
30. Sarver, D. M. (2015). "Interactions of hard tissues, soft tissues, and growth over time, and their impact on orthodontic diagnosis and treatment planning." American Journal of Orthodontics and Dentofacial Orthopedics**148**(3): 380-386.

31. Timock, A. M., et al. (2011). "Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging." American Journal of Orthodontics and Dentofacial Orthopedics**140**(5): 734-744.
32. Toklu, M. G., et al. (2015). "Periodontal, dentoalveolar, and skeletal effects of tooth-borne and tooth-bone-borne expansion appliances." Am J Orthod Dentofacial Orthop**148 1**: 97-109.
33. Truong, C. T., et al. (2021). "Short-term and long-term effects of rapid maxillary expansion on the nasal soft and hard tissue: A cone beam computed tomography study." Angle Orthodontist**91**(1): 46-53.