ORIGINAL RESEARCH

Skeletal Changes after Miniscrew-assisted Rapid Palatal Expansion in Young Adults: A Cone-beam Computed Tomography Technique Study

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Abstract

Aim: To evaluate the skeletal changes in buccal bone thickness (BBT) and height in subjects treated with miniscrew-assisted rapid palatal expansion (MARPE) using Cone-beam Computed Tomography (CBCT).

Materials and methods: CBCT records of 19 patients (age 18–30 years) were selected from the archives. The scans were taken before and immediately after the completion of expansion treatment using the MARPE appliance. These CBCT scans were calibrated and analyzed. The skeletal, dental, and airway parameters were evaluated for every patient at selected landmarks and a comparison was made before and after expansion. Skeletal measurements consisted of BBT, buccal bone height loss (BBHL), and midpalatal suture density ratio (MPSD). A paired *t*-test was employed to compare the means of the skeletal parameters pretreatment and posttreatment with the significance set at $p < 0.05$.

Results: Statistically significant differences were noted in the skeletal parameters posttreatment. BBT decreased by 1.14 mm while buccal bone height reduced by 1.84 mm with a decrease in MPSD indicating successful expansion.

Conclusion: MARPE treatment results in significant skeletal changes. The skeletal expansion opens up new avenues of treatment in contemporary orthodontics for mature patients.

Clinical significance: MARPE is an effective technique for skeletal expansion to correct the transverse discrepancy in adults without the use of surgery.

Keywords: Buccal bone, Cone-beam computed tomography, Miniscrew-assisted rapid palatal expansion, Skeletal expansion.

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Introduction

A harmonious relationship between the maxillary and mandibular dentition is a key requirement for normal occlusion and stability at any age.[1] Transverse maxillary deficiency is often associated with maxillary hypoplasia and posterior crossbite with the mandible shifting toward the crossbite.[2] Transverse disharmonies can have wide-ranging effects impacting the dental midline, facial symmetry, creating crossbites or scissor bites, and ultimately resulting in major deviations from normal occlusion.[3] Maxillary constriction not only causes malocclusion but may also lead to impaired nasal breathing further resulting in mouth breathing habits in such patients.[4] The treatment protocol for a transverse discrepancy in growing patients is well-established.[5,6] Treatment consists of rapid maxillary expansion (RME) to open up the midpalatal suture before suture ossification.[7] However, this treatment modality is less effective in adults and is associated with undesirable effects.[8] Brown developed surgically assisted rapid palatal expansion (SARPE) to overcome increased resistance from the bony buttress. However, this is a relatively invasive approach, and the procedure is associated with risks.[9–11] SARPE is also associated with a degree of relapse that may be objectionable.[12,13]

The concept of MARPE was put forth by Lee et al. in their seminal paper on the treatment of maxillary constriction in young adult patients who had completed their growth. The appliance transmits bilateral forces to separate the midpalatal suture through an expansion screw that is anchored to the bone.[14] Studies have demonstrated that MARPE presents with greater skeletal effects rather than dentoalveolar side effects as observed with conventional maxillary expanders.[15] The appliance lies tightly against the palatal vault and the forces are applied directly to the suture. This minimizes any lateral rotation component.[16]

Recent trends with wider acceptance of implants as a treatment modality have led to a proliferation of studies on the various effects of MARPE. Oliviera et al. reported that MARPE showed an increased maxillary skeletal expansion at the level of the midface and basal bone compared to surgical expansion.[17] Park et al. observed that while the maxilla exhibited lateral movement, a few landmarks had shifted forwards or superiorly, indicating the possibility of slight rotations. BBT and the height of the alveolar crest had reduced.[18] CBCT examination of posttreatment effects

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of RME found that expansion occurs through buccal crown tipping with a decline in BBT and height.[19] Unlike RME, MARPE achieves skeletal base expansion along with alveolar expansion to relieve transverse discrepancy.[20] A majority of studies concur that MARPE can correct transverse maxillary deficiency through skeletal and dentoalveolar effects.

Cone-beam computed tomography examination of the expansion with MARPE appliances allows for accurate visualization and measurement of structures and points without image distortion and overlap.[21] The use of CBCT avoids any bias due to superimposition or head positions.[22] Determining the skeletal impacts of MARPE in an adult patient is central to assessing its treatment efficacy. Ethnic and population-specific variations may exist in bone thickness and treatment effects.[23] Skeletal results of the MARPE appliance are tied to the forces applied to overcome the areas of resistance around the dentition. Delineation of the skeletal effects would allow the modulation of miniscrew placement around areas of bony resistance.

Evidence-based research has shown that treating transverse maxillary deficiency using MARPE, renders exceptional results (mean success rate 92.5%)[24] and it continues to be the only nonsurgical treatment option if the detrimental sequelae of conventional expansion techniques such as buccal crown tipping, alveolar bone dehiscence, root resorption, reduction in BBT, gingival recession, limited skeletal expansion, pain, marginal bone loss and, postexpansion relapse, are to be avoided. Furthermore, a parallel separation of the midpalatal suture in MARPE has been reported, as opposed to the conventional methods, which exhibit greater anterior and less posterior opening.[18,25] MARPE treatment is associated with extensive skeletal effects involving various perimaxillary sutures.[25–27] However, a search of the literature reveals a scarcity of high-quality studies that focus exclusively on the skeletal effects of the MARPE appliance. Thus, the current study aimed to evaluate the immediate posttreatment skeletal changes, that is, changes in the BBT, height, and MPSD in individuals treated with MARPE using CBCT.

Materials and Methods

The approval for the current study was given by the Institutional Ethics committee of AB Shetty Memorial Institute of Dental Sciences, Nitte University, Deralakatte (REF: Cert. No:ABSM/EC 40/2019). This retrospective study was conducted using records from the Department of Orthodontics and Dentofacial Orthopedics.

Based on a 5% level of significance, there was an estimated standard deviation of 3.5.12 and an estimation error of 1.6. Hence the total sample size required was 19. This was calculated using nMaster software.

The CBCT records of the patients who had completed their postpubertal growth and presented with maxillary arch constriction, patients treated with MARPE appliance before January 2021, patients who were not on any medication affecting bone metabolism, and patients who underwent nonextraction treatment, were selected from the patient database and included in the study.

Patient records showing a previous history of orthodontic treatment, systemic disease, or craniofacial congenital anomalies were excluded. A written informed consent document was present in all records.

On detailed examination, it was observed that the MARPE device used for treating all patients included in the retrospective study, was constructed in-house and consisted of a jackscrew (12 mm in length, Forestadent, Germany) connected to four tubes through which the miniscrews (6 millimeters in length, 1.8 millimeters in diameter) were connected to the palate.[28] The appliance had two customized stainless steel bands connected to the molars bilaterally. The disjunction of the midpalatal suture was confirmed by means of an intraoral periapical radiograph.

The CBCT scans were recorded prior to treatment for diagnostic purposes and posttreatment 1 month after completion of the expansion. The scans were done with the subjects in an upright posture, with their jaws in centric occlusion. The digital imaging and communications in medicine (DICOM) files obtained from the CBCT were imported into Planmeca Romexis v4.6.2 software and calibrated. The landmarks were identified by a single operator and measurements were taken by the same examiner and repeated at an interval of 2 weeks. The two sets of records (pre and postexpansion) were then studied and skeletal landmarks evaluated.

Skeletal Measurements

For evaluation of transverse cranial measurements, both coronal and axial sections, as well as a reconstructed posteroanterior view, perpendicular to the mid-sagittal plane, was used, and the following parameters were measured on pre and posttreatment CBCT records (Figs 1 and 2):

- Buccal bone thickness: Bone thickness was measured from the outermost point of the bones to the roots, at the furcation level. This measurement was taken on both sides with the mean value accepted for analysis.
- Buccal bone height loss: Difference in the buccal bone height, which was measured at the furcation level between the pre and post-CBCTs.
- Midpalatal suture density ratio (MPSD): To determine the MPSD, a 0.3 mm axial slice from the most central region through the hard palate was taken. The mean gray density values, that is, GDs (regions of the suture), GDsp (soft palate), and GDppm (the maxillary palatal process) were used for calculating the MPSD by the formula mentioned below:

$$MPSD\,ratio = \frac{GD_s - GD_{sp}}{GD_{ppm} - GD_{sp}}$$

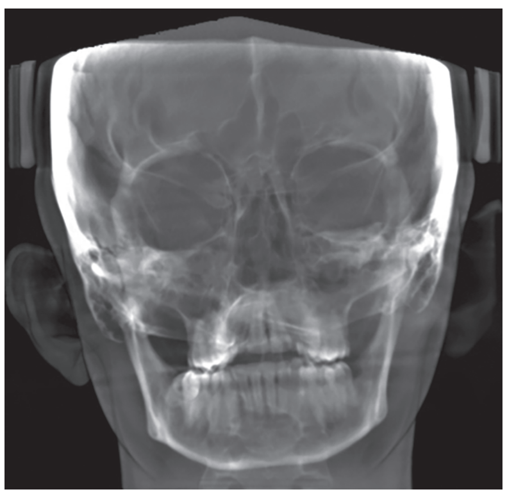

Fig. 1: Axial CBCT section of a patient with transverse deficiency of the maxilla, undergoing skeletal expansion with the MARPE appliance

This value ranged from 0 to 1; If it was closer to 0—The suture was less calcified with its density closer to that of the soft palate; conversely, if the value was closer to 1—The suture was more calcified and its density was closer to that of the maxillary palatal process. The skeletal response to RME has predicted from pretreatment CBCTs and the formula established by Grünheid et al.[29] based on the MPSD: GPFp = 0.60 x MPSD ratio + 0.50. The estimated skeletal response using the pretreatment MPSD ratios and the actual skeletal response calculated on posttreatment CBCTs were compared.

Figure 1 Axial CBCT section of a patient with transverse deficiency of the maxilla, undergoing skeletal expansion with the MARPE appliance; the skeletal parameters, BBT (measured from the outermost point of the bones to the roots, at the furcation level) and, BBHL (difference in the buccal bone height, measured at the furcation level) were measured using this axial CBCT section.

Figure 2 Coronal CBCT section of a patient undergoing skeletal expansion with the MARPE appliance; the skeletal parameter, MPSD was measured using this coronal CBCT section and calculated by the formula: where GD_s—regions of the suture, the maxillary palatal process.

$$\left(\frac{GD_s - GD_{sp}}{GD_{ppm} - GD_{sp}}\right)$$

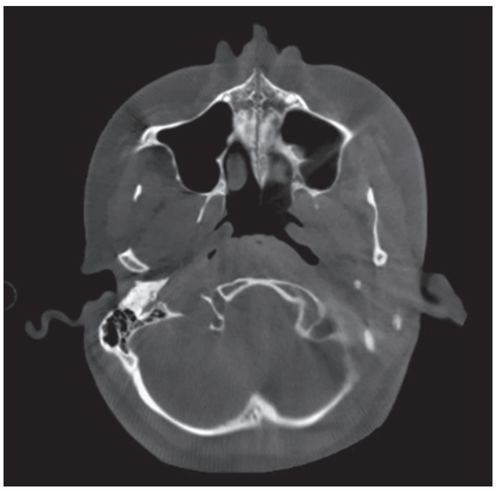

Fig. 2: Coronal CBCT section of a patient undergoing skeletal expansion with the MARPE appliance

Statistical Analysis

The data acquired were entered into a Microsoft Excel spreadsheet (Microsoft Office, Microsoft Inc., Redwood, CA, USA) and analyzed using SPSS v.22 (SPSS Inc., IL, USA). Descriptive statistics of quantitative variables were documented using mean, standard deviation, and confidence intervals. Descriptive statistics' categorical variables were presented using frequency/percentages. A paired *t*-test was applied to compare the means of the skeletal parameters pretreatment and posttreatment. $p < 0$ 0.05 was deemed significant.

Results

A total of 19 subjects' records, 10 males and 9 females, aged 18–30 years were examined during this study. All subjects exhibited maxillary expansion posttreatment. The skeletal parameters measured were greater at posttreatment as opposed to the pretreatment values. Table 1 and Figure 3 represent the pretreatment and posttreatment values.

A low-dose protocol was applied for recording the CBCT scans (exposure time of 18 seconds, 3.0 mA, 80 kV, field of view 200 × 200 mm^2, and a voxel size of 390 µm).

Both axial (for measuring BBT and BBHL) and coronal (for measuring MPSD) CBCT slices were taken at specific levels for evaluation of the skeletal parameters. The measurements were repeated after an interval of 2 weeks to maintain intraexaminer reliability.

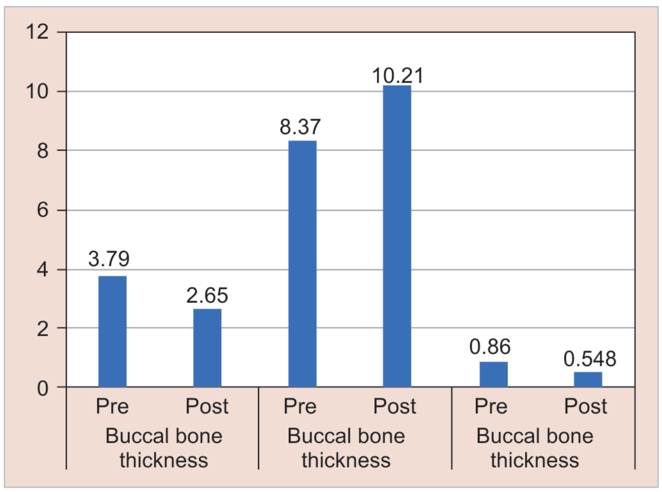

Fig. 3: Pretreatment and posttreatment skeletal parameters

Table 1: Pretreatment and posttreatment skeletal parameters

Skeletal parameters	*Buccal bone thickness*		*Buccal bone height*		*Midpalatal suture density ratio*	
Time intervals	Pre	Post	Pre	Post	Pre	Post
N	19	19	19	19	19	19
Minimum	2.1	1	7.2	8.8	0.75	0.12
Maximum	5.3	3.6	9.6	12.1	0.97	2.03
Mean	3.79	2.65	8.37	10.21	0.86	0.548
SD	0.82	0.77	0.78	0.86	0.065	0.459
Mean diff	1.41		−1.84		0.317	
p-value	0.00*		0.00*		0.005*	

$p < 0.05$ is significant

The average BBT showed a statistically significant decrease from 3.79 mm to 2.65 mm postexpansion with MARPE ($p < 0.00$).

The BBHL further increased to 10.21 mm from the initial height of 8.37 mm postexpansion with MARPE ($p < 0.00$).

The midpalatal suture ratio decreased from 0.86 to 0.548 mm after expansion with MARPE ($p < 0.05$).

Discussion

Traditional techniques to measure maxillary expansion are limited by their two-dimensional nature. They are constrained by the possibility of magnification, superimposition, and lack of clarity. In such cases, it is difficult to effectively delineate the skeletal and dental effects of an expansion treatment modality. CBCT allows for the visualization and assessment of osseous structures, allowing monitoring of treatment. CBCT produces a lower effective radiation dose than computed tomography and produces images with clarity and contrast allowing for diagnosis and monitoring.[30] Submillimetric changes are appreciable in CBCT depending on the voxel size employed with fewer artifacts.[31] This ability to capture three-dimensional data which can be examined from various orientations makes it an appealing approach to analyzing treatment outcomes.[32] Thus, the current study examined the effect of MARPE on the posttreatment skeletal parameters using CBCT. MARPE appeared to produce an orthopedic effect with maxillary expansion due to the split of the midpalatal suture.

Tooth-borne expanders and implant-supported expanders exert force, impacting the buccal bone plate. We observed that MARPE caused a significant reduction in the BBT posttreatment. Our findings of decreased BBT were similar to earlier findings by Park et al. who observed a decrease in thickness of approximately 0.6–1.1 mm in patients aged 16–26 years.[18] We observed a decrease of 1.14 mm posttreatment which was lower than the findings reported by Corbridge et al.[33] (1.6 mm) or by Rungcharassaeng et al.[19] (1.21 mm) in similar studies that used hyrax expanders.

Animal studies have demonstrated that buccal tooth movement can lead to bone dehiscences. Thinning and resorption of buccal alveolar bone can occur within 14 days of the onset of expansion.[34] Our results are in agreement with an earlier study by Digregorio et al., who observed that there was a marked reduction in the thickness of buccal bone plate thickness in young patients who underwent maxillary expansion.[35] These results reflect the findings of Garib et al. who reported a nearly identical reduction in BBT in the premolar and molar regions that is, the regions supporting the bands.[36] These findings broadly support the work of Starnbach et al. who demonstrated buccal bone resorption during orthodontic expansion in histologic animal studies. However, bone formation was evidenced after 3 months of retention. Bone levels appeared normal 3 months later.[37] Consistent with the literature, Timms et al. reported bone deposition 1 year after completion of the expansion, indicating that while the reduction in buccal bone levels is a consequence of orthodontic expansion, it is a transient condition with bone levels returning to normal during the period of retention.[38]

Copello et al. in a systematic review found that MARPE consistently showed a lesser decrease in BBT compared to rapid palatal expansion.[39]

This reduction in BBT may be concurrent with a decrease in the buccal bone height. We observed a decline in buccal bone height of 1.84 mm posttreatment. This finding is in agreement with the observations of Baysal et al. who reported a BBHL of approximately 1.2 mm after expansion.[40]

Park et al. reported similar decreases in buccal bone height ranging from 1.7–2.2 mm. Tipping movement indicates greater lateral shifts at the cervical level compared to the apex, leading to a decrease in buccal bone height. They concluded that tipping tooth movements and expansion had led to the decrease in the alveolar crest height.

Similarly, Garib et al. found that maxillary expansion caused a reduction in the alveolar crest bone and the bone loss could be predictive of possible gingival recession.[8,36]

An explanation for the varying values in these results could lie in the design of the MARPE appliance itself. MARPE refers to an appliance that uses mini-implants anchored to the bone to exert an expansion force. However, there is no singular unifying design, expansion protocol, or even the number of implants involved. Therefore, there may be a limited comparison between MARPE studies that utilize different appliance designs. The differences may also be related to the time period at which the CBCT scan was taken or the different vertical levels at which the various measurements were taken in each study.[33]

Success or failure of MARPE can be assessed by different methods namely chronological age, CVMI, and midpalatal suture stage. In the current study, we used the MPSD for its predictability. According to Grünheid et al., the MPSD is a better predictor and had shown no statistically significant relationship with the amount of long-term skeletal expansion attained. Its predictability was calculated by using Grünheid's formula.[29] The post-MPSD, that is, the actual value was compared with the predicted value. The result showed that the pretreatment MPSD ratio did not correlate to the amount of skeletal expansion attained.[9,29] Hence, the MPSD is not a favorable predictor but an indicator for expansion. This finding corroborates the results of Shin et al. who reported MPSD ratio was not always correlated to the disjunction of the midpalatal suture as characteristics of the subgroups could mask the results of an entire patient group. MPSD ratio may be better applicable in age and gender-matched patients with similar palatal lengths.[41]

Maxillary expansion can cause the displacement of the anchor teeth outside the alveolar process, damaging the periodontal apparatus.[35] MARPE offers advantages over traditional expanders as the anchorage is derived from miniscrews. While larger diameter mini-implants may offer better mechanical performance,[42] 1.8 mm diameter miniscrews appeared to anchor forces required to split the midpalatal suture for maxillary expansion in our study.

Calil et al. compared the maxillary skeletal and dentoalveolar effects in subjects treated with MARPE and self-ligating appliances. MARPE was observed to be superior to self-ligating appliances and exhibited more skeletal than dental effects.[43]

Our sample size was limited and justified due to our stringent adherence to ethical guidelines of ALARA to limit radiation exposure. CBCT records were obtained not as a part of routine orthodontic diagnostic records but only when data for monitoring maxillary expansion were not obtainable by other methods. One limitation of our study was that the posttreatment skeletal effects were recorded immediately after completion of the maxillary expansion. This fails to take into account possible relapse that may occur after a period. Future research should examine the stability of the expansion at different time periods. Future studies should focus on the dental and airway changes evident with MARPE. There is a dearth of patient-reported outcomes of the pain experience, satisfaction, and quality of life with the appliance which needs to be addressed in future studies. Other factors that influence the success of MARPE such as degree of ossification of suture, age, and sex require further elucidation. This will develop a fuller picture of the efficacy and psychological effects of MARPE treatment of transverse deficiency.

Conclusion

Within the limitations of our study, we found that MARPE had significant effects on the skeletal parameters after maxillary expansion. BBT and height were reduced with a concurrent fall in the MPSD, indicating successful skeletal expansion. MARPE appears as a viable technique for the treatment of transverse discrepancy in adults. However, further work with larger sample sizes and longer follow-up periods is required to establish its viability and validate the current findings.

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