International Journal of Medical Toxicology & Legal Medicine Volume 27, No. 4, 2024
e-ISSN: 0974-4614
p-ISSN: 0972-0448

Evaluation of the Effect of Three Types of Rapid Maxillary Expanders (Conventional, Hybrid and MSE) After 6 Months in Adolescents. Randomized controlled trial

Mohamed Abdelrhman Shendy[1], Ahmed Abouelnour[2], Sara Elkabbany[3], Abdullah M. Alhawish[4], Mostafa Magdi Abdel Monem Abdel Allah[5], Wesameldin Rafaat Ali Gouda[6], Usama Thabet Ahmed[7], Ibrahim Saad Abd El-Ghafar[8], Khaled Mohammad Taha[9], Abubakr Mohammed Fouad[10], Ahmed Mangoud Badr[11]

[1]Associate professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Cairo, Egypt, Email: shendy_ortho@azhar.edu.eg
[2]Associate professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Cairo, Egypt, Email: A.nour@azhar.edu.eg
[3]Assistant Professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt, Email: Saraelkabbany@gmail.com
[4]King Saud Medical City Orthodontic Department. Email: ahawish@ksmc.med.sa
[5]Associate professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Assiut, Egypt, Email: MostafaAbdelAllah1251.el@azhar.edu.eg
[6]Associate professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Assiut, Egypt, Email: wesamgouda.el.8.540@azhar.edu.eg
[7]Associate professor of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Assiut, Egypt, Email: dusamathabet@gmail.com
[8]Lecturer of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Assiut, Egypt, Email: ibrahemsaad1114@azhar.edu.eg
[9]Lecturer of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Cairo, Egypt, Email: Kh.taha@azhar.edu.eg
[10]Lecturer of Orthodontics, Orthodontic Department, Faculty of Dental Medicine for Boys, Al-Azhar University, Cairo, Egypt, Email: bkr20@azhar.edu.eg
[11]Lecturer of Orthodontics Department of Orthodontics, Faculty of Dentistry, Aswan University, Tingar, Egypt, Email: Dr.Mangoud@Gmail.com

Received: 12.02.2024 Revised: 04.03.2024 Accepted: 26.04.2024

ABSTRACT

Objectives: The purpose was to asses and analyze the resultant efficacy of three different maxillary expanders (conventional, hybrid, and MSE) on adolescent maxilla utilizingthree dimension dental x ray hence cone beam computed tomography (CBCT) was the proper choice.

Material and Methods: The trial wasbased on three groups, and the net sample was made up of 46 healthy 11–16-year-olds (17 girls and 29 boys). Patients were allocated to groups with the aid of sequentially numbered, opaque sealed envelopes (SNOSE). Group A received conventional hyrax appliance (CH) (5 girls, 10 boys),miniscrew assisted rapid palatal expansion (MARPE)was used with two different design in the other two groups, hence, Group B used hybrid hyrax appliance with two anterior palatal miniscrews (HH) (6 girls, 9 boys), and Group C had the maxillary skeletal expander (MSE) (6 girls, 10 boys). Using Anatomage in vivo 5.19, Dental and skeletal parameters change were assessed for each group at base line (T1) and after expansion(T2), based on 92 CBCT scans.

Results: ANOVA was used to compare normally distributed numerical variables between groups, and when a difference was shown to be significant, the post hoc test (Bonferroni) was used. In CH , 73.3% of cases were bilateral, in comparison to 53.3% and 56.3% bilateral cases in HH and MSE respectively; with no significant difference between groups (p=0.477),when comparing the type of malocclusion class in CH and HH, 73.3% of cases were class 3, in comparison to 75% class 3 cases in MSE; with no significant difference between groups (p=0.993).

Conclusion: After expansion, all kinds performed well; however, as compared to the conventional hyrax appliance, the MARPE, and particularly the MSE, had stronger skeletal impact and less buccal tilting.

Keywords: Rapid maxillary expansion; Hyrax; MARPE; Hybrid hyrax and Maxillary skeletal expander (MSE)

INTRODUCTION

To resolve a transverse maxillary discrepancy, an orthopedic therapy that expands the maxillary arch by separating the mid-palatal suture is known as rapid maxillary expansion (RME).[1–3]

It is crucial to address transverse maxillary discrepancies promptly, as maxillary width growth is completed earlier than anteroposterior and vertical growth.[4]

Backside dental tipping with conventional RPE that uses hyrax is an inevitable side effect, even with bonded hyrax.[5]

Patients with transverse maxillary deficiency find it challenging to enlarge their maxilla due to the rise in suture fusion degree since a range of orthopaedic and orthodontic methods are available, especially for individuals who are young and developing.[6–9] However, this particular obstacle is more difficult to overcome in adults and teenagers who are not growing because of the higher skeletal resistance seen when the midpalatal suture closure.[10]

Additionally, this clinical unwanted side effects such unsuccessful expansion , alveolar bone dehiscence, [11]posterior teeth crown tipping,[5] root resorption, [12]reduction in buccal bone thickness, loss of marginal bone, unrelaxed situation, edematous swelling, and gingival recession can potentially result from difficulties with the expansion technique.[8,13]

HH devices require additional procedures. The paramedian palate provides an excellent location for palatal implant placement [14–16] at the region of third raugae area.[17]and miniscrewbicortical engagement was advised to ensure stability and skeletal effect.[18]

HH experienced less force localised on the midpalatal and circummaxillary sutures, despite the fact that the banded maxillary posterior teeth in the toothborne appliances had higher stress values than those in the hybrid design but it can be presumed that when the number of anchor teeth increase, this will make side effects disappear during maxillary expansion.[19]

The surgically assisted rapid maxillary expansion (SARME) technique was developed to reduce these negative effects, and it aids in overcoming the resistance that the mature zygomatic buttress and bony palate increase.[20,21] However, a contentious question in SARME operations is whether the pterygomaxillary disjunction needs to be separated. [22,23]

SARME has a number of drawbacks, including the need for surgery, the need for general anaesthesia, the potential for cranial nerve or palatine artery damage, high expense, a difficult course of treatment, and surgical morbidity and mortalityNasal hemorrhage, extrusion of teeth attached to the Hyrax device, sinus infection, and devitalization of the teeth (if osteotomy is done too near the tooth tips) are possible potential postoperative issues that might occur with SARME..[24,25]

For class 3 patients with severe mandibular prognathism, miniscrew assisted rapid palatal expansion (MARPE) was developed as a nonsurgical expansion prior to surgery. [26]

The main difference between conventional and hybrid or MARPE that teeth were under a lot of stress from the tooth-borne appliances, and as the quantity of bone support increased, the strains on the teeth dropped proportionately[27–30]However, a different systematic evaluation found less evidence than conventional hyrax (CH).[31]

Despite the large number of studies examining maxillary expansion, orthodontics literature lacks data in this particular field since study designs vary depending on multiple confounders, including the appliance type, expansion technique, and patient characteristics. The need for more original research into the specific effects is highlighted by the small number and poor quality of the eligible studies. It was determined to compare the three types of appliances using the same technique of activation to share knowledge that could potentially lead to a useful clinically relevant result in choosing the appropriate application for the age group. This decision was made due to some clinical difficulties and scientific morals when comparing numerous different expansion methods, hence this study was directed to compare the Effect of three types of RME (conventional, Hybrid and MSE) in young adults.

MATERIAL AND METHODS

Sample power analysis

This study used a single-center, double-blind study (assessors and data analysts) with a three-arm, parallel, randomised clinical trial design, the allocation ratio 1:1:1 for individuals with transverse maxillary. Using the free G*Power software (version 3.1.9.4), the sample size was determined based on a prior study conducted by Brunetto et al.[32]. According to the research, 45 patients—at least 15 for each group—were needed, and to reach this target, starting with 54 patients, it was determined to eliminate any dropouts.

Ethical approval
The Faculty of Dental Medicine at Al-Azhar University's Institutional Ethical Committee, which upholds the requirements for medical research involving human subjects, approved this study under process number **(775/220).** The parents or guardians of the children who were permitted to participate signed informed consent forms. Separate consent papers for research participation and full-service orthodontic therapy were given out, and the clinical trial registration number was **(NCT05446714).**

Randomization
Sequentially numbered opaque sealed envelopes with assigned numbers and tagged vehicles were used to facilitate the randomisation procedures. The orthodontic outpatient clinic at Al Azhar University's faculty of dental medicine in Cairo, Egypt, served as the screening site for research participants in this randomised controlled trial (RCT).
The sample included 54 healthy (17 girls and 37boys) 11- 16-year-old patients,but at the end, 46 healthy (17 girls and 29 boys) 11. 7 -15 .8-year-old patients were analyzed due to dropoutof 6 and exclusion of 2 patients (8 boys).Group A conventional hyrax appliance (CH) (5 girls and 13 boys)finally became(5 girls and 10 boys) group B hybrid hyrax appliance with two anterior palatal miniscrews (HH) (6 girls and 12 boys) became (6 girls and 9 boys) and group C MSE (6 girls and 12 boys) became (6 girls and 10 boys) as presented in Consolidated Standards of Reporting Trials (CONSORT) **(Figure 1).**

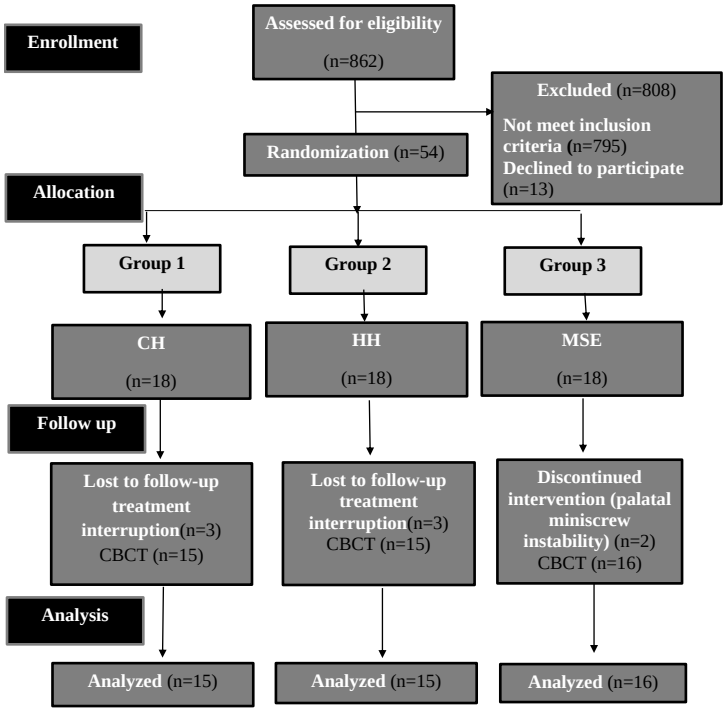


Figure 1: CONSORT flow diagram.

Inclusion criteria
Both unilateral and bilateral posterior crossbite were seen, and the ages ranged from 11 to 16 years. Maxillary collapse was present, with a skeletal framework underlying. The average height of the anterior face and the existence of fully erupted most of permanent teeth except third molars in all cases and canine and permanent second molars in a few cases. Good general body and oral health, lack of periodontal or gingival disease, lack of underlying medical conditions or drugs that could affect bone quality or periodontal health or cause orthodontic therapy to fail, and lack of prior orthodontic treatment history.

Exclusion criteria
Cleft lip and palate are examples of craniofacial disorders,no congenital facial anomaly or dysmorphism, amalgam filling in maxillary teeth or any crown and those who declined to take part in this research.
Discontinuation criteria

Improper dental hygiene maintenance care, missing follow-ups have an impact on the study's protocol, destroyed appliances with incorrect expansion screw openings that differed from the activation procedure, and failure to follow a doctor's recommendation or disregard for medical guidance.

Assessment of maxillary width

Diagnosing transverse maxillary insufficiency can be challenging due to limited soft tissue alterations and the potential for additional skeletal or dental issues to hide the difference.

Clinical features may include paranasal hollowing, narrow nasal base, exaggerated nasolabial angle, tiny zygomatic process, unilateral or bilateral posterior cross bite, or even compensated with narrow maxilla and high palatal vault.

After measuring the maxilla's transverse width using both clinical and conventional posteroanterior (PA) radiography, the trial's approved patients were asked to undergo cone beam computed tomography (CBCT).

The maxillomandibular differential index (15.3 mm) was used to calculate the transverse discrepancy.

Oral hygiene prophylaxis

Scaling, polishing, and gingival treatment (mouthwash with chlorhexidine) were administered to all patients. The periodontal prophylaxis program can be influenced by the patient's age, systemic conditions, cooperation, familial and socioeconomic situation. To standardise the pretreatment oral hygiene measures before expansion, each trial participant received a written homecare instruction sheet and subsequently followed a specified oral hygiene routine for one month.

The hyrax contains a jackscrew which is 9,10 or 11 mm wide (Figure 2 d). (Firenze, Italy: Leone Orthodontics) in groups A and B, while in group C, MSE (Figure 2 c & e)was utilised to cover biocritical involvement, with four mini-implants (diameter=1.8 mm, length=11 mm) secured into the MSE jackscrew with four holes by a specific driver that was needed to accomplish bicortical contact. The midpalatal suture (MPS) and the palatal miniscrews were positioned parallel and symmetrically (Figure 2 c & f). The miniscrews may be positioned in the roof of the mouth thanks to the inclusion of four sheaths that were welded to M1 bands on both sides, (American orthodontic), and the expansion screw arms were soldered to the two segments (CH and HH) or four segments (MSE instances) (Figure 2 a, b, and c).

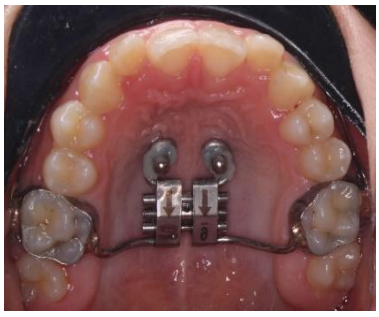
The same orthodontic technician worked on the expansion appliances. Upon delivery, and after cementation with glass ionomer cement (Medicem) and antiseptic solution (Betadine) was put on the palate at the miniscrew insertion site, and a small quantity of local anaesthesia was provided, each patient received two quarter turns (0.25 mm) daily. For 17 days, the patient or parents applied one quarter turn in the morning and another in the evening, resulting in an average enlargement of around 8 mm.The activation protocol for MSE was 4 turns every day because each turn equalled 0.133 mm, thus four turns would be comparable to 0.53 mm, resulting in a total activation of roughly 8mm after 16 days. Finally, after achieving the necessary expansion, the screw was fixed using light cure flowable composite.

The protraction face mask in class III instances was postponed until the 6-month evaluation period was completed.

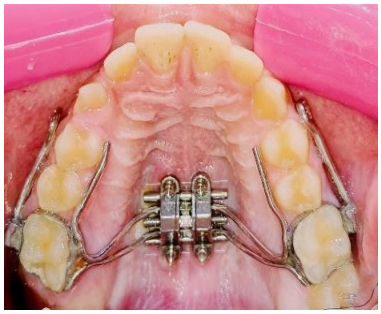
Outcomes

The study's main finding concerned the opening of the midpalatal suture. Patients were monitored once a week during the activation phase to verify the opening of the midpalatal suture. When radiographic evidence of midpalatal suture opening was absent in the periapical view four weeks after the initial activation, maxillary expansion failure using CH,HHor MARPE was determined. To ensure the safe completion of the treatment, expansion was stopped, and the orthodontic treatment plan was changed if the midpalatal suture opening with RPE or MARPE devices failed also skeletal, dentoalveolar measurements were primary outcomes, while periodontal assessments through clinical and by using CBCT images made up the secondary outcomes.

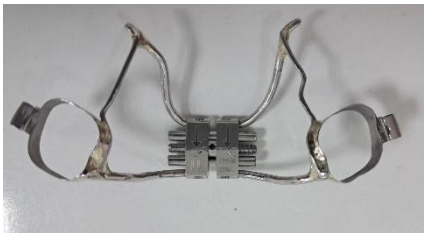
(a)



(b)



(c)



(d) **(e)** **(f)**

Figure 2: Expanders of the study (a) Conventional hyrax (b) Hybrid hyrax (c) MSE (d)Hyrax screw (e) MSE keys and(f) miniscrews.

Each patient had CBCT at baseline (T1) and six months after the last RPE activation (T2). Routine orthodontic data was obtained both before and after therapy. Anatomage in vivo 5.19 was used to analyze dental, skeletal, and buccal bone parameters in each group with adequate scan quality, free of movement artefacts.
Using the maturation of the midpalatal suture and cervical vertebrae, groups that are growing CVM 3 with MSM B and C , while those that are nothave CVM 5 and MSM D who are representing the non-growing participant.(Figure 3).

The following CBCT measurements were selected

- **Nasal floor molar**: located at the most inferior level of the nasal floor parallel to Frankfort horizontal plane.
- **Nasal floor premolar**: measured at the most inferior level of the nasal floor parallel to Frankfort horizontal plane.
- **Anterior suture opening:** In an axial incision of the palatal plane, locate the anterior nasal spines on both sides. Measured in millimeters.
- **Posterior suture opening:** In an axial incision of the palatal plane, locate the posterior nasal spines on both sides. Measured in millimeters.
- **Hard palate maxillary width 6**:distance between maxillary lateral walls at the level of the nasal floor parallel to Frankfort horizontal plane.
- **Hard palate maxillary width 4**:distance between maxillary lateral walls at the level of the nasal floor parallel to Frankfort horizontal plane.
- **Molar distance**:the distance between the mesiobuccal cusps of the right and left molars parallel to Frankfort horizontal plane.

The angle created by the junction of the lines joining the mesiobuccal and mesiolingual cusp tips of the first molars, or the buccal and palatal cusp tips of the first premolas, and the mid-sagittal plane on both sides.

- **Molar rotation**: the lines passing through mesiobuccal cusp and distopalatal cusp tip of the right and left molars with the mid palatal plane.
- **Premolar rotation**: the lines passing through buccal and palatal cusp tip of the right and left premolars with the mid palatal plane.
- The maxillary first molar or premolar's longitudinal axis and a vertical line parallel to the midsagittal plane were used to assess the buccolingual inclination of the molars on both the left and right sides.
- **Molar inclination**:the lines passing through mesiobuccalcusp and palatal root apex of the right and left molars with the mid sagittal plane.
- **Premolar inclination**:the lines passing through buccal cusp and root apex of the right and left premolars with the mid sagittal plane.
- **Arch depth:**The line created by the connection of mid line point till the inter premolar linein axial section.
- **Incisor inclination:** The angle created by the junction of lines extending the long axis of the maxillary central incisor with the Frankfort horizontal plane.

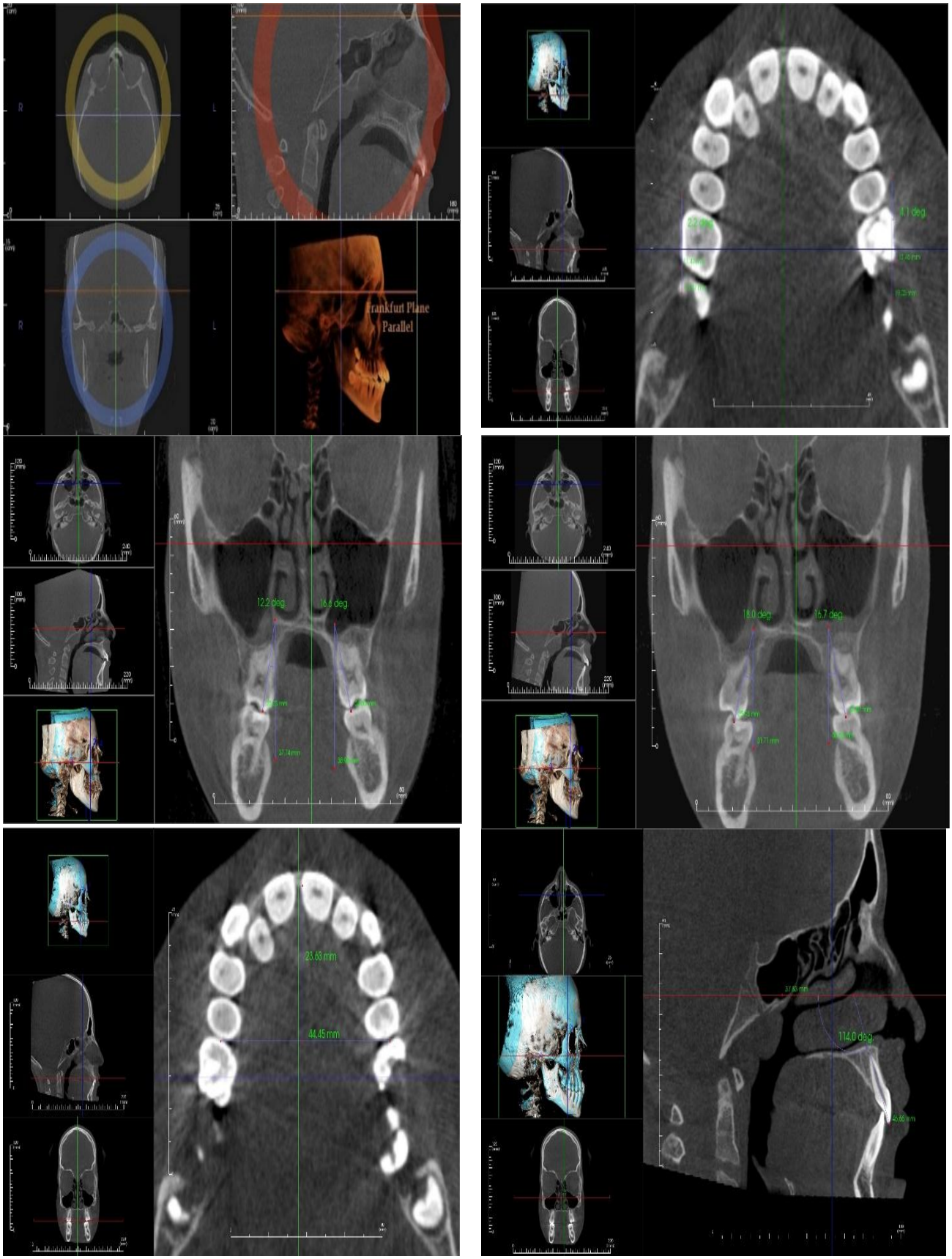


Figure 3: CBCT measurements

RESULTS

The sample comprised of 54 healthy individuals (17 females and 37 boys). 11-16-year-old patients Finally, 46 are healthy (17 girls and 29 males). 11. 7–15.8-year-old children were analysed after dropout 6 and exclusion of two patients (8 boys). Group A conventional hyrax appliance (CH) (5 girls and 13 boys) became (5 girls and 10 boys); group B hybrid hyrax with two anterior palatal miniscrews (HH) (6 girls and 12 boys) became (6 girls and 9 boys); and group C MSE (6 girls and 12 boys) became (6 girls and 10 boys).

Over a three-week period, 21 cases (seven from each group) completed inter- and intra-examiner reliability tests. Individual examiners ranged from considerable (k = 0.62) to less than chance (k = 0.2), and the mean intra-examiner agreement was slightly greater than the mean inter-examiner agreement, albeit only fair (k = 0.3).

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 20 was used for data management and statistical analysis. By examining the data distribution and applying the Shapiro-Wilk and Kolmogorov-Smirnov tests, the data were examined for normality. ANOVA and Bonferroni post hoc tests were used to compare normally distributed numerical variables between groups if a significant difference was found. The paired t test was used to compare the before and post values. The following formula was used to get the mean difference: (Value after-value before)The Kruskal Wallis test was used to assess non-parametric difference data between groups. Every p-value has two sides. P-values less than 0.05 were regarded as significant.

RESULTS

I-Demographic data

Age: Patients age ranged from 11.7 to 15.8 years. There was no significant difference in age between groups (p=0.19), (Table 1),(Figure 4).

Cross bite: In Butterfly hyrax, 73.3% of cases were bilateral, in comparison to 53.3% and 56.3% bilateral cases in Hybrid hyrax and MSE respectively; with no significant difference between groups (p=0.477), (Table 2),(Figure 5).

Malocclusion: In Butterfly hyrax and Hybrid hyrax, 73.3% of cases were class 3, in comparison to 75% class 3 cases in MSE; with no significant difference between groups (p=0.993),
(Table 3),(Figure 6).

Table 1: Descriptive statistics and comparison between age between groups (ANOVA test)

	Mean	**Std. Dev.**	**Min**	**Max**	**P value**
Butterfly hyrax	14.50	1.04	11.70	15.80	0.190 ns
Hybrid hyrax	13.96	1.21	11.70	15.40	
MSE	13.81	.98	12.10	15.10	

Significance level p≤0.05, ns=non-significant

Table 2: Distribution of cases according to cross bite and comparison between age between groups (Chi square test)

CROSS_BITE		**Groups**			**P value**
		Butterfly hyrax	**Hybrid hyrax**	**MSE**	
	Unilateral	4 (26.7%)	7 (46.7%)	7 (43.8%)	0.477 ns
	Bilateral	11 (73.3%)	8 (53.3%)	9 (56.3%)	
Total		15	15	16	

Significance level p≤0.05, ns=non-significant

Table 3: Distribution of cases according to cross bite and comparison between age between groups (Chi square test)

MALOCCLUSION		**Groups**			**Pvalue**
		Butterfly hyrax	**Hybrid hyrax**	**MSE**	
	Class 1	4 (26.7%)	4 (26.7%)	4 (25%)	0.993 ns
	Class 3	11 (73.3%)	11 (73.3%)	12 (75%)	
Total		15	15	16	

Significance level p≤0.05, ns=non-significant

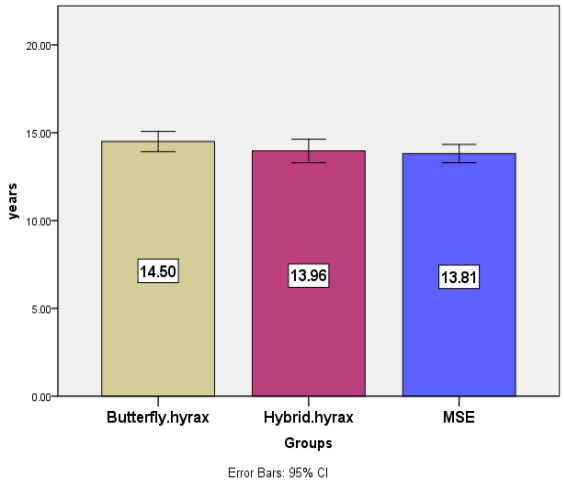


Figure 4: Bar chart illustrating mean age in different groups

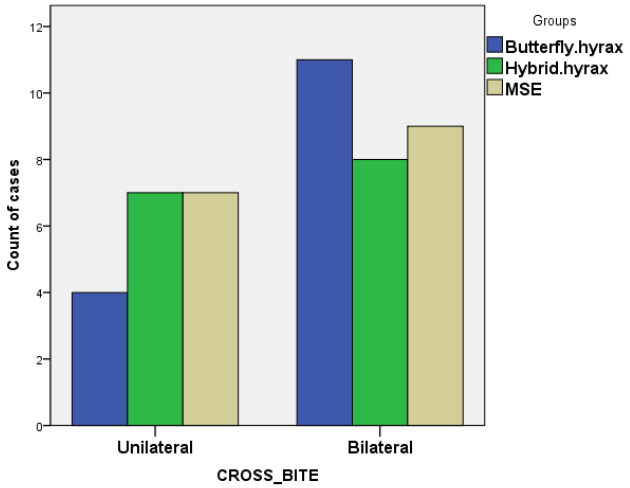


Figure 5: Bar chart illustrating distribution of unilateral and bilateral cases in different groups

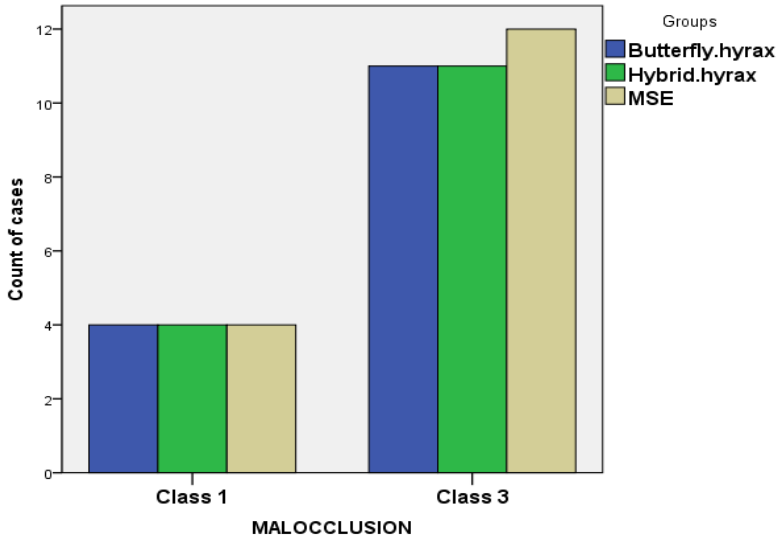


Figure 6: Bar chart illustrating distribution of malocclusion classes in different groups

II- Outcomes

I- Comparison between Hybrid and conventional hydrax groups

- **Molar distance:** There was no significant difference between groups in pre values (p= 0.094). Regarding post treatment, The mean value recorded in Hybrid hyrax (52.21±2.59) was significantly higher than that recorded in Butterfly hydrax (49.43±2.41) (p= .016). Moreover, there was a statistically significant difference between groups regarding the amount of change (difference) by treatment (p=0.000), with the highest value recorded in MSE (8.88±1.58), followed by Hybrid hyrax (7.24±1.77) and the lowest value recorded in Butterfly hyrax (5.88 ± 1.39), **(Table 4),(Figure 7& 17).**
- **Premolar distance:** There was no significant difference between groups in pre values (p= 0.058). Regarding post treatment, The mean value recorded in Butterfly hydrax (43.67±2.55) and Hybrid hyrax (42.73±2.7) was significantly higher than that recorded in MSE (38.46 ±2.61), (p= .000). Moreover, the mean value of amount of change (difference) recorded in Butterfly hydrax (6.68±1.83) and Hybrid hyrax (6.08±1.84) was significantly higher than that recorded in MSE (4.43 ±1.82), (p= .005). **(Table 4),(Figure 7&17).**
- **Molar rotation:** There was no significant difference between groups, regarding pre and post values (p= 0.175; p=0.207 respectively in right side and p=0.06; p=0.07 in left side). There was no significant difference between groups regarding the amount of change (difference) by treatment (p=0.503 in right side and p=0.757 in left side), **(Table 4),(Figure 8&18).**
- **Premolar rotation:** there was no significant difference between groups, regarding pre and post values for the right side (p= .566; p=.609 respectively) and the left side (p=.455; p=.283 respectively). Moreover, there

was no statistically significant difference between groups regrading the amount of change (difference by treatment in the right side and left sides (p=0.084; p= .410 respectively), **(Table 4),(Figure 9&18).**

- **Nasal floor molar:** There was no significant difference between groups in pre values (p= 0.058) and post value (p=0.397). There was a statistically significant difference between groups regarding the amount of change (difference) by treatment (p=0.000), with the highest value recorded in MSE (4.38±0.85), followed by Hybrid hyrax (2.6±1.04) and the lowest value recorded in Butterfly hyrax (2.2± 1.49), **(Table 5),(Figure 10&19).**
- **Nasal floor premolar:** There was no significant difference between groups in pre values (p= 0.701). Regarding post treatment value, there was a statistically significant difference between groups (p=0.001), with the highest value recorded in MSE (39.73±2.27), followed by Hybrid hyrax (38.63±1.77) and the lowest value recorded in Butterfly hyrax (37.04± 1.17). Moreover, regarding the amount of change (difference) by there was a statistically significant difference between groups (p=0.000), with the highest value recorded in MSE (4.87±0.62), followed by Hybrid hyrax (3.43±.74) and the lowest value recorded in Butterfly hyrax (2.47± 1.02), **(Table 5),(Figure 10&19).**
- **Hard palate maxillary width 6:** There was no significant difference between groups in pre values (p= 0.083). Regarding post-treatment, the mean value recorded in MSE (64.31±1.8) was not significantly different from butterfly Hyrax (63.59±2.15), but was significantly higher than that recorded in Hybrid hyrax (62.04±2.68), (p= .023). The mean value of amount of change (difference) recorded in MSE (5.91±0.92) was significantly higher than that recorded in Butterfly hydrax (3.37±0.96) and Hybrid hyrax (3.17±1.54), (p= .000). **(Table 5),(Figure 11&20).**
- **Hard palate maxillary width 4:** There was no significant difference between groups in pre values (p= 0.677). Regarding post treatment, the mean value recorded in MSE (40.34±1.56) was significantly higher than that recorded in butterfly hyrax (38.17±1.76), (p= .002). The mean value of amount of change (difference) recorded in MSE (6.35±1.25) was significantly higher than that recorded in Butterfly hydrax (4.51±1.28) and Hybrid hyrax (5.09±1.16), (p= .001). **(Table 5),(Figure 11&20).**
- **Molar inclination:** There was no significant difference between groups, regarding pre and post values (p= 0.353; p=0.734 respectively in right side and p=0.312; p=0.892 in left side). The mean value of amount of change (difference) recorded in MSE was significantly higher than that recorded in Butterfly hydrax and Hybrid hyrax, (p= .000 in right side and p=0.003 in left side). **(Table 5),(Figure 12&21).**
- **Premolar inclination:** There was no significant difference between groups, regarding pre values (p= 0.191 in right side and p=0.355 in left side). Post treatment, the mean value recorded in Butterfly hyrax was significantly higher than the other groups (p=0.003 in right side and p=0.000 in left side). The mean value of amount of change (difference) recorded in MSE was significantly higher than that recorded in Butterfly hydrax andHybrid hyrax, (p= .000 in right side and p=0.000 in left side). **(Table 5),(Figure 13&21).**
- **Arch depth:** There was no significant difference between groups, regarding pre values (p= 0.064). Post treatment, the mean value recorded in MSE was significantly lower than the other groups (p=0.007). The mean value of amount of change (decrease) recorded in MSE was significantly greater than that recorded in Butterfly hydrax andHybrid hyrax, (p= .000), **(Table 6),(Figure 14&22).**
- **Incisor inclination:** There was no significant difference between groups, regarding pre and post values (p= 0.243 and p=0.922 respectively). The mean value of amount of change (decrease) recorded in MSE was significantly greater than that recorded in Butterfly hydrax andHybrid hyrax, (p= .001), **(Table 6),(Figure 15&23).**
- **Anterior suture opening:** There was no significant difference between groups, regarding pre values (p= 0.290). The mean value recorded in MSE post treatment was significantly higher than that recorded in Butterfly hydrax andHybrid hyrax, (p= .000). The mean value of amount of change (increase) recorded in MSE was significantly higher than that recorded in Butterfly hydrax andHybrid hyrax, (p= .001), **(Table 6),(Figure 16&24).**
- **Posterior suture opening:** All groups recorded a value (0±0.00) pre-treatment. Post treatment, The mean value recorded in MSE was significantly higher than that recorded in Butterfly hydrax, while Hybrid hyrax recorded a significantly lower value than the other 2 groups (p= .000). The mean value of amount of change (increase) recorded in MSE was significantly higher than that recorded in Butterfly hydrax; while Hybrid hyrax recorded a significantly lower value than the other 2 groups (p= .000),**(Table 6),(Figure 16&24).**

II-Comparison between pre and post values Hybrid and conventional hydrax groups

Comparing the pre and post values revealed than the post treatment value was significantly higher in post value compared to the pre value in molar and premolar distance (Fig.1), right and left molar rotation (Fig.2), right and left premolar rotation (Fig.3), nasal floor first premolar and molar (Fig.4), hard palate maxillary width first molar and premolar (Fig.5), right and left molar inclination (Fig.6), right and left premolar inclination (Fig.7) and anterior and posterior suture opening (Fig.10). On the other hand, Arch depth and incisor inclination recorded significantly lower post value compared to the pre value (Fig. 8,9), (Table 1-3)

Table 4: Descriptive statistics and comparison between (ANOVA test) and within group (i.e. between pre and post value) (paired t test) regarding molar and premolar distance; molar and premolar rotation right and left

GROUP		Pre		Post		Amount of change (post-pre)			P Within group
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Median	
Molar distance	Butterfly hyrax	43.55	1.97	49.43[b]	2.41	5.88[c]	1.39	5.77	.000*
	Hybrid hyrax	44.79	4.27	52.21[a]	2.59	7.42[b]	1.77	7.50	.000*
	MSE	42.14	3.25	51.01[ab]	2.56	8.88[a]	1.58	8.95	.000*
	P value bet. groups	.094ns		.016*		.000*			
Premolar distance	Butterfly hyrax	36.99	4.60	43.67[a]	2.55	6.68[a]	1.83	6.20	.004*
	Hybrid hyrax	36.65	3.15	42.73 [a]	2.70	6.08 [a]	1.84	5.90	.002*
	MSE	34.03	3.12	38.46 [b]	2.61	4.43[b]	1.82	4.85	.002*
	P value bet. groups	.058 ns		.000*		.005*			
Molar rotation right	Butterfly hyrax	58.32	4.68	59.57	4.74	1.25	.67	1.10	.000*
	Hybrid hyrax	61.50	4.54	62.54	4.42	1.04	.58	1.10	.000*
	MSE	61.95	7.38	62.99	7.26	1.04	.65	0.90	.000*
	P value bet. groups	.175ns		.207 ns		.503 ns			
Molar rotation left	Butterfly hyrax	59.75	5.31	61.17	5.27	1.42	.51	1.50	.000*
	Hybrid hyrax	64.31	5.57	65.55	5.46	1.25	.82	1.10	.000*
	MSE	60.43	5.65	61.90	5.54	1.48	1.06	1.20	.000*
	P value bet. groups	.060 ns		.070 ns		.757 ns			
Premolar rotation right	Butterfly hyrax	74.71	6.68	75.84	6.64	1.13	.40	1.10	.000*
	Hybrid hyrax	73.79	6.58	74.71	6.48	.93	.48	0.90	.000*
	MSE	76.43	7.60	77.21	7.60	.78	.42	0.75	.000*
	P value bet. groups	.566 ns		.609 ns		.084ns			
Premolar rotation left	Butterfly hyrax	74.23	6.40	75.27	6.33	1.05	.32	1.10	.000*
	Hybrid hyrax	76.99	6.07	78.65	5.55	1.65	2.50	1.10	.000*
	MSE	75.14	5.83	76.16	5.95	1.02	.47	1.10	.000*
	P value bet. groups	.455ns		.283ns		.410ns			

Significance level p≤0.05, *significant, ns=non-significant

Post hoc test: Within the same comparison, means sharing the same superscript letter are not significantly different

Table 5: Descriptive statistics and comparison between (ANOVA test) and within group (i.e. between pre and post value) (paired t test) regarding nasal floor, hard palate maxillary width molar and premolar; molar and premolar inclination right and left

GROUP		Pre		Post		Amount of change (post-pre)			P Within group
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Median	
Nasal floor 1st.molar	Butterfly hyrax	65.13	5.07	67.33	1.67	2.20 [b]	1.49	1.80	.003*
	Hybrid hyrax	63.48	3.13	66.08	2.80	2.60[b]	1.04	2.40	.000*
	MSE	62.00	3.36	66.38	3.07	4.38[a]	.85	4.45	.000*
	P value bet. groups	.058ns		.397ns		.000*			
Nasal floor 1st.premolar	Butterfly hyrax	34.57	1.55	37.04[c]	1.17	2.47[c]	1.02	2.40	.001*
	Hybrid hyrax	35.21	2.09	38.63[b]	1.77	3.43[b]	.74	3.50	.000*
	MSE	34.86	2.40	39.73[a]	2.27	4.87[a]	.62	5.00	.000*

		.701ns		.001*		.000*			
Hard palate Maxillary width 6	Butterfly hyrax	60.43	2.49	63.59[ab]	2.15	3.17[b]	1.54	3.10	.000*
	Hybrid hyrax	58.67	2.99	62.04[b]	2.68	3.37[b]	.96	3.40	.000*
	MSE	58.39	2.44	64.31[a]	1.80	5.91[a]	.92	6.10	.000*
	P value bet. groups	.083ns		.023*		.000*			
Hard palate Maxillary width 4	Butterfly hyrax	33.66	1.85	38.17[b]	1.76	4.51[b]	1.28	4.50	.001*
	Hybrid hyrax	34.22	1.79	39.31[ab]	1.39	5.09[b]	1.16	4.90	.001*
	MSE	33.99	1.58	40.34[a]	1.56	6.35[a]	1.25	6.10	.003*
	P value bet. groups	.677ns		.002*		.001*			
Right.1st molar inclination	Butterfly hyrax	18.58	4.41	24.24	5.32	5.66[a]	1.52	5.80	.000*
	Hybrid hyrax	18.43	5.33	23.27	5.20	4.85[a]	2.10	6.00	.000*
	MSE	20.74	5.06	22.82	4.77	2.08[b]	1.30	1.70	.000*
	P value bet. groups	.353ns		.734ns		.000*			
Left.1st molar inclination	Butterfly hyrax	18.45	4.34	23.67	6.07	5.21[a]	2.74	6.30	.000*
	Hybrid hyrax	19.09	3.08	23.71	3.68	4.62[a]	1.62	4.90	.000*
	MSE	20.49	3.78	23.01	3.53	2.52[b]	1.31	2.35	.000*
	P value bet. groups	.312ns		.892ns		.003*			
Right.1st premolar inclination	Butterfly hyrax	6.70	2.51	11.72[a]	3.96	5.02[a]	2.18	5.90	.000*
	Hybrid hyrax	6.43	1.56	8.34[b]	1.63	1.91[b]	.98	1.60	.000*
	MSE	7.76	2.16	8.72[b]	2.37	.96[b]	.51	0.90	.000*
	P value bet. groups	.191ns		.003*		.000*			
Left.1st premolar inclination	Butterfly hyrax	7.37	2.39	12.46[a]	3.48	5.09[a]	5.09	5.80	.003*
	Hybrid hyrax	6.57	1.60	8.63[b]	1.51	2.06[b]	2.06	2.20	.000*
	MSE	7.61	2.17	8.41[b]	2.08	.80[c]	.80	0.70	.000*
	P value bet. groups	.355ns		.000*		.000*			

Significance level p≤0.05, *significant, ns=non-significant
Post hoc test: Within the same comparison, means sharing the same superscript letter are not significantly different

Table 6: Descriptive statistics and comparison between (ANOVA test) and within group (i.e. between pre and post value) (paired t test) regarding arch depth; incisor inclination

	GROUP	**Pre**		**Post**		**Amount of change (post-pre)**			**P Within group**
		Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Median**	
Arch depth	Butterfly hyrax	26.92	2.87	26.19[a]	2.47	-.74[a]	.38	-0.70	.000*
	Hybrid hyrax	25.93	2.47	25.39[a]	2.43	-.53[a]	.22	-0.50	.000*
	MSE	24.72	2.25	23.38[b]	2.41	-1.34[b]	.60	-1.30	.000*
	P value bet. groups	.064ns		.007*		.000*			
Incisor inclination	Butterfly hyrax	117.31	3.65	114.46	3.37	-2.85[a]	2.00	-2.80	.000*
	Hybrid hyrax	118.45	4.29	114.67	4.30	-3.79[a]	1.80	-3.70	.000*
	MSE	120.05	5.32	114.63	5.79	-5.43[b]	1.48	-5.30	.000*
		.243 ns		.992 ns		.001*			
Anterior suture opening	Butterfly hyrax	.09	.27	3.57[b]	.47	3.47[b]	.34	3.50	.004*
	Hybrid hyrax	.27	.44	3.93[b]	.64	3.67[b]	.36	3.70	.000*
	MSE	.30	.42	5.99[a]	.46	5.69[a]	.33	5.70	.002*
	P value bet. groups	.290 ns		.000*		.000*			

Posterior suture opening	Butterfly hyrax	.00	.00	2.14[c]	.44	2.14[c]	.44	2.20	.000*
	Hybrid hyrax	.00	.00	3.06[b]	.37	3.06[b]	.37	3.10	.000*
	MSE	.00	.00	5.16[a]	.49	5.16[a]	.49	5.05	.000*
	P value bet. groups	---		.000*		.000*			

Significance level p≤0.05, *significant, ns=non-significant

Post hoc test: Within the same comparison, means sharing the same superscript letter are not significantly different

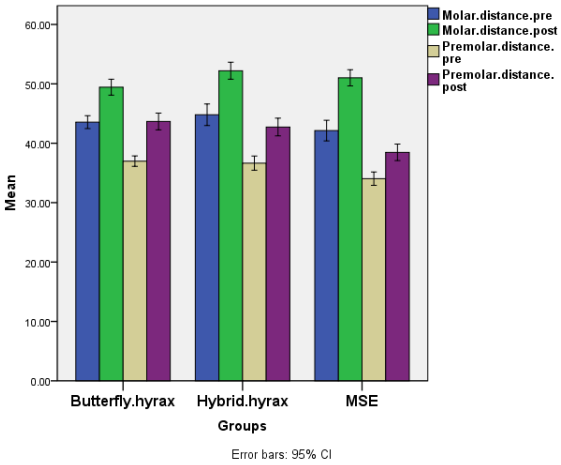


Figure 7: Bar chart illustrating mean value of molar and premolar distances in different groups

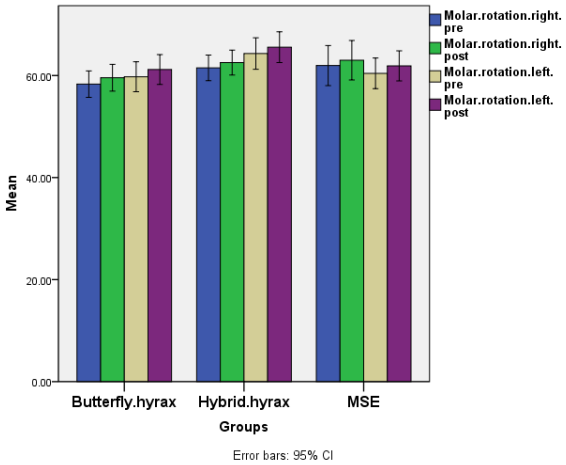


Figure 8: Bar chart illustrating mean value of molar rotation in different groups

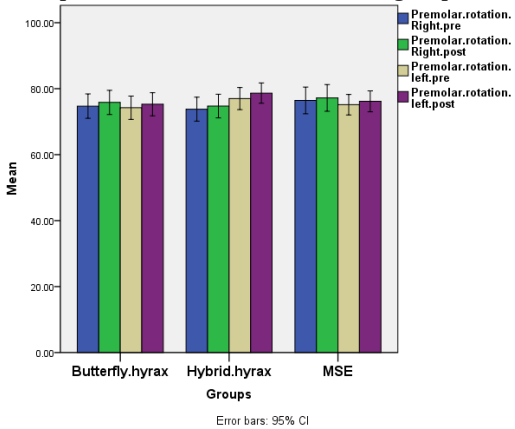


Figure 9: Bar chart illustrating mean value of premolar rotation in different groups

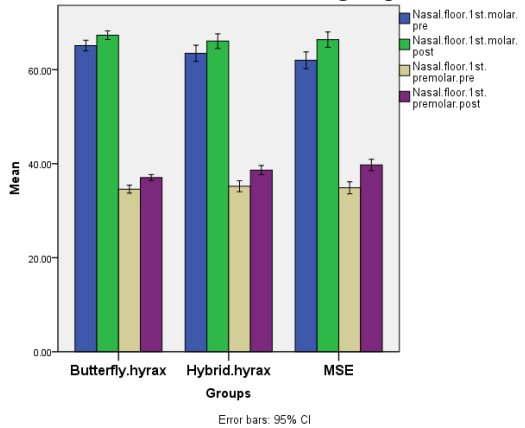


Figure 10: Bar chart illustrating mean value of nasal floor first molar and premolar in different groups

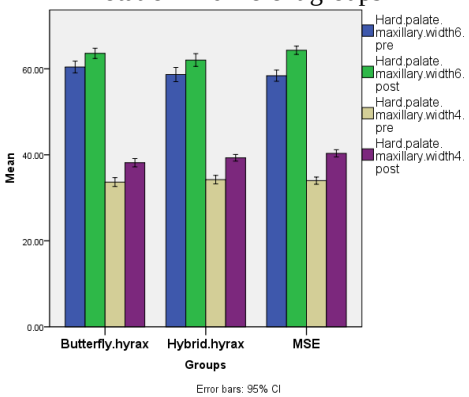


Figure 11: Bar chart illustrating mean value of hard palate maxillary width first molar and premolar in different groups

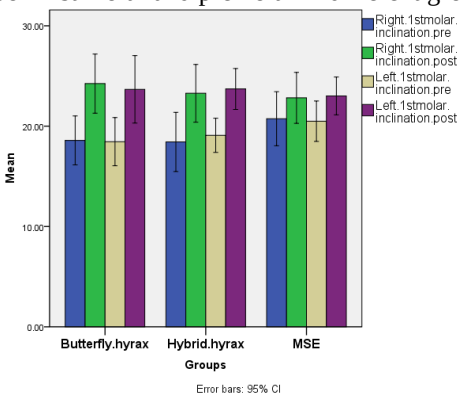


Figure 12: Bar chart illustrating mean value of molar inclination in different groups

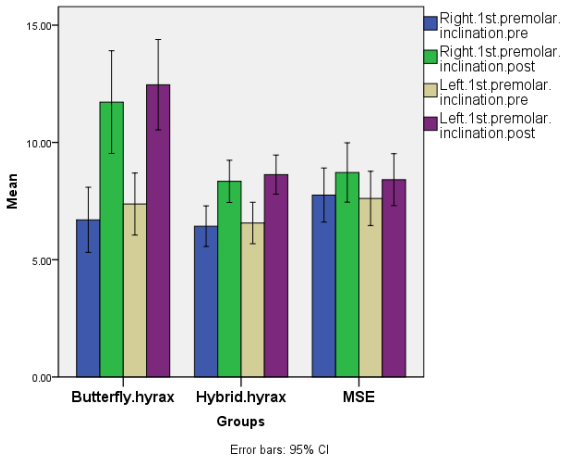


Figure 13: Bar chart illustrating mean value of premolar inclination in different groups

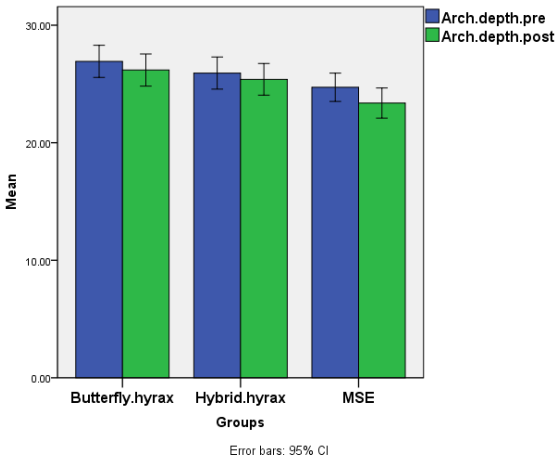


Figure 14: Bar chart illustrating mean value of arch depth in different groups

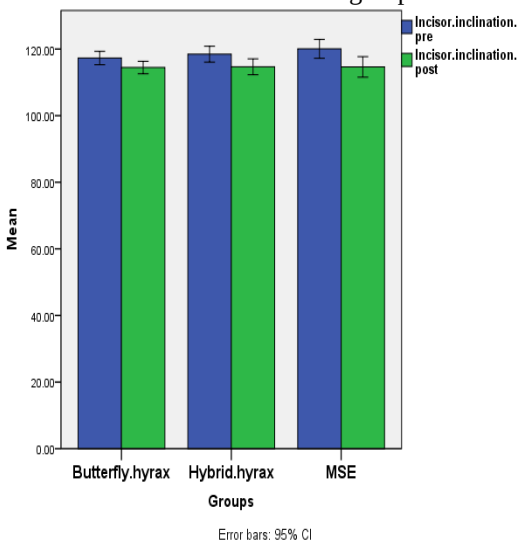


Figure 15: Bar chart illustrating mean value of incisor inclination in different groups

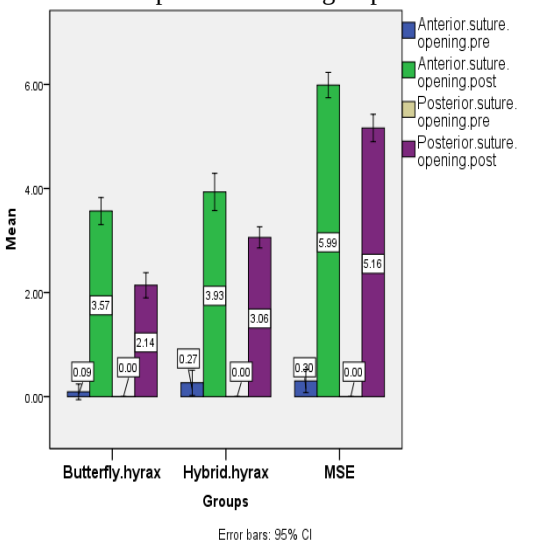


Figure 16: Bar chart illustrating mean value of anterior and posterior suture opening in different groups

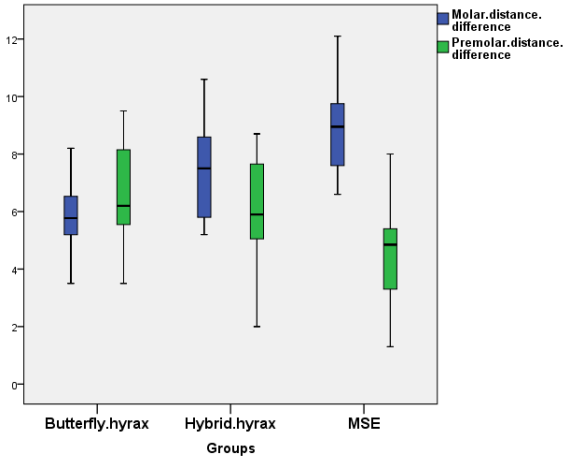


Figure 17: Box plot illustrating value of difference in molar and premolar distance in different groups

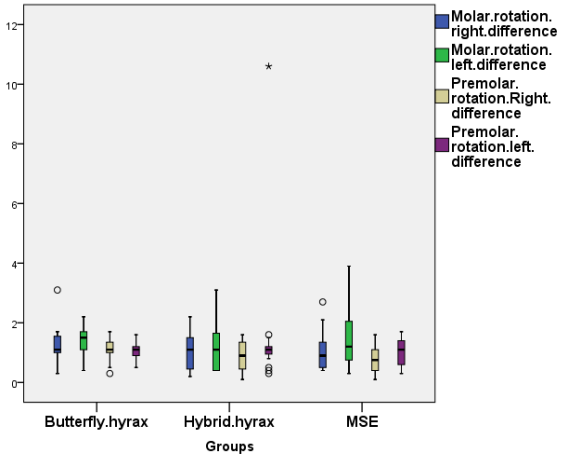


Figure 18: Box plot illustrating value of difference in molar and premolar rotation in different groups

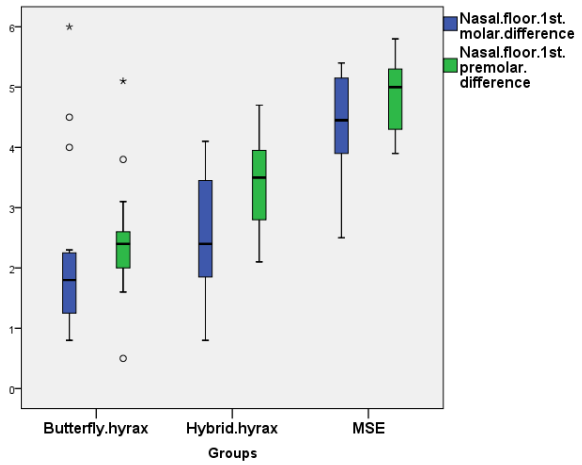


Figure 19: Box plot illustrating value of difference in nasal floor difference in different groups

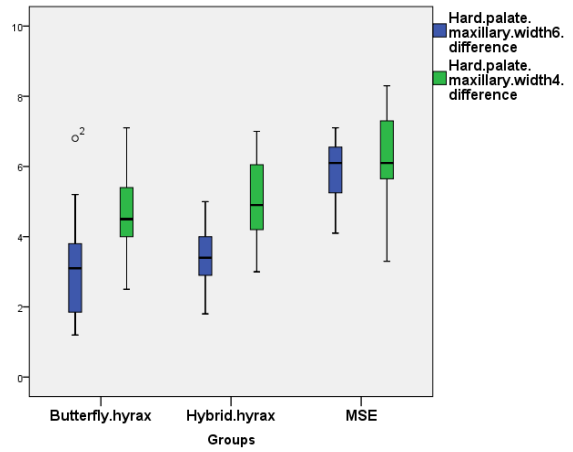


Figure 20: Box plot illustrating value of difference in hard palate maxillary molar and premolar in different groups

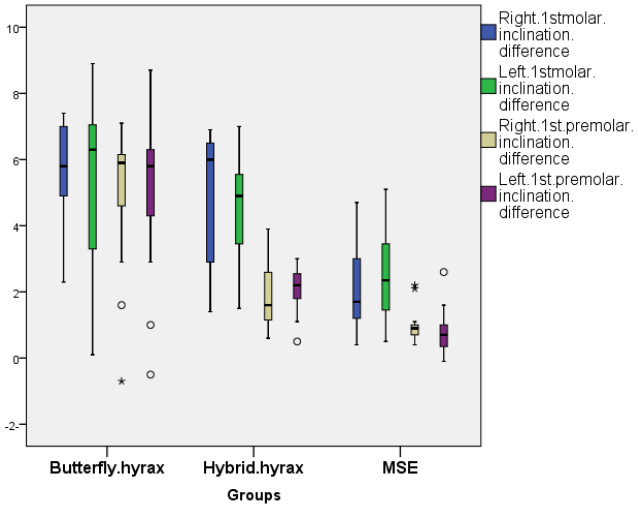


Figure 21: Box plot illustrating value of difference in molar and premolar inclination in different groups

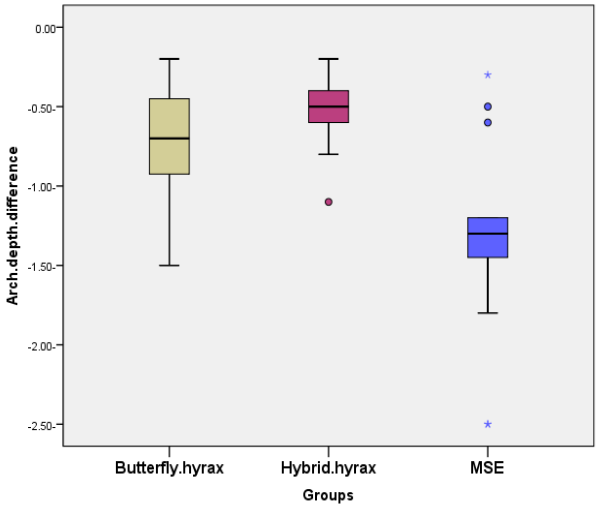


Figure 22: Box plot illustrating value of difference in arch depth in different groups

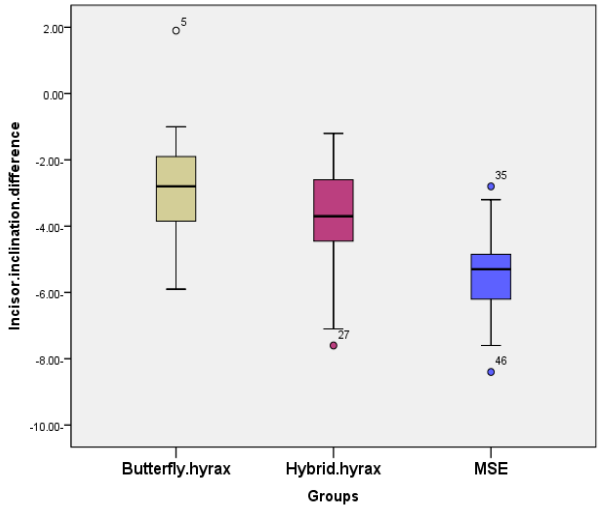


Figure 23: Box plot illustrating value of difference in incisor inclination in different groups

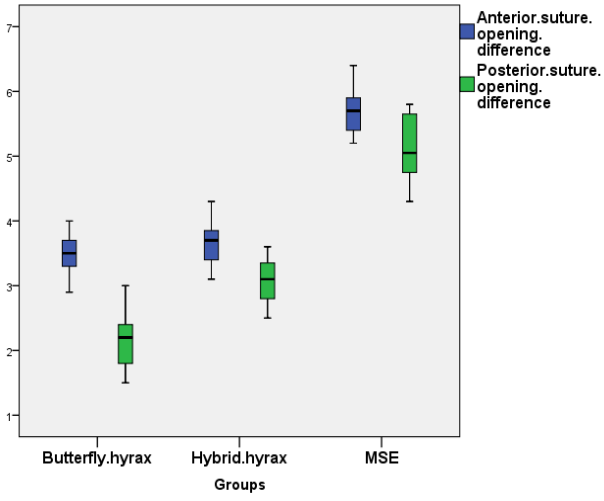


Figure 24: Box plot illustrating value of difference in anterior and posterior suture opening in different groups

DISCUSSION

Because of the nature of the clinical work, the issue of blindness toward the patients or the practitioners to the processes was very difficult and cannot be avoided entirely; nevertheless, the outcome assessors were not aware of the groups to which the patients belonged.[33]

Due to ethical concerns, it was not possible to have a group mimic skeletal pattern to the treated sample act as control because the activation period lasted 16 days as standardization and to reduce bias,[8,34]and this period is non-significant in the facial growth curve because all of the patients were expected to pass the peak of maxillary growth. [35]

CBCT was selected to calculate the linear parameters. Previous studies[36–38] have proved that acurate measurements hether linear or angular dento-skeletal can be donethrough using CBCT were images. A minute systematic error was mentioned in study,[36] but it has no statistical effect except in summation of the total combined value. on the other hand, CBCT can tell multiple knowledge on various levels about the remodeling style of bone and soft tissues after rapid maxillary expansion.[39]

One of the image quality drawbacks was the wide field of view, which increased susceptibility to scatter noise and, as a result, decreased spatial resolution. However, full skull exposure was necessary to permit accurate skull alignment and link the results with more conventional reference planes, such as FH and MSP..[40,41]

This result was consistent with earlier researches that used CBCT as an assessment tool.[38,42–45]

To permit more stable skeletal effect, to discard metallic artifacts during the second exposure of CBCT at T2,[46] and permit for deposition of mierals at the midpalatal suture, comprehensive treatment was performed after suitable six months retention period.[34]

The type of appliance used, sample age, gender, bone density, midpalatal suture maturity, and muscle and soft tissue behaviour may all have an impact on the results obtained following maxillary expansion.[47,48]

The anatomical elements that vary significantly include the pyramidal process's size and shape, the thickness and density of each individual bone , the degree of interdigitation between sutures, or the intimate relationships between several circummaxillary sutures, all of these confounders should be considered.

Moreover, it was not surprising that the midline diastema appeared except in 3 cases in group 1 CH. The breadth of the diastema was not measured since it was probably not a reliable sign of sutural expansion, as multiple factors, such as the perioral musculature, frenum attachment, tongue location, and transeptal fiber strength, can influence the degree of diastema.[10,49]

Using a conventional RPE on developing patients, Lione et al[50] found that the spiliting of midpalatal suture at the anterior and posterior nasal spines was 3.01 and 1.15, respectively, while Cantarella et al.[51] found that In late adolescents, MSE effectively separated the midpalatal suture, resulting in a nearly good split and paralism of the suturewhen viewed sagittaly. The separation at the posterior nasal spine (4.3 mm) was roughly 90% of that at the front nasal spine (4.8 mm).[52]

Skeletal expansion 5.91 mmwas higher with tooth-bone-borne devices (MSE and HH) compared to tooth-borne devices (CH expanders). The direct projection of force on the maxilla at the depth of the palatal vault brings it closer to the center of resistance compared to a CH appliance.

An essential component of the MARPE design is the miniscrew's location. One of the best places for practical anchorage needs is the T-zone in the anterior palate.[53–55] Due to its remoteness from anatomical structures, this region offers superior stability with minimal soft tissue annoyance and strong bone quality. It is also safe in avoiding accidental touch with roots.[56]

The ideal for placing temporary anchoring devices at the first and second premolar levels.[57]

In the present study ,when viewed axially, the MSE's four mini-screws—two anterior and two posterior—allow the mid-palatal suture to separate in a parallel fashon to the zygomatic buttress bones, in comparison to the CH and HH this is due to the biomechanical effect of the two posterior miniscrews.

In 36 patients of group 2 and 3, only twowere discarded due to failure of the miniscrews in the MSE and 3 patients in hybrid hyrax lost to follo up the treatment, whereas 31 had clinically acceptable mobility.

The occurrence of unilateral crossbite cases or the distinct physiology of the circummaxillary suture response to the application of expansion force in the right and left sides may be the cause of asymmetrical spiliting, this was by previous study.[51]

The average rise in TI results at themaxillary permanent first molar both right and left sideamong the groups was cleared,with no difference suggesting a symmetrical effect of expansion, which was in agreement with others.[45,58,59] and was at odds with earlier researches.[43,44] Since the molars in Akin et al [43] which used a different expander with a different activation protocol in patients with actual unilateral posterior crossbite, had more tipping (7.3) degree on the affected side than on the unaffected side (2.5)degree.[43]

As regard to skeletal changes at the level of nasal floor related to first molar highest value recorded in MSE (4.38±0.85) mm, followed by HH (2.6±1.04) mm and the lowest value recorded in CH (2.2± 1.49) mm. This agreed with previous studies.[39,50,51,60–63]

The skeletal changes at the level of nasal floor related to first premolar showed that the highest value recorded in MSE (4.87±0.62) mm, followed by HH (3.43±.74) mm and the lowest value recorded in CH (2.47± 1.02) mm,

At the level of hard palate related to first premolar, the skeletal changes clear the effect of MSE is higher in comparison to the other two devices. On the other hand when hard palate related to first premolar was evaluated, the changes confirmed the real orthopedic effect of MSE is the highest when compared to the CH and HH, this was in accordance with previous studies.[61,62,64–66].The changes in maxillary width at the nasal floor and in the palatal level (NF and HP) were fewer than those in inter dental level . RME's differential impact is described by the lateral rotation of the maxillary halves, with a fulcrum placed near the frontomaxillary suture.

The inter molar distance in the present study was 5.88mm in CH, 7.42 mm in HH and 8.88 mm in MSE, where the teeth inclination in the present study of first molar was 1.52 and 2.74in CH, 2.1and 1.62 in HH and in MSE was 1.30 for the right side and 1.31degree in the left side. As pointed to the inter premolar distance in the current study was 5.88mm in CH, 7.42 mm in HH and 8.88 mm in MSE, respectively,where the teeth inclination in the first premolar was 5.02 degree and 5.09 in CH, 1.91degree and 2.06 in HH and in MSE was 0.51 for the right side and 0.8 degree in the left side this was in agreement with Choi et al[66], Akyalcin et al [64], while it was in discordance with Garib etal[60], since the design of the CH in the present study does not contain band on the first premolar and the difference in age of participants.

In HH and MSE, the less teeth inclination in comparison to conventional hyrax due to the additional stability and direct effect on bone provided by the miniscrews, which can increase the expansion results in more skeletal form in the palatal bone and suture. This was consistent with earlier research[32,34,67–70]

The molar rotation was 1.25 degree in CH while in HH and MSE was 1.04 that means the amount of rotation at the molar level did not show any significant difference while the premolar results were 1.13 degree in CH , 0.93 in HH and 0.78 degree in MSE, revealing lees rotation in MSE due to no band on the first premolar

The current study's results for tooth rotation disagreed with Corbridge et al[65] who observed a substantial increase in molar rotation, owing to the fact that they utilized a different approach (SME), a different device (quad helix), and a different age group (9.2 years).

The arch depth after expansion exposed a distinctive decrease in all groups, -0.74 mm in CH ,-0.53mm in HH and – 1.34 mm in MSE

In the current investigation, palatal movement of the maxillary incisors was seen in all groups, which is consistent with prior findings.[61,62] However, this contradicted the findings published by Doruk et al[71], who highlighted some incisor proclination in group I (fan type), but group II (hyrax type) was consistent with the current study.

Perhaps perioral musculature or other physiologic pressures kept the incisors from tilting toward the labium. The molars showed modest buccal tilting, as predicted, while the incisors did not, which might be explained by the molars' firm connection to the appliance, preventing the perioral musculature and other physiologic pressures from operating on them.[72–74]

Previous researches.[69,70,75,76]on the skeletal effects of these devices supports the MSE's superior ability to induce skeletal expansion and promote alveolar stability. In the current study, the MSE tends to exert less force on the surrounding gingival and periodontal tissues than conventional expanders, potentially lowering the risk of periodontal complications.

As regard the palatal measurements, it was stated thatthe changes resulting from the effect of growth on the palate per year are minor and little [63,77]

CONCLUSIONS

After expansion, all kinds performed well; however, as compared to the conventional hyrax appliance, the MARPE, and particularly the MSE, had stronger skeletal impact and less buccal tilting.

Since palatal expansion always results in a short-term increase in transverse dimension, it is a successful technique for treating dental posterior crossbite.

LIMITATIONS

Evaluation of gender differences, hormonal effects, and the lack of a passive group as a control for moral and medical-legal concerns.

Application of indirect miniscrew positioning in the hybrid group was neglected to simulate direct application of miniscre in MSE,appliance first group.

Using three-dimensional printed expansion appliances instead of bands may encourage more effective transformation.

REFERENCES

1. McNamaraa JA. Maxillary transverse deficiency. American journal of orthodontics and dentofacial orthopedics 2000;117(5):567–70.
2. Shendy MA, Assadawy MI, Galal AM, Mahmoud HM, Ahmed AI, Abdelhameed WB, et al. A Retrospective CBCT Investigation utilizing a New 3D Segmentation Method to Assess Mid-Palatal

Suture Response After Rapid Maxillary Expansion with a Hybrid Expander in Adolescents. Neuroquantology 2022;20(19):3900.
3. Bucci R, D'Antò V, Rongo R, Valletta R, Martina R, Michelotti A. Dental and skeletal effects of palatal expansion techniques: a systematic review of the current evidence from systematic reviews and meta-analyses. J Oral Rehabil 2016;43(7):543–64.
4. Björk A. Sutural growth of the upper face studied by the implant method. Acta Odontol Scand 1966;24(2):109–27.
5. Karaman A, Danisman H, Genc E, Buyuk SK. Comparison of skeletal and dental effects of two different tooth-tissue–borne types of rapid maxillary expansion appliances: A CBCT retrospective study. OrthodCraniofac Res 2023;26(1):123–31.
6. Haas AJ. The Treatment Of Maxillary Deficiency By Opening The Midpalatal Suture. Angle Orthod1965;35:200–17.
7. Bishara SE, Staley RN. Maxillary expansion: clinical implications. American journal of orthodontics and dentofacial orthopedics 1987;91(1):3–14.
8. AShendy M, A Atwa A, Y Abu Shahba R. Effect of rapid maxillary expansion on the buccal alveolar bone: Clinical and radiographic evaluation. Al-Azhar Journal of Dental Science 2018;21(2):175–82.
9. Bazargani F, Lund H, Magnuson A, Ludwig B. Skeletal and dentoalveolar effects using tooth-borne and tooth-bone-borne RME appliances: a randomized controlled trial with 1-year follow-up. Eur J Orthod 2021;43(3):245–53.
10. Stuart DA, Wiltshire WA. Rapid palatal expansion in the young adult: time for a paradigm shift? Journal-Canadian Dental Association 2003;69(6):374–7.
11. Rinaldi MRL, Azeredo F, de Lima EM, Rizzatto SMD, Sameshima G, de Menezes LM. Cone-beam computed tomography evaluation of bone plate and root length after maxillary expansion using tooth-borne and tooth-tissue-borne banded expanders. American Journal of Orthodontics and Dentofacial Orthopedics 2018;154(4):504–16.
12. Yildirim M, Akin M. Comparison of root resorption after bone-borne and tooth-borne rapid maxillary expansion evaluated with the use of microtomography. American Journal of Orthodontics and Dentofacial Orthopedics 2019;155(2):182–90.
13. Lo Giudice A, Barbato E, Cosentino L, Ferraro CM, Leonardi R. Alveolar bone changes after rapid maxillary expansion with tooth-born appliances: a systematic review. Eur J Orthod 2018;40(3):296–303.
14. Winsauer H, Vlachojannis C, Bumann A, Vlachojannis J, Chrubasik S. Paramedian vertical palatal bone height for mini-implant insertion: a systematic review. Eur J Orthod 2014;36(5):541–9.
15. King KS, Lam EW, Faulkner MG, Heo G, Major PW. Predictive factors of vertical bone depth in the paramedian palate of adolescents. Angle Orthod 2006;76(5):745–51.
16. Ryu JH, Park JH, Thu TVT, Bayome M, Kim Y, Kook YA. Palatal bone thickness compared with cone-beam computed tomography in adolescents and adults for mini-implant placement. American Journal of Orthodontics and Dentofacial Orthopedics 2012;142(2):207–12.
17. Hourfar J, Bister D, Lux CJ, Al-Tamimi B, Ludwig B. Anatomic landmarks and availability of bone for placement of orthodontic mini-implants for normal and short maxillary body lengths. American Journal of Orthodontics and Dentofacial Orthopedics 2017;151(5):878–86.
18. Yang L, Li F, Cao M, Chen H, Wang X, Chen X, et al. Quantitative evaluation of maxillary interradicular bone with cone-beam computed tomography for bicortical placement of orthodontic mini-implants. American Journal of Orthodontics and Dentofacial Orthopedics 2015;147(6):725–37.
19. Kaya N, Seker ED, Yücesoy T. Comparison of the effects of different rapid maxillary expansion techniques on craniofacial structures: a finite element analysis study. Prog Orthod 2023;24(1):7.
20. Loriato L, Ferreira CE. Surgically-assisted rapid maxillary expansion (SARME): indications, planning and treatment of severe maxillary deficiency in an adult patient. Dental Press J Orthod2020;25:73–84.
21. Sygouros A, Motro M, Ugurlu F, Acar A. Surgically assisted rapid maxillary expansion: cone-beam computed tomography evaluation of different surgical techniques and their effects on the maxillary dentoskeletal complex. American Journal of Orthodontics and Dentofacial Orthopedics 2014;146(6):748–57.
22. Zandi M, Miresmaeili A, Heidari A, Lamei A. The necessity of pterygomaxillary disjunction in surgically assisted rapid maxillary expansion: A short-term, double-blind, historical controlled clinical trial. Journal of Cranio-Maxillofacial Surgery 2016;44(9):1181–6.
23. Laudemann K, Petruchin O, Mack MG, Kopp S, Sader R, Landes CA. Evaluation of surgically assisted rapid maxillary expansion with or without pterygomaxillary disjunction based upon preoperative and post-expansion 3D computed tomography data. Oral Maxillofac Surg 2009;13:159–69.
24. Olszewski R, Wisniewski M. Complications in surgically assisted rapid maxillary expansion: a systematic review of the medical literature. Nemesis Negative Effects in Medical Sciences Oral and Maxillofacial Surgery 2019;8(1):20.

25. Carvalho PHA, Moura LB, Trento GS, Holzinger D, Gabrielli MAC, Gabrielli MFR, et al. Surgically assisted rapid maxillary expansion: a systematic review of complications. Int J Oral Maxillofac Surg 2020;49(3):325–32.
26. Lee KJ, Park YC, Park JY, Hwang WS. Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism. American Journal of Orthodontics and Dentofacial Orthopedics 2010;137(6):830–9.
27. Kapetanović A, Theodorou CI, Bergé SJ, Schols JGJH, Xi T. Efficacy of Miniscrew-Assisted Rapid Palatal Expansion (MARPE) in late adolescents and adults: a systematic review and meta-analysis. Eur J Orthod 2021;43(3):313–23.
28. Moon HW, Kim MJ, Ahn HW, Kim SJ, Kim SH, Chung KR, et al. Molar inclination and surrounding alveolar bone change relative to the design of bone-borne maxillary expanders: a CBCT study. Angle Orthod 2020;90(1):13–22.
29. Lin L, Ahn HW, Kim SJ, Moon SC, Kim SH, Nelson G. Tooth-borne vs bone-borne rapid maxillary expanders in late adolescence. Angle Orthod 2015;85(2):253–62.
30. Shendy MA, Shouman AA, Eshky RT, Althagafi NM, Elsayed SA, Abd-El Meneim MH. Changes in digital cast measurements related with two types of rapid maxillary expanders, tooth-borne versus hybrid one: A retrospective cohort study.
31. Krüsi M, Eliades T, Papageorgiou SN. Are there benefits from using bone-borne maxillary expansion instead of tooth-borne maxillary expansion? A systematic review with meta-analysis. Prog Orthod2019;20:1–12.
32. Brunetto M, Andriani J da SP, Ribeiro GLU, Locks A, Correa M, Correa LR. Three-dimensional assessment of buccal alveolar bone after rapid and slow maxillary expansion: a clinical trial study. American Journal of Orthodontics and Dentofacial Orthopedics 2013;143(5):633–44.
33. Lowe CJM, Wilson MS, Sackley CM, Barker KL. Blind outcome assessment: the development and use of procedures to maintain and describe blinding in a pragmatic physiotherapy rehabilitation trial. Clin Rehabil 2011;25(3):264–74.
34. Ballanti F, Lione R, Fanucci E, Franchi L, Baccetti T, Cozza P. Immediate and post-retention effects of rapid maxillary expansion investigated by computed tomography in growing patients. Angle Orthod 2009;79(1):24–9.
35. Miller FG, Emanuel EJ, Rosenstein DL, Straus SE. Ethical issues concerning research in complementary and alternative medicine. JAMA 2004;291(5):599–604.
36. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. American journal of orthodontics and dentofacial orthopedics 2009;136(1):19–25.
37. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. American Journal of Orthodontics and Dentofacial Orthopedics 2008;134(1):112–6.
38. de Faria Vasconcelos K, Evangelista KM, Rodrigues CD, Estrela C, De Sousa TO, Silva MAG. Detection of periodontal bone loss using cone beam CT and intraoral radiography. Dentomaxillofacial Radiology 2012;41(1):64–9.
39. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. American Journal of Orthodontics and Dentofacial Orthopedics 2012;142(2):269–73.
40. Vogiatzi T, Menz R, Verna C, Bornstein MM, Dagassan-Berndt D. Effect of field of view (FOV) positioning and shielding on radiation dose in paediatric CBCT. Dentomaxillofacial Radiology 2022;51(6).
41. Elshenawy H, Aly W, Salah N, Nasry S, Anter E, Ekram K. Influence of Small, Midi, Medium and large fields of view on accuracy of linear measurements in CBCT imaging: diagnostic accuracy study. Open Access Maced J Med Sci 2019;7(6):1037.
42. Paredes N, Colak O, Sfogliano L, Elkenawy I, Fijany L, Fraser A, et al. Differential assessment of skeletal, alveolar, and dental components induced by microimplant-supported midfacial skeletal expander (MSE), utilizing novel angular measurements from the fulcrum. Prog Orthod2020;21:1–12.
43. Akin M, Baka ZM, Ileri Z, Basciftci FA. Alveolar bone changes after asymmetric rapid maxillary expansion. Angle Orthod 2015;85(5):799–805.
44. Woller JL, Kim KB, Behrents RG, Buschang PH. An assessment of the maxilla after rapid maxillary expansion using cone beam computed tomography in growing children. Dental Press J Orthod2014;19:26–35.
45. Rungcharassaeng K, Caruso JM, Kan JYK, Kim J, Taylor G. Factors affecting buccal bone changes of maxillary posterior teeth after rapid maxillary expansion. American Journal of Orthodontics and Dentofacial Orthopedics 2007;132(4):428-e1.

46. Troca BS, Felizardo HMA, Gaêta-Araujo H. Expression of artefacts from different orthodontic brackets and wires in cone beam computed tomography scans-an in vitro study. Clin Oral Investig 2024;28(8):450.
47. Lee HK, Bayome M, Ahn CS, Kim SH, Kim KB, Mo SS, et al. Stress distribution and displacement by different bone-borne palatal expanders with micro-implants: a three-dimensional finite-element analysis. Eur J Orthod 2014;36(5):531–40.
48. Lee RJ, Moon W, Hong C. Effects of monocortical and bicortical mini-implant anchorage on bone-borne palatal expansion using finite element analysis. American Journal of Orthodontics and Dentofacial Orthopedics 2017;151(5):887–97.
49. Sayar G, Kılınç DD. Rapid maxillary expansion outcomes according to midpalatal suture maturation levels. Prog Orthod2019;20:1–7.
50. Lione R, Ballanti F, Franchi L, Baccetti T, Cozza P. Treatment and posttreatment skeletal effects of rapid maxillary expansion studied with low-dose computed tomography in growing subjects. American journal of orthodontics and dentofacial orthopedics 2008;134(3):389–92.
51. Cantarella D, Dominguez-Mompell R, Mallya SM, Moschik C, Pan HC, Miller J, et al. Changes in the midpalatal and pterygopalatine sutures induced by micro-implant-supported skeletal expander, analyzed with a novel 3D method based on CBCT imaging. Prog Orthod2017;18:1–12.
52. Salmoria I, de Souza EC, Furtado A, Franzini CM, Custodio W. Dentoskeletal changes and their correlations after micro-implant-assisted palatal expansion (MARPE) in adults with advanced midpalatal suture ossification. Clin Oral Investig 2022;1–11.
53. Becker K, Unland J, Wilmes B, Tarraf NE, Drescher D. Is there an ideal insertion angle and position for orthodontic mini-implants in the anterior palate? A CBCT study in humans. American Journal of Orthodontics and Dentofacial Orthopedics 2019;156(3):345–54.
54. Wilmes B, Ludwig B, Vasudavan S, Nienkemper M, Drescher D. The T-zone: median vs. paramedian insertion of palatal mini-implants. J Clin Orthod 2016;50(9):543–51.
55. Lyu X, Guo J, Chen L, Gao Y, Liu L, Pu L, et al. Assessment of available sites for palatal orthodontic mini-implants through cone-beam computed tomography. Angle Orthod 2020;90(4):516–23.
56. Wilmes B, Neuschulz J, Safar M, Braumann B, Drescher D. Protocols for combining the Beneslider with lingual appliances in Class II treatment. J Clin Orthod 2014;48(12):744–52.
57. Baumgaertel S. Quantitative investigation of palatal bone depth and cortical bone thickness for mini-implant placement in adults. American Journal of Orthodontics and Dentofacial Orthopedics 2009;136(1):104–8.
58. Weissheimer A, de Menezes LM, Mezomo M, Dias DM, de Lima EMS, Rizzatto SMD. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. American journal of orthodontics and dentofacial orthopedics 2011;140(3):366–76.
59. Garib DG, Henriques JFC, Janson G, de Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. American journal of orthodontics and dentofacial orthopedics 2006;129(6):749–58.
60. Garib DG, Henriques JFC, Janson G, Freitas MR, Coelho RA. Rapid maxillary expansion—tooth tissue-borne versus tooth-borne expanders: a computed tomography evaluation of dentoskeletal effects. Angle Orthod 2005;75(4):548–57.
61. Lagravère MO, Carey J, Heo G, Toogood RW, Major PW. Transverse, vertical, and anteroposterior changes from bone-anchored maxillary expansion vs traditional rapid maxillary expansion: a randomized clinical trial. American Journal of Orthodontics and Dentofacial Orthopedics 2010;137(3):304-e1.
62. Farronato G, Giannini L, Galbiati G, Maspero C. Sagittal and vertical effects of rapid maxillary expansion in Class I, II, and III occlusions. Angle Orthod 2011;81(2):298–303.
63. Kim HK, Moon SC, Lee SJ, Park YS. Three-dimensional biometric study of palatine rugae in children with a mixed-model analysis: a 9-year longitudinal study. American Journal of Orthodontics and Dentofacial Orthopedics 2012;141(5):590–7.
64. Akyalcin S, Schaefer JS, English JD, Stephens CR, Winkelmann S. A cone-beam computed tomography evaluation of buccal bone thickness following maxillary expansion. Imaging Sci Dent 2013;43(2):85–90.
65. Corbridge JK, Campbell PM, Taylor R, Ceen RF, Buschang PH. Transverse dentoalveolar changes after slow maxillary expansion. American Journal of Orthodontics and Dentofacial Orthopedics 2011;140(3):317–25.
66. Choi SH, Shi KK, Cha JY, Park YC, Lee KJ. Nonsurgical miniscrew-assisted rapid maxillary expansion results in acceptable stability in young adults. Angle Orthod 2016;86(5):713–20.
67. Yoon S, Lee DY, Jung SK. Influence of changing various parameters in miniscrew-assisted rapid palatal expansion: a three-dimensional finite element analysis. Korean J Orthod 2019;49(3):150.
68. Choi EHA, Lee KJ, Choi SH, Jung HD, Ahn HJ, Deguchi T, et al. Skeletal and dentoalveolar effects of miniscrew-assisted rapid palatal expansion based on the length of the miniscrew: a randomized clinical trial. Angle Orthod 2023;93(4):390–7.

69. Mehta S, Arqub SA, Vishwanath M, Upadhyay M, Yadav S. Biomechanics of conventional and miniscrew-assisted rapid palatal expansion. J World Fed Orthod2024;
70. Oliveira PLE, Soares KEM, ANDRADE RM de, OLIVEIRA GC de, Pithon MM, ARAÚJO MT de S, et al. Stress and displacement of mini-implants and appliance in Mini-implant Assisted Rapid Palatal Expansion: analysis by finite element method. Dental Press J Orthod 2021;26(04):e21203.
71. Doruk C, Bicakci AA, Basciftci FA, Agar U, Babacan H. A comparison of the effects of rapid maxillary expansion and fan-type rapid maxillary expansion on dentofacial structures. Angle Orthod 2004;74(2):184–94.
72. Braun S, Bottrel JA, Lee KG, Lunazzi JJ, Legan HL. The biomechanics of rapid maxillary sutural expansion. American Journal of Orthodontics and Dentofacial Orthopedics 2000;118(3):257–61.
73. Takahashi M, Koide K, Arakawa I, Mizuhashi F. Association between perioral muscle pressure and masticatory performance. J Oral Rehabil 2013;40(12):909–15.
74. Bianco T, Freour V, Cossette I, Bevilacqua F, Caussé R. Measures of facial muscle activation, intra-oral pressure and mouthpiece force in trumpet playing. J New Music Res 2012;41(1):49–65.
75. Hartono N, Soegiharto BM, Widayati R. The difference of stress distribution of maxillary expansion using rapid maxillary expander (RME) and maxillary skeletal expander (MSE)—a finite element analysis. Prog Orthod2018;19:1–10.
76. Cantarella D. Skeletal effects induced by Maxillary Skeletal Expander (MSE) and Hyrax appliance in the midface. University of California, Los Angeles; 2017.
77. Pazera C, Gkantidis N. Palatal rugae positional changes during orthodontic treatment of growing patients. OrthodCraniofac Res 2021;24(3):351–9.