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Evaluation of Three Types of Rapid Maxillary Expanders (Conventional, Hybrid, and MSE) on Morphological Changes in the Nasal Airway. A Randomized Clinical Trial -CBCT Study

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Abstract

***Aim of the study**: To compare radiographically the morphometric changes in the nasal airway after using three types of rapid maxillary expansion (RME) conventional hyrax (CH), hybrid hyrax (HH) and maxillary skeletal expander (MSE) using cone beam computed tomography (CBCT).*

***Material and Methods:** A total sample of thirty patients presented with constricted maxilla were randomized in to three equal groups. Group 1 CH, group 2 HH and group 3 Maxillary skeletal expander (MSE). The age ranges from 11 to 17 years (Y) with mean age 14.28, 15.06 and 15.40 Y respectively.*
CBCT records were taken before expansion (T1) and after six months (T2) of RME; the airway was segmented and quantified using Romexis software (version 5.3.4.39USA).

***Results:** The paired t test was used to compare the pre and post values. To compare the three groups, a one-way analysis of variance (ANOVA) was utilized. When the ANOVA test was significant, the Bonferroni post-hoc test was employed for pair-wise comparisons between groups. $P \leq 0.05$ was used as the significant level. In all groups, the post-treatment value was considerably larger than the pre-treatment value in total volume, nasopharyngeal volume, retropalatal volume, and nasal cavity, whereas the difference in retroglossal volume was not statistically significant in only group 3 (MSE).*

***Conclusions:** RME may have a good effect on airway regardless the appliance type.*

***Keywords:** Nasal airway; Morphometry; Morphological change Orthodontic expansion; Rapid palatal expansion; RPE; Rapid maxillary expansion; RME; Hyrax; Hybrid hyrax; Maxillary skeletal expansion; MSE; Cone beam computed tomography; CBCT*

Introduction

Rapid maxillary expansion (RME) is a common procedure for correcting posterior crossbite, mild maxillary crowding and maxillary arch constriction through opening the mid palatal suture. (1-3)

RME can open the palatal and circum maxillary sutures, splitting of maxilla into two parts which affect nasal airway through increase nasal cavity volume followed by decreased nasal resistance and improved airflow especially in children with obstructive sleep apnea. (4-7)

Previous studies reported that RME can improve the airway (8-10)

On the other hand, other studies reported that RME does not affect oropharynx dimension. (11,12)

A systematic review mentioned that small changes in volume does not guaranty improvement in breathing mode, hence they advised the clinician not to do RME to improve the breathing mode. (13)

Current evidence suggested that the conflict might be the different protocols of Cone beam computed tomography (CBCT) between studies, Head posture, tongue position, and segmentation protocols were not standardized in the selected studies hence they recommended more accurate and reliable protocol with fixed head and tongue positioning, also the segmentation method. (14)

Other evidence showed improvement only limited to short term evaluation rather than long term one (15) While other evidence showed no improvement even with short term especially with miniscrew assisted rapid palatal expansion (MARPE). (16)

From the above mentioned it is clear enough that the link between RME and the upper airway especially the oropharyngeal (OP) is still a mystery, So the aim of this study was to compare volumetric Three dimension (3D) and morphometric changes in the nasal airway after using three different Rapid maxillary expanders (RMEs) (conventional, hybrid and MSE) using cone beam computed tomography (CBCT).

Material and Method

This randomized controlled trial was conducted on patients seeking orthodontic treatment in the outpatient clinic, Orthodontic department, Faculty of Dental Medicine, Al-Azhar University, Cairo, Boys branch. It was approved with the ethical committee at Faculty of Dental Medicine, Al-Azhar University, Cairo, Boys branch. under code number 772/220.

The study followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Figure 1).

Sample size calculation using G power software was based on the previous article. (11) The following eligibility criteria were used to select the patients for the study: Patients suffering maxillary collapse

with a skeletal background, unilateral or bilateral posterior crossbite, varied in age from 11 to 17 years old and were in good dental and general health, with no systemic disorders that could influence bone quality or interfere with orthodontic treatment and no periodontal disease. Exclusion criteria include a history of trauma, midface syndromes, previous surgery of upper airway and previous orthognathic or orthodontic therapy. (17-19)

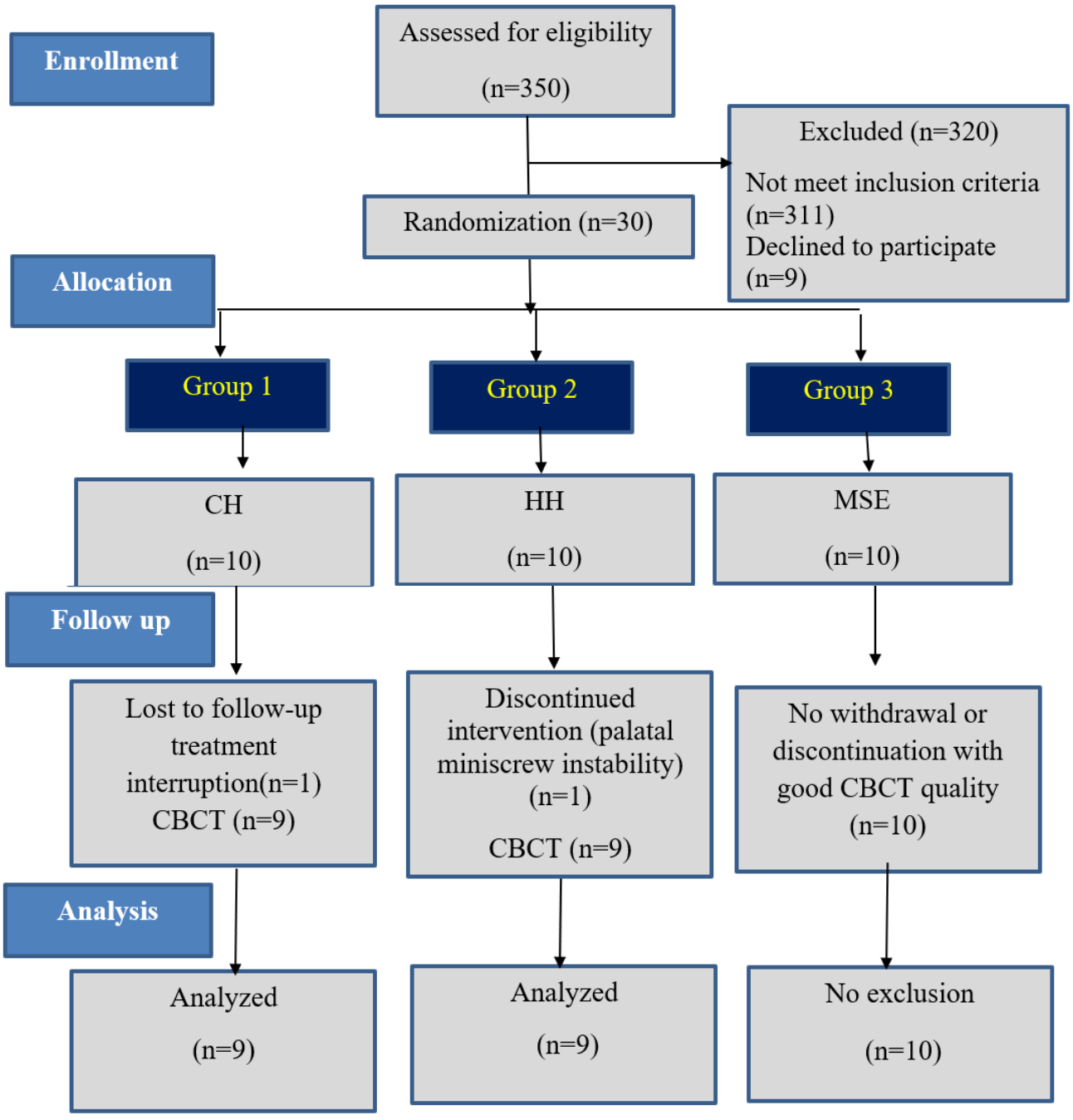


Figure (1): CONSORT flow diagram.

Thirty young adult orthodontic patients (20 girls and 10 boys) were selected, classified and randomly allocated into three equal groups, using online generated randomization plan (Graph Pad) found at the website; http://www.graphpad.com/quickcalcs/index.cfm.:

Group (1): The conventional hyrax (CH) (3 males and 7 females). (Figure 2A). Group (2): The Hybrid hyrax (HH) (4 males and 6 females). (Figure 2B). Group (3): The Maxillary skeletal expander (MSE) (3 males and 7 females). (Figure 2C).

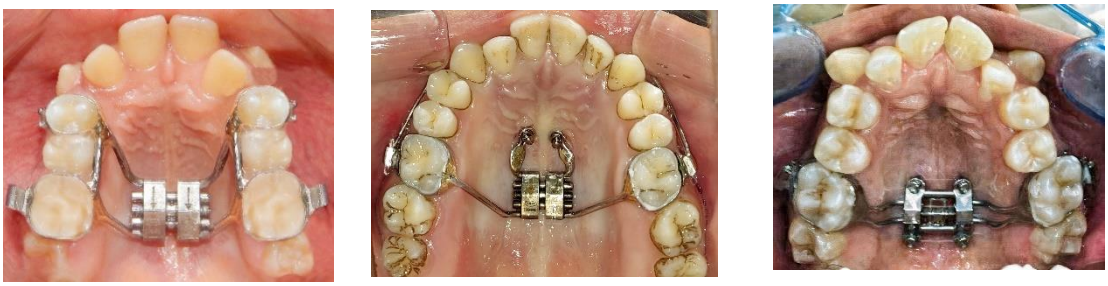


Figure (2): Three Different types of expansion appliances (A) Hyrax(B) Hybrid hyrax(C) MSE.

The following diagnostic records were taken for each patient before and after the completion of expansion treatment including: Orthodontic study casts, extra-oral and intra-oral photographs, Panoramic radiographs.

Hyrax expanders 9mm screw length were used and supported bilaterally by first premolars and first permanent molars in group 1 (conventional) (Figure 2A) and supported only with bilateral first permanent molar with two miniscrew in group 2 (hybrid) (Figure 2B) while group 3 has MSE which is composed of two soft titanium arms were attached to two molar bands and four miniscrews (1.8mm in diameter, 11mm in length) were inserted into the MSE jackscrew (Figure 2C) with four holes to increase posterior and superior expansion of the maxilla. By engaging the bicortical bony system.

After appliance insertion and cementation, the protocol of rapid expansion was two turns per day for about 16 days.

Patient frequent observation in the follow up was mandatory to ensure the soundness of opening procedures. After the last activation, the screw was stabilized with ligature wire and masked with a small piece of flowable composite and kept as a retainer for six months. No further orthodontic treatment was started in both jaws until the retention phase was completed.

The cone beam computed tomography (CBCT) were taken before the start of the orthodontic expansion (T1) and six months later, shortly after the expander was removed (T2) using a Planmeca ProMax 3D Mid (at T1 and T2). Scan time: 18 seconds, 90 kV, 12.5 mAs, 20 x 17 mm field of view, time of exposure: 6.22 seconds at 194 degrees. With a 200 mm voxel size. (Figure 3).

They were uploaded to a computer as DICOM (digital imaging and communications in medicine) data files and reassembled in 0.3 mm increments before being examined with Romexis software (version 5.3.4.39USA).

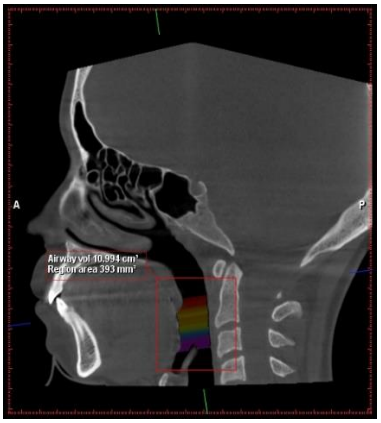
The patients were positioned by aligning the Frankfort horizontal plane with the floor and using laser beams as a guide for head orientation in the FH plane. (10) tongue posture was standardized as possible (put the tongue behind upper incisors with light touch after pronunciation of letter N).

The following volumetric measurements were evaluated based on previous research. (20) Manual segmentation of the airway using segmentation tool in the software was made by tracing of the airway layer by layer in the coronal cross section until the last layer. The Sagittal view showing completed volume segmentation and its volume in mm3 and the 3D volume reconstruction of the nasal airway.

The completeness of volume segmentation and its volume in mm3 were confirmed by the Sagittal view. The Nasal cavity was measured in 3D volume from Anterior nasal spine (ANS) to Posterior nasal spine (PNS), and the nasopharynx was drawn from line anteriorly from PNS to Sella (S) point extended posteriorly to the posterior wall of the pharynx above the line joining ANS and PNS.

The oropharynx was separated into two sections: retropalatal just below the ANS-PNS line to the uvula, and retroglossal from the uvula line to the epiglottis nearly at the same level of antero-inferior point of the third cervical vertebrae (C3).

The total air volume was the summation of nasopharynx, retropalatal and retroglossal airway.



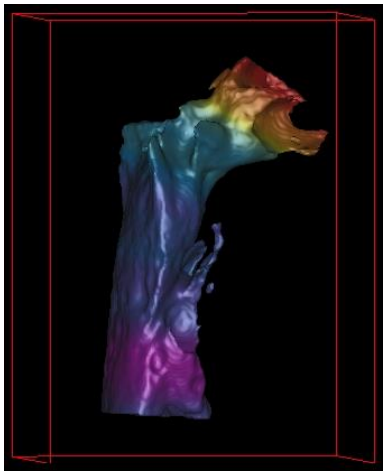


Figure (3): measurements of the nasal cavity and upper airway.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 18 was used for data management and statistical analysis. After 3 weeks, the intra examiner error was investigated through repeated measurements on 20 CBCT of randomly selected patients. The reliability of repeated measures and the correlation between software were assessed using the intraclass correlation coefficient (ICC) and Bland-Altman bounds of agreement.

Thirty patients were included in the study, however only 28 were analyzed because one male was lost to follow-up treatment interruption in group 1 and the other was discontinued in group 2 (one male) due to ceased intervention (failure of palatal miniscrew).

The paired t test was used to compare the pre and post values. To compare the three groups, a one-way analysis of variance (ANOVA) was utilized. When the ANOVA test was significant, the Bonferroni post-hoc test was employed for pair-wise comparisons between groups. P 0.05 was used as the significant level. Non-parametric percent change data were compared across groups using the Kruskall Wallis test and Dunn's post hoc test, and between unilateral and bilateral cases using the Mann Whitney U test. The Chi square test was used to compare categorical qualitative data expressed as a number and a percentage. All p-values are two-sided. P-values ≤0.05 were considered significant.

Result

Conventional Hyrax group and MSE groups comprised 3 unilateral cases each, while Hybrid Hyrax group comprised 4 unilateral cases. The remainder of cases were bilateral.

Gender	Conventional Hyarx	Hybrid Hyrax	MSE		Age	Conventional Hyrax	Hybrid Hyrax	MSE
Males	2(22.2%)	3(33.3%)	3 (30%)		Mean	14.28	15.06	15.40
Females	7 (78.8%)	6 (66.7%)	7 (70%)		SD	1.21	0.95	.94
X^2	0.288				F	2.87		
P	0.866 ns				P	0.076 ns		

Significance level p≤0.05, ns=non-significant

Table (1) Demographic data of the study sample

I- Comparison between groups

Total volume: Pre-treatment, there was no significant difference between groups (p=0.230). After treatment, the highest mean value was recorded in MSE, followed by Conventional Hyrax, while the least value was recorded in Hybrid Hyrax, with no significant difference between groups (p=0.089). (Table 2, Fig. 4,5&6)

Nasopharynx volume: Pre-treatment, there was no significant difference between groups (p=0.989). After treatment, the highest mean value was recorded in MSE, followed by Conventional Hyrax and Hybrid Hyrax, with no significant difference between groups (p=0.970). (Table 2, Fig. 4,5&6)

Retropalatal volume: Pre-treatment, there was no significant difference between groups (p=0.548). After treatment, the highest mean value was recorded in MSE, followed by Hybrid Hyrax, while the lowest value was recorded in Conventional Hyrax and, with no significant difference between groups (p=0.578). (Table 2, Fig. 4,5&6)

Retroglossal volume: Pre-treatment, the highest mean value was recorded in MSE, followed by Conventional Hyrax and Hybrid Hyrax, with a statistically significant difference between group (p=0.002). After treatment, the highest mean value was recorded in MSE, followed by Hybrid Hyrax and Conventional Hyrax, with a statistically significant difference between groups (p=0.002). (Table 2, Fig. 4,5&6)

Percent change in nasal cavity volume: The greatest percent increase was noted in MSE, followed by Conventional Hyrax and Hybrid Hyrax, with no significant difference between groups (p=0.125), (Table 2, Fig. 4,5&6)

II- Comparison between pre and post values

Conventional Hyrax: the post treatment value was significantly higher than the pre value in total volume (p=0.007), nasopharynx volume (p=0.007), retropalatal (p=0.032), retroglossal (p=0.023) and nasal cavity (p=0.001), (Table 2, Fig. 4)

Hybrid Hyrax: the post treatment value was significantly higher than the pre value in total volume (p=0.009), nasopharynx volume (p=0.002), retropalatal (p=0.004), retroglossal (p=0.012) and nasal cavity (p=0.001), (Table 2, Fig. 4)

MSE: the post treatment value was significantly higher than the pre value in total volume (p=0.00), nasopharynx volume (p=0.002), retropalatal (p=0.015) and nasal cavity (p=0.004), while the difference in retroglossal volume was not statistically significant (p=0.060) (Table 2, Fig. 4)

		Conventional Hyrax		Hybrid Hyrax		MSE			
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	F	P value
Total	pre	11.99	3.93	12.00	3.93	14.62	3.46	1.561	.230ns
	post	14.07	3.89	14.02	3.90	17.70	4.20	2.670	.089ns
	Percent change	20.03	20.78	19.53	21.08	21.39	13.43	.199 ns	
		11.90		11.89		18.76			
	P value Pre vs post	.007*		.009*		.000*			
Naso-pharynx	pre	3.67	.74	3.60	.63	3.65	1.40	.011	.989ns
	post	4.24	.96	4.24	.96	4.36	1.46	.031	.970ns
	Percent change	15.36	10.85	16.96	9.21	25.24	29.83	.783 ns	
		11.55		12.49		19.75			
	P value Pre vs post	.007*		.002*		.002*			
Retro-palatal	pre	5.94	2.39	5.94	2.40	6.89	1.69	.615	.548ns
	post	6.80	2.54	7.65	2.51	7.82	1.61	.545	.587ns
	Percent change	15.91	16.65	32.82	25.41	15.24	18.50	.145 ns	
		10.41		29.36		9.41			
	P value Pre vs post	.032*		.004*		.015*			
Retro-glossal	pre	2.71[b]	1.14	2.70[b]	1.15	5.47[a]	2.54	7.764	.002*
	post	3.37[b]	1.29	3.42[b]	1.24	6.29[a]	2.54	8.034	.002*
	Percent change	30.40	41.67	33.18	39.97	26.43	41.41	.862 ns	
		14.40		22.68		12.75			
	P value Pre vs post	.023*		.012*		.060 ns			
Nasal cavity	pre	39.66	6.61	39.87	6.40	36.31	6.85	.873	.430ns
	post	44.43	6.92	44.44	6.92	43.88	10.22	.015	.985ns
	Percent change	12.35	7.05	11.65	6.65	20.56	18.73	.125 ns	
		7.86		7.86		22.73			
	P value Pre vs post	.001*		.001*		.004*			

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

Table (2) Descriptive statistics and comparison between groups (ANOVA, Kruskall Wallis test) and within the same group (pre versus post -paired t test)

Bonferroni post hoc test for ANOVA & Dunn Post-hoc test for Kruskal–Wallis test: Values sharing the same superscript letter within the same row (for percent change) are not significantly different

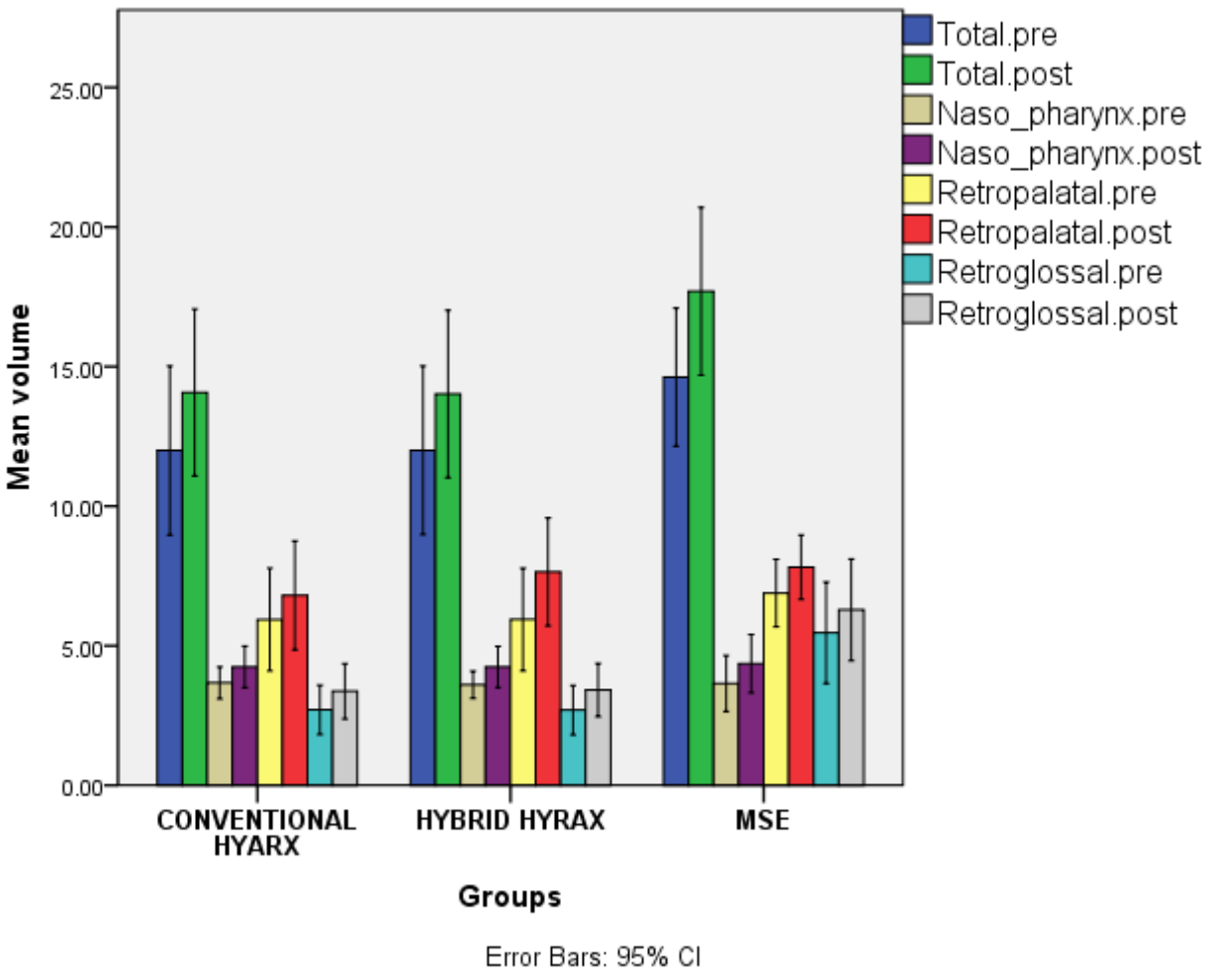


Figure. (4) Bar chart illustrating mean pre and post volume value in each group

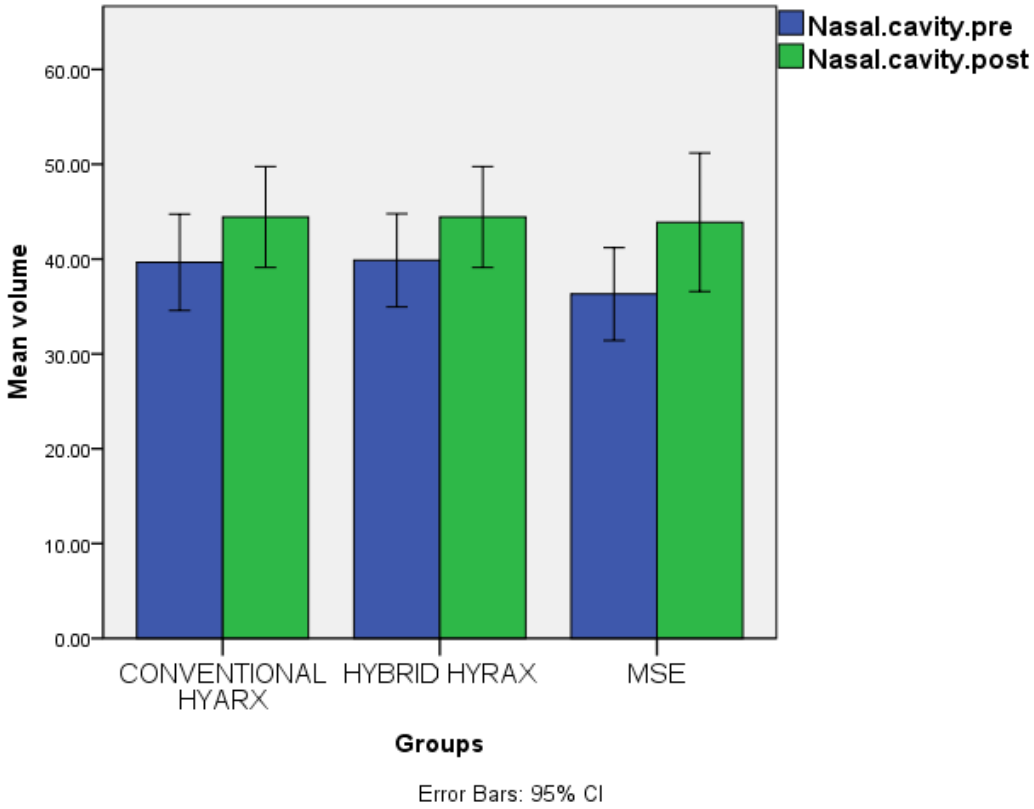


Figure. (5) Bar chart illustrating mean pre and post volume of nasal cavity in each group

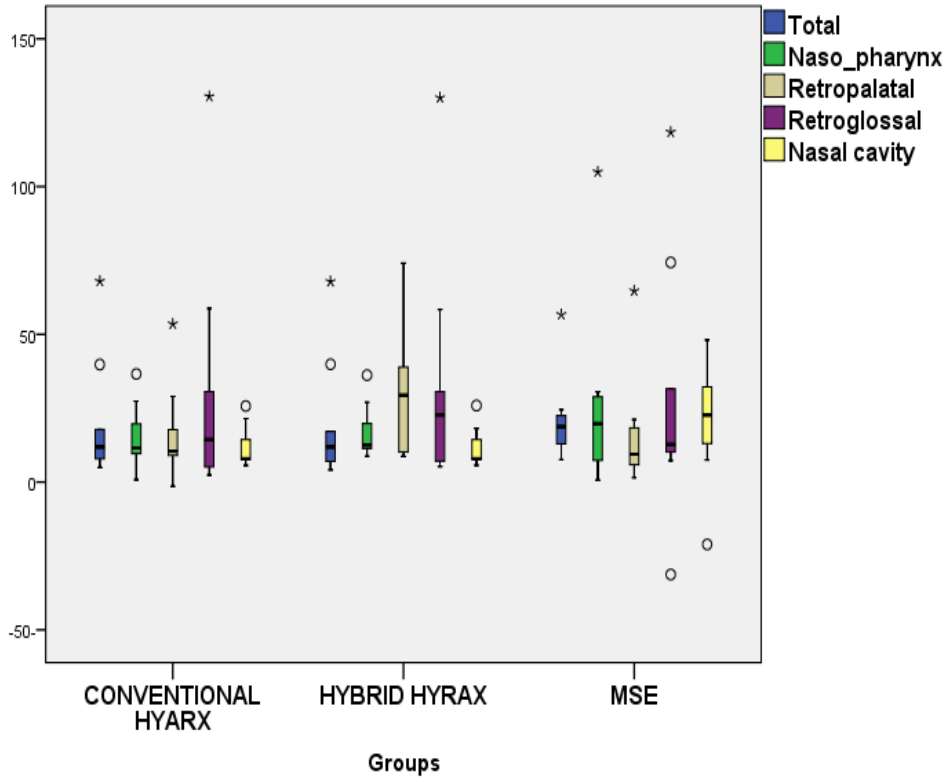


Figure. (6) Box plot illustrating median percent change in volume in each group

III-Comparison between unilateral and bilateral crossbite cases

Total volume, Retropalatal volume, Retroglossal volume and Nasal cavity volume A higher value was recorded in bilateral cases, however with no significant difference between unilateral and bilateral cases, but as regard to Nasopharynx Volume A higher value was recorded in bilateral cases, with a statistically significant difference between unilateral and bilateral cases (Table 4, Fig. 7,8&9)

IV-Comparison between pre and post values in unilateral and bilateral cases

Unilateral cases: the post treatment value was significantly higher than the pre value in total volume (p=0.007), nasopharynx volume (p=0.006), retropalatal (p=0.012), and nasal cavity (p=0.001); while the difference in retroglossal volume was not statistically significant (p=0.109)

Bilateral cases: the post treatment value was significantly higher than the pre value in total volume (p=0.00), nasopharynx volume (p=0.000), retropalatal (p=0.010), retroglossal (p=0.00) and nasal cavity (p=0.00), (Table 4, Fig. 7,8&9)

		Unilateral			Bilateral			t	P value Unilateral vs bilateral
		Median	Mean	Std Dev	Median	Mean	Std Dev		
Total volume	pre	10.56	11.743	3.40	12.51	13.599	4.01	1.24	.228 ns
	post	12.58	13.633	3.45	16.17	16.307	4.43	1.65	.112 ns
	P value pre vs post	.007*			.000*				
	Percent change	12.48	18.249	20.15	18.14	21.523	17.02	--	.256 ns
Naso-pharynx	pre	3.08	3.125	.83	3.91	3.928	.93	2.27	.032*
	post	3.58	3.577	.67	4.89	4.675	1.15	2.76	.010*
	P value pre vs post	.006*			.000*				
	Percent change	11.47	19.758	30.38	19.29	19.205	10.47	--	.175 ns
Retropalatal	pre	5.44	5.991	1.51	5.50	6.438	2.44	.52	.606 ns
	post	6.70	7.350	1.77	6.75	7.484	2.45	-.15	.881 ns
	P value pre vs post	.012*			.000*				
	Percent change	13.97	25.386	26.67	11.72	18.730	18.15	--	.759 ns
Retroglossal	pre	1.78	2.919	2.06	3.70	4.115	2.18	1.42	.168 ns
	post	2.73	3.504	2.02	4.20	4.939	2.27	.66	.108 ns
	P value pre vs post	.109 ns			.000*				
	Percent change	27.46	32.586	43.32	13.34	28.367	38.59	---	.464 ns

Nasal cavity	pre	34.05	35.881	6.00	38.87	40.000	6.61	1.63	.115 ns
	post	42.53	42.377	7.74	48.55	45.273	8.10	92	.366 ns
	P value pre vs post	.003*			.000*				
	Percent change	11.34	18.409	14.58	13.70	13.191	11.61	---	.408 ns

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

Table (4) Descriptive statistics and comparison of pre and post values in unilateral and bilateral cases (paired t test) and between the unilateral and bilateral cases within each group (independent t test) and comparison of percent change in unilateral and bilateral cases (Mann Whitney U test)

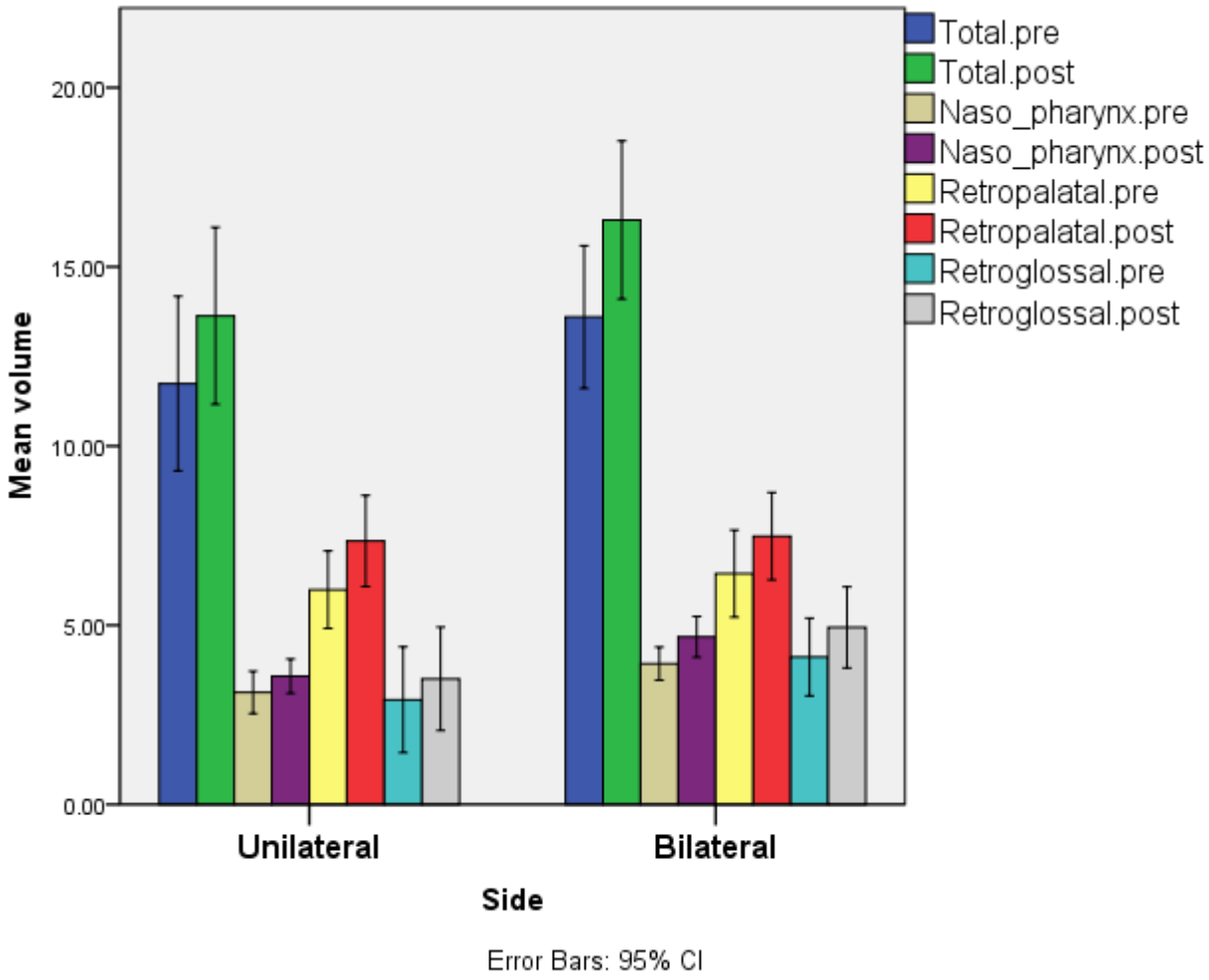


Figure. (7) Bar chart illustrating mean pre and post value of volume in unilateral and bilateral cases

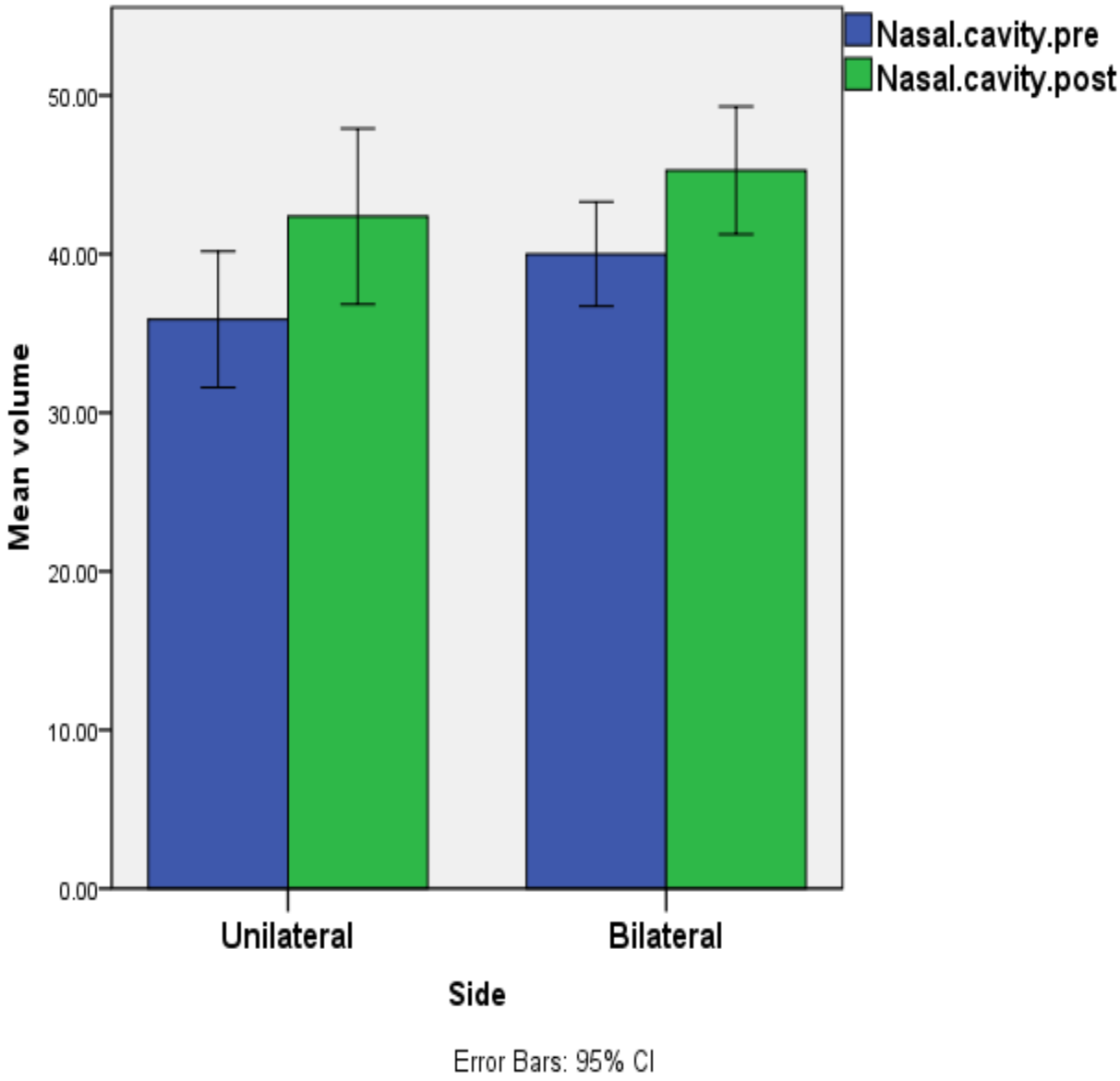


Figure. (8) Bar chart illustrating mean pre and post value of nasal cavity volume in unilateral and bilateral cases

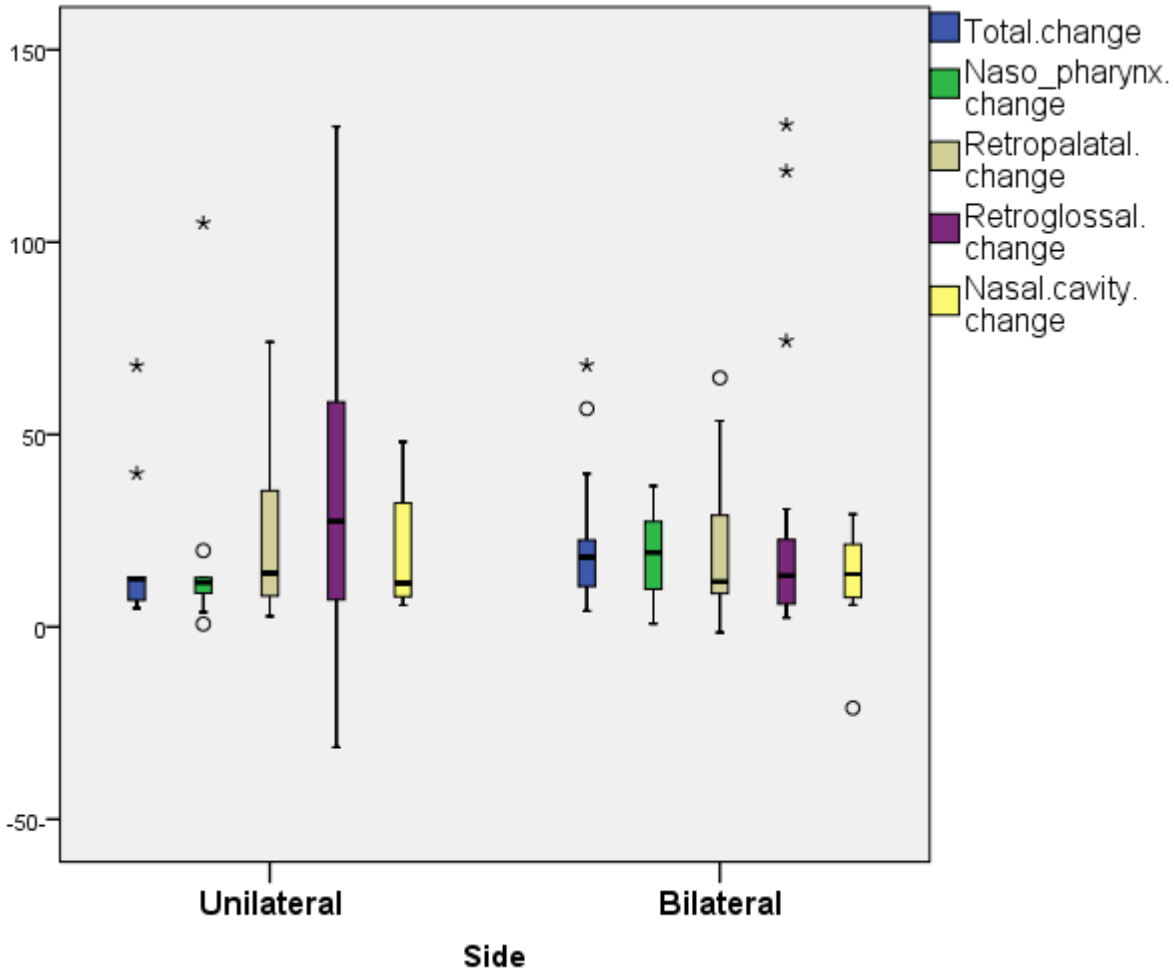


Figure. (9) Box plot illustrating median percent change of volume in unilateral and bilateral cases

Discussion

The Cephalometry can be used as a screening tool for the adenoid, but it is not capable for measuring the true nasopharyngeal full size, because it is a 3D object. (21)

Despite the fact that there were three different expanders, the mean age in Conventional Hyrax (group 1) was 14.28±1.21, compared to 15.06±0.95 in Hybrid Hyrax (group 2) and 15.4±0.94 in MSE (group 3), with no significant difference between groups (p=0.076) even in the activation protocol, this indicated the homogeneity of all groups. In Adults miniscrew assisted rapid palatal expansion (MARPE) can be utilized as a nonsurgical alternative to surgery to treat maxillary constriction. (22)

In the present study, the use of CBCT with natural head and tongue posture to reduce the confounders that may affect pharyngeal volume, since in previous study showed that low tongue position and

concomitant retroglossal narrowing can be caused by maxillary constriction combined with nasal obstruction. (17)

In the present study the change in total air volume showed significant increase in post expansion period (T2) in all groups, this was in accordance to previous studies (23-25) hence, following RME, increased oropharyngeal volume, so the maximal negative pressure and pharyngeal resistance during inspiration reduced, along with decreased nasal resistance finally airway and nasal breathing may be improved. (26-28)

The change in total air volume in the current study was in discordance with other studies. (12,29,30)

El et al (12) who found no change in oropharyngeal airway area this might be due to different expansion protocol and measurements since they measured a volumetric change of an extracted lateral cephalometry from CBCT. While in the study of Zhao et al. (29) who proved no alteration in the OP airway in patients with maxillary constriction treated with conventional hyrax RME and came to the conclusion that RME would not widen the OP airway volume, this might be due to different expansion protocol and retention period since they did not have a standardized protocol and the retention period was nearly 3 months. And for the study of Malkoc¸ et al (30) the method of evaluation was through lateral and posteroanterior cephalometry with different patients mean age (20±2.3) Y.

The nasal passage was increased in the present study this was in accordance with previous studies (10,12,25,31,32-40) since, Kavand et al (10) proved that Both tooth- and bone-borne RME can increase nasal cavity and nasopharynx capacity in adolescents.

El et al (12) were compared RME to the control group and concluded the RME group had a twofold increase in NP airway volume.

Haralambidis et al (31) found that the amount of nasal cavity volume increase was determined by the length of the expansion in other word proportional relation between activation period and nasal cavity volume.

Gunyuz et al (32) found no difference between CH and HH finally both increase nasal cavity volume. On the other hand, Garib et al (33) When compared the CH to the HH they found that HH produce higher increases in nasal cavity. this was in disagreement with the present study due to different assessment of the nasal cavity since they assessed with a linear measurement while in the present study it is a volumetric one.

In a sample of adolescents, Lin et al (34) found that the bone-borne expander group increased maxillary width more than the CH group. (34)

When a pure bone borne expander with 4 miniscrews was used in comparison to a CH, the nasal cavity widened. (35)

Kim et al (39) showed following MARME, the volume of the nasal cavity and nasopharynx rose and remained stable throughout the retention period with good adaptability of the lateral wall of nasal cavity, these was in agreement with the result of current study.

Aljawad et al (40) mentioned significant increase in upper airway after RME in comparison to matched control group.

Percent change in nasopharynx volume: The greatest percent increase was noted in MSE, followed by HH, while the least value was recorded in CH, with no significant difference between groups (p=0.783), so the nasopharynx showed slight increase in all groups in comparison to improvement of nasal cavity this was in accordance to previous studies. (10,12,29, 36-40)

As regard to the change of oropharyngeal (OP) volume in the current study OP showed significant increase in all groups. The retropalatal and retroglossal volumes showed the highest mean value in MSE, followed by HH, while the lowest value was recorded in CH, but with no significant difference between groups (p=0.578) in retropalatal while retroglossal volume change showed a statistically significant difference between groups (p=0.002) this was in agreement with previous studies. (12,38,40) and was in disagreement with studies concluded no change of OP volume (10,26-29,30,37,41) or even decreased after RME. (36) these might attribute to different methodology of assessment and the used software.

Following RME, Chang et al (41) found no significant changes in oropharyngeal, retropalatal, or retroglossal airway volumes, this may urged to different activation protocol, they used only 1 turn activation per day for 4 weeks or until the posterior crossbite is resolved.

Previous studies (17,29) had evaluated the change of oropharyngeal airway using CBCT which increased by about 1100 mm3 but this change did not show statistical significance.

Smith et al (36) showed that OP volume decreased after RME, despite the fact that the drop was not large. The lowering of the palatal plane could explain the decline.

Ribeiro et al (38) despite he found significant increase in OP he attributed this change to irregularities in the examination acquisition since tongue posture, head inclination, breathing, and swallowing movements were not standardized.

Hence, tongue posture plays an important role in evaluation of the retropalatal and retroglossal area, since high tongue posture might be found in patients with obstructive sleep apnea (42) while low tongue posture might be seen in constricted maxilla with mouth breathing patients. (17,43,44)

It is predicted after RME low tongue posture might be corrected or not, since there are possibilities of retained mouth breathing habit or low improvement of airway dimension (17) or even low position of hyoid bone.(45)

Finally, when the pre and post values in unilateral posterior crossbite (PC) and bilateral cases were compared, the post expansion value was higher in all parameters, including total, nasopharynx, retropalatal, nasal cavity, and retroglossal volume in the bilateral PC cases, while in unilateral cases, the difference in retroglossal volume was not statistically significant (p=0.109), this might be due to after expansion of bilateral cases adequate tongue position improved regardless the tongue size, this was matched with Ozbek et al (45)

After comparing the post expansion value in unilateral and bilateral PC cases the higher value was recorded in bilateral cases, however with no significant difference in all parameter except in nasopharynx volume which showed a statistically significant difference between unilateral and bilateral PC cases (p=0.010), this might be due to the variation of involved tissue of nasopharyngeal tonsil (adenoid) size, this explanation was in disagreement with Smith et al(36) since the different software assessment might play a role in this issue.

Conclusion

- RPE can improve airway regardless the appliance type, but bone borne proved clinical improvement than CH.
- No statistical difference between unilateral PC and bilateral PC, but bilateral PC showed better improvement of airway clinically.

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