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Three-dimensional evaluation of maxillary sinus volume following the use of different designs of rapid maxillary expander: A comparative study

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***Abstract*---**Aim of the study: to assess maxillary sinus volume changes (MSV) in adolescent patients with class III malocclusion after application of three types of rapid maxillary expanders (RME). Material and Methods: This was a prospective cohort study that recruited adolescent (13-17 years old) class III malocclusion patients with maxillary deficiency. Patients were randomly assigned to three study groups according to the type of RME: Conventional hyrax (CH), hybrid hyrax (HH), and maxillary skeletal expanders (MSE). Cone-beam computed tomography (CBCT) was used to measure MSV prior to and 6 months after application of RME. Measurements were compared between right and left sides and within study groups. P-values of less than 0.05 were considered significant. Results: A total of 51 patients (30 girls and 21 boys) were included. Mean ages were 14.89±1.6, 15.31±1.73, and 15.59±1.9 Y in the CH, HH and MSE groups respectively. Measurements in all groups were significantly increased. In CH and MSE groups, there was no significant difference between the right and left side before treatment (P =0.386). But in HH, both before and after treatment, the right side values were considerably greater than the left side value ($P \leq 0.05$). There was no significant difference between unilateral and bilateral posterior cross-bite cases (P=0.713), with unilateral cases showing the largest proportion increase. CH had the greatest MSV increase, followed by HH and MSE, with no statistically significant difference across groups (P =0.650). Conclusion: The RME is relevant for improving MSV bilaterally.

***Keywords*---**Rapid Maxillary Expansion, Maxillary Sinus Volume, Hyrax, Maxillary Skeletal Expander, Palatal Expansion, CBCT.

Introduction

A substantial proportion of patients suffer from posterior cross-bite associated with significant maxillary deficiency, high arched palate, and airway constriction. This could present in mild to severe forms according to the associated skeletal growth abnormalities, or congenital clefts [1–3].

Rapid maxillary expansion (RME) has been commonly used to correct the posterior cross-bite (PCB)-related maxillary arch constriction by expansion of the mid-palatal suture, [4–6]. Further, the circum-maxillary sutures , are also affected thereby improving the nasal capacity by reducing nasal resistance and improving airflow [7,8].

During the process of RME the maxillary sinus may be affected. The Maxillary sinus (MS) is a bilateral air-filled cavity that represents the largest and the earliest to develop among the four paranasal sinuses [9]. The maxillary sinus volume (MSV) on the constricted side may be lower than the contralateral one, particularly when a severely impacted tooth is present, however, thorough orthodontic treatment, may bring the MSV to identical values [10,11].

The maxillary sinus floor (MSF), which can be above, below, in contact with, or between the roots of the maxillary first molars, has a varied relationship to the apical region of these teeth. This variable locations could be crucial during molar intrusion[12,13].

The goal of this study was to assess morphometric changes in the maxillary air sinus volume (MSV) by using cone beam computed tomography (CBCT) following the use of three distinct rapid maxillary expanders included (traditional, hybrid, and skeletal) groups.

Material and Methods

Study design and sample determination

This prospective cohort study was carried out on fifty-one young adult orthodontic patients (30 girls and 21 boys). The sample size was determined based on the sample power analysis of Agakayac et al[4] using G-power software (version 3). Patients were randomly assigned to the three study groups (17 patients each) using sequentially numbered, opaque sealed envelopes (SNOSE)-coded vehicles, with the number chosen. Patients were screened in the outpatient clinic of the Orthodontic department, Faculty of Dental Medicine, Al-Azhar University, Cairo, Boys branch. The study adhered to the Helsinki Declaration of Clinical Study Guidelines.

Patients

The inclusion criteria were patients with class III transverse maxillary deficiency, aged 13 to 17 years, no pathology affecting the MS, and no systemic diseases. Exclusion criteria included an impaction or missing teeth except the 3rd molar, mid-face syndromes, earlier orthodontic or orthognathic management, history of previous trauma and any systemic disease that could interfere with treatment.

Study technique

Informed consent was obtained from patients and their parents verbally and in writing after explanation of the study goals and procedures. Patients were allocated into three groups as follows: group 1 used the conventional hyrax (CH); group 2 used the hybrid hyrax (HH); and group 3 used the maxillary skeletal expander (MSE) (Figure 1).

Figure 1: Intraoral photographs showing three types of expansion appliances (a) Hyrax, (b) Hybrid Hyrax, and (c) MSE

For group 1 and 2, two-banded Hyrax expanders with a 9 or 10mm screw length were supported by the maxillary permanent first molars on either side (Figure 2a&b). Two quarter turns (0.25 mm each) were applied to each device at the time of delivery. The patient or parents then applied one quarter turn in the morning and another in the evening for 15 days, producing a total expansion around 8 mm across all patients.

In group-3 four mini-screws (diameter=1.8 mm, length=11 mm) were placed into the MSE jackscrew with four holes, which was made of two soft titanium arms connected to two molar bands, to promote posterior along with superior maxillary expansion through bicortical interaction.

Patients were closely monitored to control the process of appliance activation. After the last activation of the active screw a ligature wire was used to secure the screw then coated with flowable composite and kept in place as a retainer for six months. No further orthodontic treatment was started in either jaw until the retention phase was completed.

Radiographic evaluation

All 48 patients (3 patients had dropped out) had CBCTs scans just before commencement of expansion (T1) and six months later following the last activation just after the expander has been removed (T2).CBCT images were recorded using a Planmeca ProMax 3D Mid (Planmeca Oy, Helsinki, Finland) (at T1 and T2), with the following parameters: 20 mm x 17 mm field of view, 12.5 mAs, 90 kV, and an 18-second scan duration with 200 mm voxel size.

Romexis software was used to examine and reconstruct all CBCT data in increments of 0.3 mm (version 5.3.4.39,USA). Laser beams were used as a guide to align the patient's head with the Frankfort horizontal plane (FHP), which was set to be parallel to the ground. Based on previous research, the volumetric measures listed below were analyzed. The maxillary sinus was manually segmented using the software's segmentation tool via tracing successive layers of the sinus in the coronal and sagittal cross sections until the last layer (Figure 2,3).

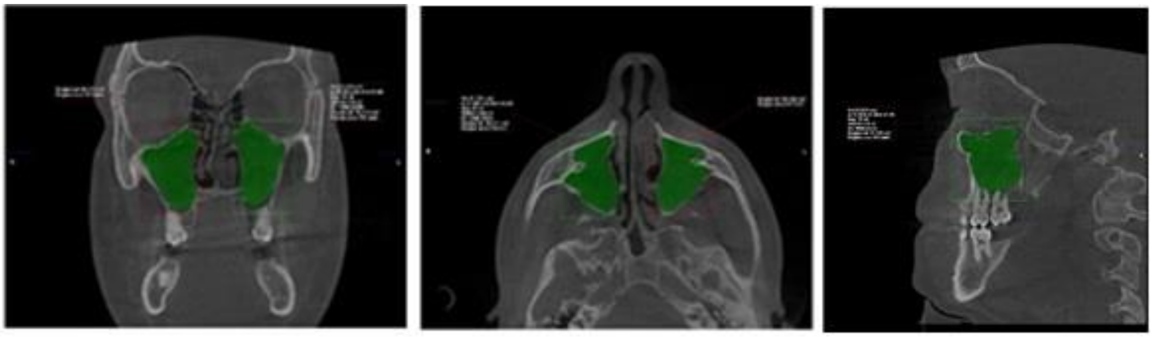

Figure 2: CBCT (Coronal, Axial, Sagittal cuts) photograph shows volumetric

Measurements of the maxillary sinuses in both the right and left sides with 3D rendering

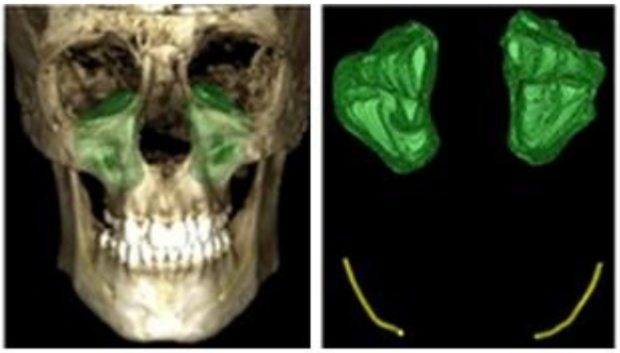

Figure 3: The maxillary sinus in 3D volume reconstruction after volume segmentation is complete, with volume measured in cubic millimetres

Statistical analysis

The formula below was used to determine the mean difference: (Post-operative value – Preoperative value). Non-parametric difference data were compared between groups using the Kruskall Wallis test and Dunn's post hoc test; the right and left sides were compared using the Wilcoxon signed rank test. P-values less than 0.05 were regarded as significant.

Results

Demographic data

The majority of the sample were females (62.5%), with no discernible variation between groups (*P*=0.861). The age range of the patients was 12.9 to 17 years. Mean age in the Conventional Hyrax group was 14.89±1.6, while the Hybrid Hyrax group was 15.31±1.73 and the MSE group was 15.31±1.73, with no significant difference among groups (*P*=0.156).

CBCT Regional volume (cm³) results

No significant differences were found in MSV before expansion or after 6 months of expansion between the studied groups, at both the right and left sides (*P*>0.05, table 1). Postoperatively, the highest mean value was recorded in MSE group, followed by Hybrid Hyrax, while the least value was recorded in Conventional Hyrax, with no significant difference between groups at both the right and left (*P* >0.05, table-1).

Postoperatively, the MSE group the highest mean value then Hybrid Hyrax then Conventional Hyrax which recorded the lowest mean value, with no significant difference between groups at both the right and left (*P* >0.05, table1). The highest postoperative difference at both the right and left MSV was identified in the Conventional Hyrax, then Hybrid Hyrax, and the MSE showed the least amount of increase (Table 1). In all groups the postoperative values of MSV were significantly higher than the preoperative values in both right and left sides ($P \leq 0.05$) (Table 1).

In the right side the greatest increase in MSV was detected in the conventional and hybrid groups. In the left side the greatest increase in MSV was noticed in the MSE group, however, no statistically significant difference was noticed between the groups in either side.

At both Right and left sides there was no significant difference between unilateral and bilateral cross bite cases pre-operatively, or postoperatively ($P \geq 0.05$). Bilateral cross bite cases showed the most increased percentage on the right side, and in left side the greatest percent increase was noted in unilateral cases (Fig.4)

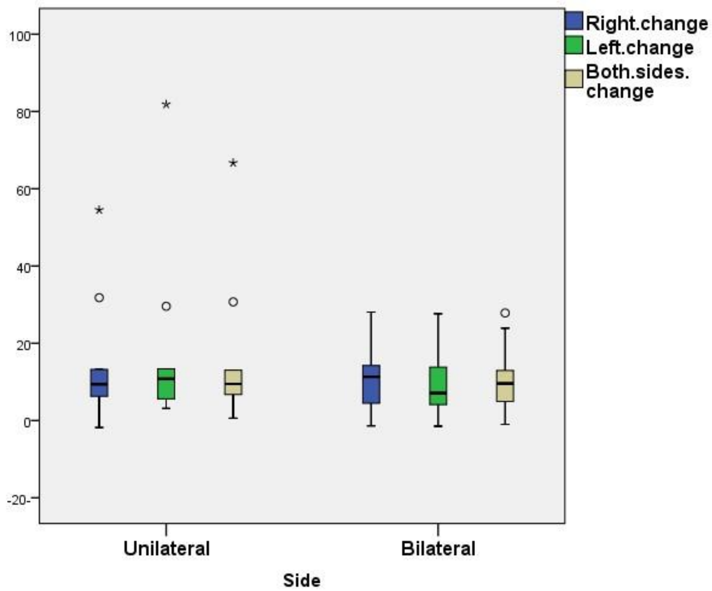

Figure 4. Box plot illustrating median percent change in right and left side and both sides in unilateral and bilateral posterior cross bite cases

Discussion

The current study assessed the maxillary sinus volume changes after RME in a group of adolescent patients aged 13-17 years. Including this specific age group was essential to exclude possible age-related changes in maxillary volume which mainly take place in the age groups of 0–3 and 7–12 years. [14] Due to ethical concerns, it was not possible to include a control group in this study that had a skeletal pattern similar to the study sample. Further, the 15-day long activation period does not impact the facial growth curve significantly. It was also anticipated that all patients would pass the maxillary growth peak which precluded that.

Previous studies [15–18] using two-dimensional radiography examinations and three-dimensional CBCT scans have reported the effects of RME on airways and maxillary sinus size. Some researchers concluded a limited effect or even questioned such effects. [19,20] Through the use of CBCT 3D imaging, the maxillary sinus anatomy may be accurately analysed, allowing for the observation of anatomical details that are difficult to analyse while using the two-dimensional panoramic view [13].

According to a systematic review, MARPE is a viable alternative for maxillary expansion, having effects equivalent to those of adults who have surgically assisted palatal expansion.[21]. Darsey et al. [23] Smith et al [22] claimed no significant increase of the MSV after RME treatment. Also, Garrett et al. [24] found that there is an increase in nasal width accompanied with decrease in MSV after RME.

According to Pangrazio-Kulbersh et al [25], there was no difference between the right and left sides and a considerable increase in the post expansion effect on MSV, which was in agreement with the findings of the current study. Erdur et al [26] also concluded that RME is effective for treating transverse maxillary deficiency and resulting in improving MSV and Pharyngeal airway. Although Garrett et al [24] found that maxillary sinus width reduced with RME, which was a possible cause of decreased MSV. Therefore, the maxillary sinuses may be smaller. In light of this, expansion therapy may really have no impact on volumetric size. [48] This might be because they employed linear measurements, whereas the present study evaluated several expander designs using volumetric analysis which resulting in different measurements. Rapid maxillary expansion can cause change in both pyriform width and height with returning the enlarged nasal soft tissue to the normal growth and development with time.[27]

Regarding a deviated nasal septum it was noted that the sinus volume was reduced on the nasal septum's deviated side than on the opposite side[28]. According to the results of this study, an increase in MSV may be caused by skeletal reorganization following expansion or by generalized growth. This finding was in agreement with Pamporakis et al. [29], who justified the increase in the maxillary sinus volume encountered in their study by the normal growth mechanism. This outcome is significant due to the possibility that an increase in MSV will lead to both a decrease in nasal resistance and an increase in nasal capacity. According to Pangrazio-Kulbersh et al.[25], it was challenging to identify whether the changes in the MSV were caused by the therapy or by the individuals' natural development in the current investigation which goes in accordance with Ozbilen et al[30]. The real increase in MSV could be attributed to a shift in the inferior limit of the sinus caused by alveolar bending in the molar and premolar areas, as Adkin et al[31] and Erdur et al[26] hypothesized.

No statistically significant differences found between the baseline changes in the right and left MSVs for all groups in the current study and this results goes in accordance with Lanteri et al.[32], who reported that maxillary sinuses may be symmetrical in all populations.

In the current study, there was no statistically significant difference in MSV between unilateral and bilateral PCB, with approximately equal mean of MSV in all groups. Although there was no statistically significant difference between both sides, the right side was greater in volume than compared to the left side, which was in accordance with Lanteri et al.[32]. However, this was contradictory to Erdur et al. [26], who found difference between the affected PCB side in comparison to the other non-affected side which may be attributed to the different device design. Additionally, no significant difference found between males and females in MSV, which is consistent with Nagim et al[33].

In comparison to each other, no statistically significant difference was found between groups following the retention phase. Which is consistent with earlier study by Pangrazio–Kulbersh et al[25] and in disagreement with Garrett et al[24] and Darsey et al.[23]. This could be related to the various methodologies used for linear analysis of CBCT scans, varied period of investigation (3 months). In addition, secretions may interfere with MSV assessment using CBCT, however the investigation time in the current study was almost 6 months, which may have been sufficient for enhancement of the airway and afterwards resolve any congestion or sinus discharges.[34]

Despite the fact that the findings contradict common thinking, because it might be expected that MSE would experience the greatest growth due to its ability to enhance the skeletal effect in comparison to CH and HH, the actual findings of this study revealed that this did not occur, demonstrating that it is not necessary for MSV growth to be correlated to the expander type rather than other forms of growth.

Conclusions

Rapid maxillary expansion is a valuable protocol for correction of both unilateral and bilateral cross bite malocclusion with enhancement of maxillary sinus volume bilaterally. Further clinical studies might be recommended with a larger sample size, different designs of palatal expander.

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Table (1): Descriptive statistics and comparison of Regional sinus volume (cm^3) between groups and within the same group (pre versus post)

CH: Conventional hyrax; HH: Hybrid hyrax; MSE: Maxillary skeletal expander; *Statistically significant; Volume measured in cm^3

Side	Group	Conventional Hyrax		Hybrid Hyrax		MSE		P-value
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	
Right	Preoperative volume measurements in cm^3	15.35	4.44	16.30	5.37	17.70	5.78	0.604
	Postoperative volume measurements in cm^3	16.36	3.72	17.09	5.30	18.18	5.67	0.715
	Difference	1.01	1.29	0.79	0.58	0.48	0.31	0.359
	Postoperative versus preoperative P value	0.035*		0.002*		0.001*		
Left	Preoperative volume measurements in cm^3	15.36	4.34	15.76	5.26	17.46	5.52	0.620
	Postoperative volume measurements in cm^3	16.29	3.67	16.33	5.17	18.00	5.52	0.672
	Difference	0.92	1.32	0.57	0.37	0.54	0.26	0.983
	P-value	0.05*		0.001*		0.000*		