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MAXILLARY SINUS VOLUMETRIC CHANGES FOLLOWING BONE-ANCHORED MAXILLARY PROTRACTION IN PATIENTS WITH UNILATERAL CLEFT LIP AND PALATE: A RETROSPECTIVE CBCT STUDY

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ABSTRACT

Objective: To evaluate maxillary sinus volumetric changes using CBCT, following BAMP with and without maxillary expansion in a sample of patients with surgically repaired complete unilateral cleft lip and palate (UCLP).

Material and methods: The pre and posttreatment full skull CBCT scans of 20 growing patients (mean age= 10.8, SD=1.2) with surgically repaired complete UCLP, who were treated with BAMP protocol were retrieved from the archive of the Orthodontic Department -Ain Shams University. Patients were divided into two groups: the first group was treated with BAMP alone while the second group was treated with BAMP preceded by maxillary expansion. Maxillary sinus volumetric changes were evaluated three-dimensionally after 9 months investigation period using CBCT scans.

Results: There was a significant increase in the volume of both the right and left maxillary sinuses in both groups. No significant difference in volume increase was found between both sides in each group and between the two groups. The average sinuses volume showed a significant increase in each group without a significant difference between the two groups.

Conclusion: BAMP protocol could increase the maxillary sinus volume in patients with UCLP, in both the cleft and the non-cleft sides. Preceding the protocol by maxillary expansion has no significant additional effect.

KEY WORDS: Maxillary sinus volume; BAMP; unilateral cleft lip and palate

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INTRODUCTION

The maxillary sinus is a paired pyramidal pneumatized cavity in the midface, and it is the largest among all the paranasal sinuses.[1,2] It is one of the vital structures of the face that has several functions including guiding the growth of the nasomaxillary complex, increasing the vocal resonance, humidification of the inhaled air, and decreasing the weight of the skull.[3,4]

Cleft lip and palate (CLP) is a common developmental craniofacial anomaly that happens due to failure of fusion of the developmental processes of the face.[2] As the medial nasal process is responsible for the development of the medial portion of the maxilla, nose and lip, lack of fusion of the medial and lateral nasal processes can affect the maxillary sinus.[5-8] The affected children accordingly suffer from different functional and anatomical problems including otologic, rhinologic and audiologic disorders together with greater susceptibility to maxillary sinusitis.[2]

Several studies were carried out to determine the etiologic factor of maxillary sinusitis in patients with CLP, with no one single factor identified as the main cause. These factors include velopharyngeal insufficiency, presence of pharyngeal flap, height of the maxillary sinus floor, impaired nasal mucociliary function, and hypoplasia of the maxillary sinus.[9-11]

Patients with unilateral cleft lip and palate (UCLP) were found to have smaller maxillary sinus volumes compared to normal individuals with no difference detected between the cleft and the non-cleft sides.[12] The volume of the maxillary sinus is an important topic due to its major contribution in maxillary sinus disease. In addition, sinus volume differentiation should be considered during sinus surgeries and dental implant applications.

Different treatment modalities have been proposed for the correction of the midface deficiency characteristic for patients with CLP. The most recent is the bone-anchored maxillary protraction (BAMP) protocol introduced by Hugo De Clerck.[13,14] This protocol proved its efficiency in both cleft and non-cleft individuals.[14-17] It is a preferred treatment option due to its pure skeletal effects free from any dental compensations and better patient cooperation being a completely intra-oral protocol. In addition to lack of need for pre-treatment maxillary expansion as in the traditional facemask treatment, as the force is applied directly at the level of bone eliminating the need to disarticulate the sutures, which was proved by a recent study that did not find any difference between the amount of protraction achieved with and without maxillary expansion.[15]

The traditional facemask treatment was found to have no significant effect on the volume of the maxillary sinus.[18] However, no previous studies investigated the effect of BAMP protocol; as a recent protocol for maxillary protraction, on the volume of the hypoplastic maxillary sinus characteristic for patients with UCLP. Moreover, there is no available literature examining the effect of maxillary expansion on the maxillary sinus volume in patients with CLP.

Hence, the aim of this study was to assess maxillary sinus volumetric changes three-dimensionally using CBCT, following BAMP with and without maxillary expansion in a sample of patients with surgically repaired complete UCLP.

MATERIAL AND METHODS

A retrospective study was carried using the pretreatment and posttreatment CBCT scans of 20 growing patients (11 boys and 9 girls) with surgically repaired complete UCLP, who were treated with BAMP protocol in a previous clinical trial.[15] The records were retrieved from the archive of the Orthodontic Department-Faculty of Dentistry -Ain Shams University after the approval of the ethical committee. The age of the selected patients ranged from 9 to 13 years with mean age= 10.8,

SD=1.2. The following inclusion criteria were used for sample selection:

Surgically repaired complete unilateral cleft of the lip, alveolar process and secondary palate not associated with any syndromes; skeletal Class III malocclusion due to maxillary deficiency confirmed by measuring SNA< 78^0; active growth period assessed by cervical vertebral maturation (CVM) method (CS1-CS3)[19] ; mixed dentition with erupted lower permanent lateral incisors or full permanent dentition stages; anterior crossbite or edge-to-edge incisor relationship together with the presence of unilateral or bilateral posterior crossbite.

Patients who had previous orthopedic or orthodontic treatment, or who had medical problems other than CLP deformity were excluded. Any CBCT scan where any of the 2 maxillary sinuses was not able to be evaluated due to the presence of retention cysts, mucositis, excessive mucosal thickening, sinusitis, sinus obliteration or any other type of maxillary sinus pathosis were excluded from this study as well.

The original clinal trial divided the patients into two groups considering the amount of maxillary arch constriction: Group I were treated with BAMP protocol alone. Group II were treated with BAMP protocol preceded by rapid maxillary expansion (RPE).

The mean age of the 10 patients included in group I was 10.3 ± 0.9 years. The protocol for BAMP described by EL-abbassy et al.[15] was followed. It involves surgical placement of 4 miniplates in the 4 quadrants followed by maxillary orthopedic protraction using intra-oral Class III intermaxillary elastics attached between the miniplates hooks (Figure 1).

For group II (mean age was 11.3 ± 1.4 years), the same protocol was applied but before the start of orthopedic protraction, RME was carried using a fan-shaped expander for 1 week. Further expansion was carried using slow expansion rate whenever further increase in the transverse dimension was needed.

Fig. (1): BAMP using intermaxillary Class III elastics attached to miniplates' hooks.

The pretreatment CBCT scans were taken for each patient 1 week after surgical placement of the miniplates (T1), while the posttreatment scans were acquired after 9 months investigation period (T2) to evaluate treatment changes. The fan expander was removed for patients in Group II before the final CBCT scan was taken.

CBCT image acquisition

Standardized CBCT scans were acquired using i-CAT® Next Generation CBCT unit (Imaging Sciences International, Hatfield, PA, USA) at 120 kV, 5 mA, field of view (FOV) 17 x 23 cm, voxel size 0.3 mm, and an exposure time of 8.9 sec. The patient position was standardized according to manufacturer's instructions. All CBCT images were saved as digital imaging and communication in medicine (DICOM) files format.

Maxillary sinus segmentation and volume measurement

For maxillary sinus segmentation, a calibrated oral and maxillofacial radiologist with 10 years' experience in CBCT examinations imported the DICOM files into OnDemand3DApp software version 1.0.10.7462 (Cybermed Inc., Seoul, Korea).

In a dim light room and using 21.5-inch-Lenovo LI2215 monitor with a resolution of 1920×1080, the radiologist performed all steps of maxillary sinus segmentation. Utilizing the 3D-module, the coronal, axial, and sagittal cuts were reconstructed with 0.1 mm slice thickness, 1.0 mm slice interval and 1x filter. The volume of right and left maxillary sinuses were calculated separately. First, the right maxillary sinus was displayed in the three planes with its maximum dimension. Then the volumetric region of interest (VOI) overlay option in the tool bar was selected to outline and crop the right sinus. The fine tuning was used to adjust the threshold values manually to include the sinus air space only. Later, the pick tool of segmentation depending on threshold values was selected. Then base points were placed within the cropped sinus, so the segmentation of connected components was obtained (Figure 2). The software calculated the segmented right maxillary sinus volume in cm^3. Second, the volume of left maxillary sinus was obtained using the same process. Finally, using the measured right and left sinus volumes, an average sinus volume was calculated for each patient. To assess the reliability, the volumetric measurements of 10 maxillary sinuses were repeated by the same investigator after one month interval.

Statistical analysis

All Data were collected, tabulated, and statistically analyzed using SPSS software (version 20.0, IBM; Armonk, NY). Microsoft office Excel was used for data handling and graphical presentation. Quantitative variables were described by the Mean and Standard Deviation (SD), and Standard Error (SE). Shapiro-Wilk test of normality was used to test normality hypothesis of all quantitative variables for further choice of appropriate parametric and non-parametric tests. All the variables are found normally distributed allowing the use of parametric tests. Paired sample t-test was used for comparing post and pre maxillary sinus measurements within each group**.** Independent samples t-test was used for comparing the difference in the maxillary sinus changes between the two groups as well as between the right and left sides within each group. Significance level was set at $P < 0.05$. Cronbach's alpha reliability coefficient was used to assess intra-observer agreement.

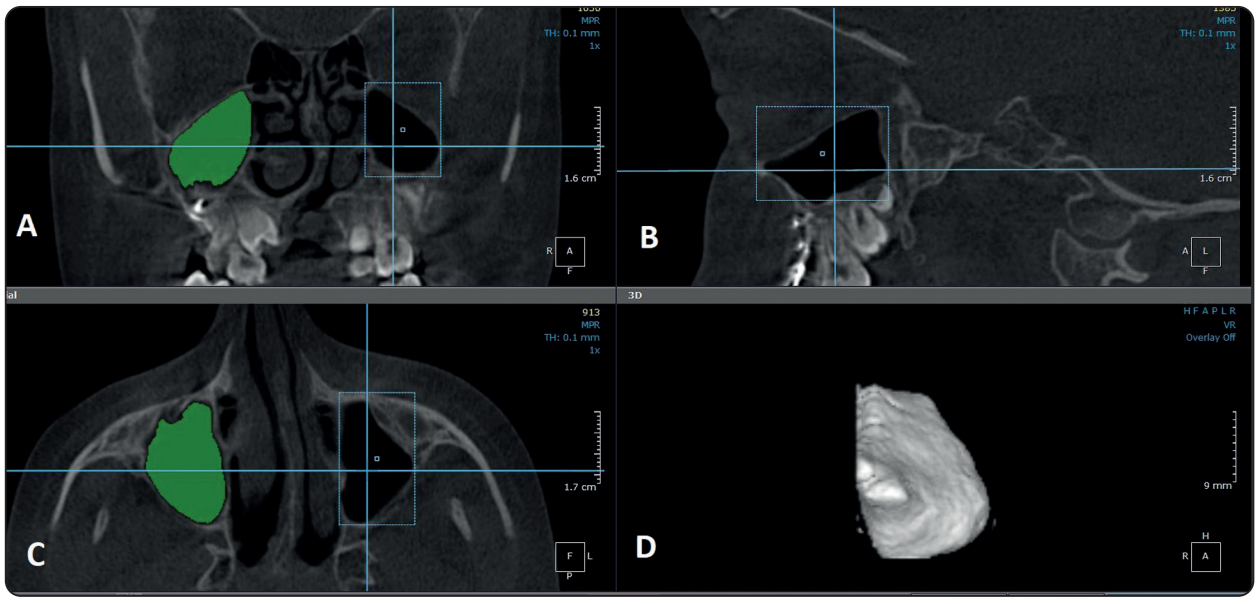

Fig. (2): (A) coronal, (B) sagittal, and (C) axial CBCT images showing contour of segmented right maxillary sinus and the cropped left maxillary sinus using the volumetric region of interest (VOI) and its isolated 3D volume (D).

RESULTS

There was a very good intra-observer agreement as indicated by Cronbach's alpha value of 0.800 for all the variables. Table 1 shows a significant increase in the volume of both the right and left maxillary sinuses as well as in the average sinuses volume in each group. There was no significant difference between the amount of increase of the right and the left sinuses in each group (Table 2). Independent samples t-test did not show any significant difference between the two groups ($P > 0.05$) (Table 3).

TABLE (1). Paired t- test for the mean volume differences (Post-Pre)

	Right sinus Post-Pre volumes			Left sinus Post-Pre volumes			Average sinuses Post-Pre volumes		
	Mean	SD	P value	Mean	SD	P value	Mean	SD	P value
Group I	2.54	1.93	**0.04221***	1.48	0.53	**0.00332****	2.01	1.06	**0.01311***
Group II	1.48	1.29	**0.04990***	1.88	0.95	**0.01172***	1.68	0.94	**0.01599***

, Significant P < 0.05

TABLE (2). Comparison of the measurement differences (Post-Pre) of the right and the left sinuses volumes within each group; Independent samples t-test.

	Right sinus Post-Pre volume		Left sinus Post-Pre volume		Mean	SD	P value
	Mean	SD	Mean	SD			
Group I	2.54	1.93	1.48	0.53	1.06	1.90	0.27944
Group II	1.48	1.29	1.88	0.96	-0.40	1.30	0.53234

, Significant at P < 0.05

TABLE (3). Comparison of the mean differences (Post-Pre) of the measurements between the 2 groups; Independent samples t-test.

Parameter	Group I		Group II		Mean diff.	Standard Error Difference	P value
	Mean	SD	Mean	SD			
Right sinus volume	2.54	1.93	1.48	1.29	1.06	1.04	0.33903
Left sinus volume	1.48	0.53	1.88	0.96	-0.40	0.49	0.43964
Average sinuses volume	2.01	1.06	1.68	0.94	0.33	0.63	0.61301

, Significant at P < 0.05

DISCUSSION

Maxillary sinusitis was found to be more prevalent in patients with CLP than in the normal population.[2] The different embryological development in cleft patients might be one of the causes.[5-8] Moreover, the hypoplastic maxilla characteristic for patients with UCLP has been reported to be one of the etiological factors.[12] Bone-anchored maxillary protraction (BAMP) protocol was proved to be an effective method to correct maxillary deficiency whether it was accompanied by maxillary expansion or not [15], despite the fact that most of the UCLP patients still need a phase of expansion to correct the transverse discrepancy as well. Hence, it was prudent to evaluate whether the treatment effects produced by this smart protocol can improve the volume of the maxillary sinus in cleft patients or not, which can help to decrease the incidence of maxillary sinusitis that is widely spread among those patients.

The results of this study showed significant positive treatment effects of BAMP protocol on the maxillary sinus volume, with a significant volumetric increase in both the cleft and the non-cleft sides in both groups. No previous studies were carried out to evaluate the effect of BAMP on maxillary sinus volume, so there were no data to compare with. However, Pamporakis et al in their study to investigate the effect of facemask, as the traditional protocol for maxillary protraction, on the maxillary sinus volume in normal individuals, reported an increase in the maxillary sinus volume after treatment, but they related this effect to normal growth and not because of facemask treatment.[18] They did not have a control group in their study, so they used the data provided by previous 3D growth studies [20,21] concerning the normal growth of maxillary sinus between the 8-12 years of age. Concerning our study, there was no available literature about the normal growth of the maxillary sinus in cleft patients that may differ than that in normal individuals. Moreover, due to ethical reasons, it was not possible to include a control group having a skeletal problem that needs quick interference just for the aim of comparison of the results.

Regarding the effect of maxillary expansion on maxillary sinus volume, the results of previous studies in non-cleft patients are controversial. Garrett et al found that maxillary sinus width reduced with RPE which can be the cause of decreased maxillary sinus volume.[22] Smith et al found no statistically significant change in the sinus volumes after RPE.[23] On the other hand, Motro reported a significant volumetric increase in the maxillary sinus after maxillary expansion.[24] Similarly, Shendy et al reported a significant increase in maxillary sinus volume following RPE regardless the type of maxillary expander used.[25] The results of our study, which is the only one available for patients with UCLP, did not find any additional statistically significant effect for maxillary expansion on the maxillary sinus volume.

From the mentioned results, we can conclude that BAMP protocol is an effective treatment modality that does not only correct the antero-posterior maxillary deficiency characteristic for patients with UCLP, but also it was found to be an effective method to increase the volume of the hypoplastic maxillary sinus characteristic for those patients, in both the cleft and the non-cleft sides, which can help to decrease the incidence of maxillary sinus diseases common in those patients. Maxillary expansion can be carried together with this protocol whenever there is a transverse discrepancy but without any additional effect on the maxillary sinuses volume.

Limitations of this study were the small sample size and absence of a control group together with absence of baseline data about the normal growth and development of the maxillary sinus in patients with CLP.

CONCLUSIONS

- Maxillary protraction using BAMP protocol could increase the maxillary sinus volume in patients with UCLP, in both the cleft and the non-cleft sides.
- Preceding BAMP protocol by maxillary expansion did not produce any additional increase in the maxillary sinus volume than that produced by the protocol alone.

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