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ORIGINAL ARTICLE

Maxillary sinus and alveolar bone levels in subjects with skeletal anterior open bite: Is there room for mini-implant supported molar intrusion?

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ABSTRACT... Objective: To compare the maxillary sinus (MS) and alveolar bone (AB) heights in adult subjects with normal occlusion and those with skeletal anterior open bite (AOB). **Study Design:** Cross-sectional. **Setting:** Aga Khan University Hospital, Karachi. **Period:** December 2020 to June 2021. **Material & Methods:** The study was conducted on the pretreatment orthodontic records of sixty adult subjects (30 males, 30 females). Skeletal high angle cases with AOB >1 mm were included in skeletal AOB while a matched sample with normal dental and skeletal relationships was included in normal occlusion group. The MS and AB heights were measured on lateral cephalograms and orthopantomograms at interdental regions from maxillary 1st premolar to 2nd molar. The MS and AB heights were compared between males and females and between skeletal AOB group and normal occlusion groups using independent sample t-test. **Results:** The mean age of the subjects with skeletal AOB (22.68±4.04 years) and those with normal occlusion (23.19±4.68 years) were comparable ($p=0.653$). In general, MS height and AB heights were greater in males than females. There was no significant difference in the MS height between the skeletal AOB and normal occlusion groups for both genders ($p>0.05$). However, both males and females with skeletal AOB had greater AB heights between 2nd premolar and 1st molar and between 1st molar and 2nd molar than those with normal occlusion ($p<0.05$). **Conclusion:** The MS height in skeletal AOB and normal occlusion groups were comparable. Subjects with skeletal AOB had maximum AB height mesially and distally to maxillary 1st molar that was significantly greater than those with the normal occlusion.

Key words: Alveolar Bone, Maxillary Sinus, Open Bite.

INTRODUCTION

The skeletal anterior open bite (AOB) is characterized by the lack of a vertical overlap between the maxillary and mandibular incisors, decreased maxillary incisor show, long slender nose, excessive vertical maxillary growth, increased lower anterior facial height, decreased posterior facial height, a short ramus and a hyperdivergent mandibular plane angle.[1] In adults, the correction of skeletal AOB can be achieved by surgical orthodontics such as LeFort I posterior maxillary impaction or orthodontically by the intrusion of posterior dentoalveolar segments using skeletal anchorage.[2] Dental implants, miniplates and mini-implants are various types of temporary anchorage devices (TADs) that have been used to obtain absolute anchorage.[3,4] Kuroda et al[5] proposed that the correction of skeletal AOB with TADs is simpler as compared to the orthognathic surgical procedure. This technique is not associated with any functional problems or neurosensory loss.[6] Hence, TADs have become a popular choice among clinicians as a conservative treatment modality with minimal complications and decreased morbidity for the correction of skeletal AOB.

Mini-implants are titanium screws that are usually placed in the inter-radicular space in maxillary posterior region. The mesiodistal inter-radicular distance is important whenever mesialization or distalization of posterior segment is expected. Similarly, when the intrusion of posterior teeth is planned the proximity to maxillary sinus (MS)

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and the presence of alveolar bone (AB) near the root apices is important for the success of mini-implants.[7] Mini-implants are placed as apically as possible in the buccal sulcus to allow maximum intrusion of the posterior dentoalveolar segment which may result in perforation of the MS.[7] On the other hand, presence of inadequate inter-radicular AB may result in trauma to the root surface and the surrounding periodontal ligament fibers during insertion of mini-implant or during tooth movement.

The MS develops around the third month of intrauterine life and continues to expand with facial growth. As an individual continues to grow, the sinus floor may extend between the adjacent teeth and even between the roots of the teeth creating protrusions in the sinus floor. This may also effect the level of inter-radicular AB in the maxillary posterior teeth. The proximity of the roots of maxillary posterior teeth with the sinus floor may vary according to age, size and amount of pneumatization of the sinus.[8] A thorough knowledge about the anatomy of the MS is essential for diagnosing and planning the placement of mini-implants to minimize any associated complications.[9] Moreover, the presence of sinus hillocks between the roots may also hinder the orthodontic tooth movement.[10]

Mini-implants supported intrusion of the posterior dentoalveolar segment can treat the skeletal AOB. However, the amount of intrusion is limited by the inter-radicular AB height. The maxillary sinus (MS) pneumatization with age may also decrease the distance between the root apices and the sinus floor further restricting the amount of intrusion. Hence, this study aimed to evaluate the AB and MS heights in subjects with normal occlusion and skeletal AOB.

MATERIAL & METHODS

A cross-sectional study was conducted from December 2020 to June 2021 with the data collected from the pretreatment radiographs of orthodontic patients aged 18 to 30 years visiting our dental clinics. The study was approved by ethical committee (4686-Sur-ERC-17). The sample size was calculated using the findings of Ryu et al[11] who reported a mean MS height of 36.7 ± 5.0 mm in subjects with normal occlusion and 40.5 ±4.7 mm in subjects with AOB. Keeping $\alpha = 0.05$ and power of study as 80 %, the sample size was calculated to be at least 26 subjects in each group. We inflated this number by 15% to obtain a final sample size of minimum 60 subjects (30 in each group).

The entire sample was divided into two groups i.e. normal occlusion and skeletal AOB with an equal number of males and females. Adult subjects with openbite > 1 mm as indicated by the dental casts and skeletally high angle cases (i.e. SN-MP > 36º and FMA > 29º) were included in the skeletal AOB group. While those patient who had overbite > 1mm and skeletal normal angle cases (i.e. SN-MP <36º and FMA <29º) were included in the normal occlusion group. Subjects with missing teeth, previous history of orthodontic treatment, trauma, allergies or any significant medical condition were excluded. The digital images of the lateral cephalograms and orthopantomograms were analyzed using View Pro-X (Rogan-Delft, Veenendaal, Netherlands) software for accurate visualization of the maxillary sinus and basal bone. All the radiographs were coded before being analyzed by the principal investigator to minimize the risk of bias.

The MS height was evaluated on lateral cephalograms taken with rigid head fixation and a 165cm film to tube distance using Orthoralix R 9200 (Gendex-KaVo, Milan, Italy) using the method described by Endo et al.[12] The left maxillary sinus is positioned more posteriorly as compared to the right maxillary sinus as the radiographs are taken with the patient's head turned towards the left side. The outline of the left maxillary sinus was carefully marked with a white outline on the digitized radiographs. The x-axis and y-axis parallel and perpendicular to the Frankfort horizontal plane through the sella point were traced, respectively. The linear distances between the superior point on the sinus roof and inferior most point on the sinus floor in the region between the first and second molars, first molar and second premolars, and first and second premolars were measured, respectively. All the measurements were made parallel to the y-axis to keep the measurements standardized (Figure-1).

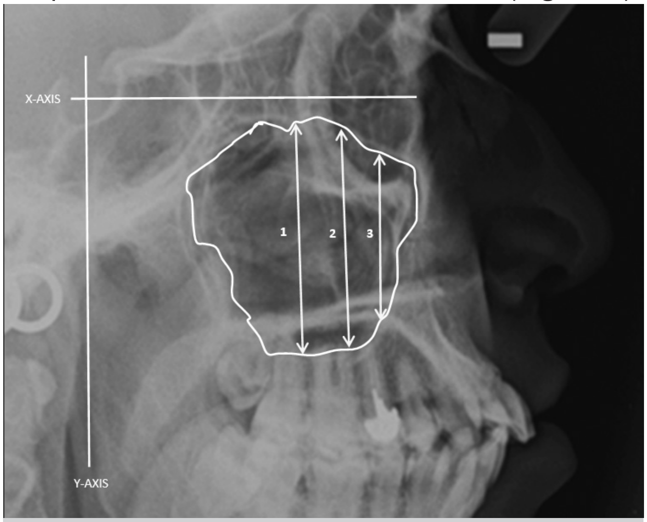

Figure-1. Measurement of maxillary sinus height on lateral cephalogram

1 – maxillary sinus height between first and second molar (MS-M1.M2); 2 – maxillary sinus height between first molar and second premolar (MS-M1.PM2); 3 – maxillary sinus height between first and second premolars (MS-PM1.PM2)

The AB height was evaluated on the orthopantomograms. The bone boundaries are easy to identify due to the lack of superimposing structures. The apical extent of the alveolar bone in the region of the first and second molars, first molar and second premolars, and first and second premolars were marked, respectively. The maximum linear distance between the sinus floor and the apical extent of the alveolar bone was measured on both the right and the left sides in the aforementioned regions (Figure-2). The final values of the AB heights were taken as the mean of the right and the left side readings.

1 – alveolar bone height between first and second molar (ABH-M1.M2); 2 – alveolar bone height between first molar and second premolar (ABH-M1.PM2); 3 – alveolar bone height between first and second premolars (ABH-PM1.PM2)

Data were analyzed using SPSS for windows (version 20.0, SPSS Inc. Chicago). To assess the intra-examiner reliability, ten radiographs were revaluated and measurements repeated by the principal investigator. The errors were calculated according to Dahlberg's[13] equation and the coefficient of reliability (ICC). The Shapiro-Wilk test was used to assess the normality of the measurements which showed a normal distribution. The independent sample t- test was used the compare the MS and AB heights between genders and subjects with normal occlusion and AOB. Similarly, various parameters such as patient's age, overjet, overbite, maxillary posterior alveolar heights and cephalometric readings were also compared using an independent sample t test.

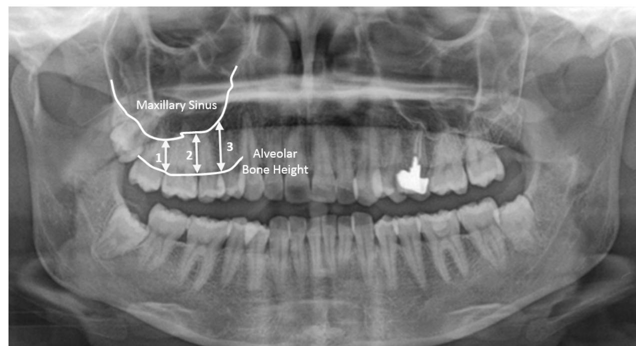

Figure-2. Measurements of alveolar bone heights on orthopantomogram

RESULTS

The mean age of the subjects in skeletal AOB group and normal occlusion group were 22.68 ± 4.04 and 23.19 ± 4.68 years, respectively. There was no significant difference in the mean age of two groups ($p=0.653$). A detailed comparison of various characteristics of subjects in the two groups is given in Table-I.

U6-PP: maxillary posterior alveolar height, SN-MP: angle of sella-nasion line to mandibular plane, FMA: angle of Frankfort line to mandibular plane, SN-PP: angle of sella-nasion line to palatal plane, FH-PP: angle of Frankfort line to palatal plane; MMA: angle of the palatal plane to the mandibular plane; Facial height ratio, the ratio of posterior facial height to anterior facial height.

The results of the ICC showed a high correlation between the two sets of readings. The Dahlberg's error ranged from 0.103 to 0.890 (Table-II).

ICC - Intra-class correlation coefficient; MS-M1.M2 - maxillary sinus height between first and second molar; MS-M1.PM2 - maxillary sinus height between first molar and second premolar; MS-PM1.PM2 - maxillary sinus height between first and second premolars; ABH-M1.M2 - alveolar bone height between first and second molar; ABH-M1.PM2 - alveolar bone height between first molar and second premolar; ABH-PM1.PM2 - alveolar bone height between first and second premolars.

The MS and AB heights in the various regions were compared between males and females. In general, the measurements were found to be generally greater in males as compared the females (Table-III). Hence, the results were further stratified according gender.

N = 60; SD **-** Standard deviation**;** MS-M1.M2 - maxillary sinus height between first and second molar; MS-M1.PM2 - maxillary sinus height between first molar and second premolar; MS-PM1.PM2 - maxillary sinus height between first and second premolars; ABH-M1.M2 - alveolar bone height between first and second molar; ABH-M1.PM2 - alveolar bone height between first molar and second premolar; ABH-PM1.PM2 - alveolar bone height between first and second premolars *p < 0.05; *Independent sample t-test

The MS and AB heights were compared between the subjects with normal occlusion and those with AOB using the independent sample t test (Table-IV). The MS height was found to comparable in both the groups for both males and females (p>0.05). The AB height mesially and distally to maxillary first molar was found to be significantly greater in subjects with AOB as compared to the normal occlusion (p<0.05). The maximum AB height was found more anteriorly in the region between the first and second premolars. The pattern was same for both genders.

	Normal Occlusion n=30 (mean ± SD)	**Skeletal Anterior Open Bite n=30 (mean ± SD)**	**P**
Age (years)	23.19±4.68	22.68±4.04	0.653
Age (range)	18-29	18-30	-
Males	15	15	-
Females	15	15	-
Overjet (mm)	2.31 ± 1.12	3.01 ± 0.98	0.012*
Overbite (mm)	3.17 ± 0.83	-2.24 ± 1.54	<0.001*
U6-PP (mm)	24.87 ± 2.47	27.91 ± 2.11	<0.001*
ANB °	2.41 ± 2.01	3.32 ± 3.49	0.221
SN-MP °	32.71 ± 3.81	43.52 ± 4.12	<0.001*
FMA°	25.12 ± 3.51	34.81 ± 3.67	<0.001*
SN-PP °	11.02 ± 3.00	9.05 ± 2.88	0.011
FH-PP °	2.03 ± 2.91	1.09 ± 1.91	0.144
MMA °	24.32 ± 3.49	35.24 ± 3.55	<0.001*
Facial height ratio (%)	65.91 ± 2.75	57.83 ± 3.33	<0.001*

Table-I. Characteristics of subjects
N=60, SD - Standard deviation, Independent sample t-test. *p<0.05

Parameters	**1st Reading Mean ± SD (mm)**	**2nd Reading Mean ± SD (mm)**	**ICC**	**Dahlberg's Calculations**
MS-M1.M2	41.29 ± 3.71	43.43 ± 3.7	0.852	0.646
MS-M1.PM2	39.90 ± 4.82	40.59 ± 4.12	0.913	0.103
MS-PM1.PM2	36.48 ± 4.66	39.5 ± 4.48	0.950	0.245
ABH-M1.M2	10.16 ± 2.32	10.2 ± 1.81	0.929	0.480
ABH-M1.PM2	11.55 ± 2.33	11.52 ± 2.0	0.934	0.245
ABH-PM1.PM2	13.1 ± 2.98	12.2 ± 2.60	0.977	0.560

Table-II. Intra-Examiner reliability
N = 10; SD - Standard Deviation

Parameters	Males Mean ± SD (mm) n = 30	Females Mean ± SD (mm) n = 30	P-Value
MS-M1.M2	42.91 ± 3.68	38.96 ± 3.60	0.001**
MS-M1.PM2	40.44 ± 4.65	37.5 ± 4.74	0.012*
MS-PM1.PM2	35.56 ± 5.65	32.84 ± 4.94	0.042*
ABH-M1.M2	11.51 ± 3.28	10.36 ± 2.46	0.523
ABH-M1.PM2	13.08 ± 4.33	11.07 ± 2.81	0.092
ABH-PM1.PM2	18.25 ± 6.68	14.7 ± 3.2	0.008*

Table-III. Comparison of maxillary sinus and alveolar bone heights between genders

Gender	Parameters	Normal Occlusion Mean ± SD (mm)	Skeletal AOB Mean ± SD (mm)	P-Value
Male n = 30	MS-M1.M2	42.65 ± 4.05	43.17 ± 3.4	0.838
	MS-M1.PM2	40.60 ± 4.46	40.29 ± 4.98	0.967
	MS-PM1.PM2	35.25 ± 4.04	35.87 ± 7.05	0.567
	ABH-M1.M2	10.17 ± 2.04	12.85 ± 4.23	0.035*
	ABH-M1.PM2	11.39 ± 1.94	14.77 ± 5.37	0.050*
	ABH-PM1.PM2	17.79 ± 8.63	18.71 ± 4.18	0.098
Female n = 30	MS-M1.M2	40.09 ± 2.63	37.75 ± 4.19	0.186
	MS-M1.PM2	37.25 ± 2.94	37.74 ± 6.14	0.870
	MS-PM1.PM2	31.85 ± 4.0	33.83 ± 5.70	0.325
	ABH-M1.M2	9.61 ± 1.88	11.22 ± 2.84	0.041*
	ABH-M1.PM2	9.90 ± 2.15	12.24 ± 2.96	0.026*
	ABH-PM1.PM2	13.56 ± 2.31	15.75 ± 3.62	0.085

Table-IV. Comparison of maxillary sinus and alveolar bone heights between normal occlusion and skeletal AOB groups

N = 60; SD - Standard Deviation; MS-M1.M2 - maxillary sinus height between first and second molar; MS-M1.PM2 - maxillary sinus height between first molar and second premolar; MS-PM1.PM2 - maxillary sinus height between first and second premolars; ABH-M1.M2 - alveolar bone height between first and second molar; ABH-M1.PM2 - alveolar bone height between first molar and second premolar; ABH-PM1.PM2 - alveolar bone height between first and second premolars; AOB - anterior open bite.
*p < 0.05; ** p < 0.001; Independent sample t test

DISCUSSION

In recent years, the use of TADs have greatly extended the range of tooth movement for the correction of moderate to severe orthodontic problems.[14] This has resulted in selection of treatment modalities that are more conservative with minimal complications as compared to the orthognathic surgical procedures. The TADs placed in strategic positions for dentoalveolar movements achieve results that were previously possible only with surgery.[15] Yao et al[16] reported that the first and second maxillary molars can be intruded around 4 and 2mm, respectively. This can result in closure of an AOB as great as 6 to 7mm. The TADs, though an effective and efficient method of posterior dentoalveolar intrusion, has certain limitations in aspects of site selection and amount of intrusion.

Daimaruya et al[17] investigated the effects of molar intrusion on the nasal floor and root morphology in beagles. They found that the nasal floor remodeled and formed a thin lining around the roots as these teeth were intruded intra-nasally. They also reported mild to moderate external apical root resorption of 0.18 ± 0.18 mm without the formation of reparative dentine in these subjects. Another study reported similar findings with respect to remodeling of sinus lining with molar intrusion, but cautioned that use of excessive forces can result in root resorption.[18] The site of placement may also limit the intrusion with mini-implants. An inferior positioning of sinus floor may result in the perforation of sinus lining during TAD placement.[7] As the correction of skeletal AOB is dependent on effective molar intrusion, this study aimed to evaluate and compare the MS and AB heights in subjects with normal occlusion and skeletal AOB.

In the present study, all the variables were found to be greater in males as compared to the females. Teke et al[19] reported similar findings with respect to the MS heights. They suggested that the difference in the maxillary sinus dimensions may be used for gender determination in subjects when extreme post-mortem changes had occurred. As majority of the parameters used to assess MS and AB heights showed statistically significant differences, the results were further stratified based on gender.

In our sample, the MS heights in skeletal AOB were comparable to those with normal occlusion while the AB heights were increased in the skeletal AOB group. Which shows that with the increase in the vertical facial proportions the vertical dimensions of maxillary sinus are not significantly affected rather the overeruption of maxillary posterior teeth may occur ultimately increasing the AB heights. The maximum MS height was found to be in the region between the first and second molars in both genders. Ryu et al[11] reported an overall increase in MS heights in subjects with skeletal AOB. The amount of maxillary molar intrusion is limited by level of the sinus floor.[17,18] The force is concentrated in a very small area in the apical region during the intrusive movement. A lower level of MS floor implies that caution is advised, as excessive contact between the root apex and sinus lining may result in apical root resorption.

In both genders, the AB heights were found to be greater in subjects with skeletal AOB as compared to those with normal occlusion. Vibhute et al[20] reported similar findings. In contrast, Ryu et al[11] found the AB heights were reduced in subjects with skeletal AOB. A major reason for the variation in results may be the differences in the measurement technique used. Additionally, various other factors such as ethnic variations, sample size and method of assessment may also have contributed to the difference in results. The minimal height was found to be in the region of first and second molars in all the aforementioned studies.

The maximum amount of intrusion in the molar region close to the angle of the mandible will result in increased counter clockwise rotation of the mandible. This autorotation of the lower jaw facilitates in the closure of the AOB. Our results showed maximum AB height between the premolars, a site that is not suitable for mini-implant supported intrusion of maxillary posterior teeth. However, patients with skeletal AOB had more AB height mesially and distally to maxillary first molar which may be selected as a suitable site for mini-implant supported intrusion of posterior teeth. The mini-implants placed in the buccal cortical region are preferred for ease of insertion and accessibility; however they have an increased risk of maxillary sinus perforation due to close proximity. Hence, the clinicians should be cautious during the placement. The mini-implants may be placed perpendicular to minimize the contact with the sinus floor.[21] The use of TADs on the palatal side in the mid and/or parasagittal regions may also be considered.

The use of a two-dimensional imaging technique may be a possible limitation of the present study. The presence of superimpositions may pose certain difficulties in identification of the anatomic landmarks. To minimize this, digitalized images were utilized so that the appropriate image contrast may be customized for the ease of identification and to facilitate the measurements. Furthermore, a strict protocol for identification of the left maxillary sinus as described by Endo et al[12] was followed. The authors recommend using the three-dimensional imaging technique for volumetric assessment of the maxillary sinus and its relationship with the maxillary posterior dentoalveolar segment. This will ensure the efficient use of TADs for the conservative management of skeletal AOB with minimal complications.[6,7]

CONCLUSION

The AB heights mesially and distally to maxillary first molar were significantly greater in patients with skeletal AOB as compared to those with normal occlusion. The greatest AB height was found between the maxillary premolars. MS height was found to be greater posteriorly in the region of first and second molars. However, there was no significant difference in the MS height between patients with skeletal AOB and those with normal occlusion. It is suggested that these biological and anatomical limitations should be considered prior to the selection of any treatment modality and mechanics for subjects with skeletal AOB.

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2	Waqar Jeelani	Study design, literature review, experimental/laboratory/treatment procedures, statistical analysis, manuscript preparation, editing and review.	
3	Mubassar Fida	Study design, literature review, experimental/laboratory/treatment procedures, manuscript preparation, editing and review.	