Influence of orthodontic treatment on changes in the maxillary sinus dimensions

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Introduction

During orthodontic movement of the tooth along with the maxillary sinus, the migrating root is moved into the alveolar bone by surrounding bone resorption and apposition. Alveolar bone modeling and remodeling systems are able to adapt rapidly to changes in mechanical loading. New bone formation on the sinus floor can be stimulated by orthodontic tooth movement. Given this information, tooth movement passing through the maxillary sinus has an effect on the sinus dimensions and volume in comparison to the sinus without tooth movement. However, predicting the volumetric and dimensional changes in the maxillary sinus after orthodontic treatment is still unclear. Thus, this study aimed to investigate the correlation of craniofacial morphology with maxillary sinus morphology and to evaluate whether orthodontic treatment facilitates maxillary sinus enlargement in adults.

Materials and methods

Participants

Forty-five female patients with a variety of malocclusions who underwent orthodontic treatment with multibracket appliances at the Yamada Orthodontic Office from January 2010 to December 2022 were used as participants in this study. This study was approved by Tokushima University Hospital Ethics Committee (permit no. 3900).

CBCT images of maxillary sinus

All patients underwent pretreatment and posttreatment CBCT (Alphard-3030, Asahi Roentgen Ind. Co., LTD., Kyoto,
Japan). From a series of CT DICOM images, a 3-dimensional model of the maxillary sinus was extracted (**Figure 1**).
Before and after treatment, lateral cephalograms were also performed using a cephalometric radiographic system.

Craniofacial morphology

According to the maxillomandibular horizontal jaw-base relationship, the ANB angle, the participants were classified
into three groups.
Skeletal Class II group: patients with more than 5.0^{o} ANB angle
Skeletal Class I group: patients with 1.0^{o} $\leq$ ANB angle <5.0^{o}
Skeletal Class III group: patients with less than 1.0^{o} ANB angle
From the lateral cephalography, the following measurements were assessed for morphometric evaluation:

Angular measurement items (^{o})
SNA; SNB; ANB; Gonial angle (Go. A); FMA; Occlusal plane to SN (Occl. pl. A); Palatal plane to FH; U1 to SN; Interincisal angle (IIA); IMPA; FMIA

Linear measurement items (mm)
SN; U1 to NA; L1 to NB; Overjet; Overbite; N-Me; Ar-Go; Ar-Me; Go-Me

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Maxillary sinus morphology

The 3-dimensional maxillary sinus models were constructed from CT DICOM data. A specific threshold was set for volumetric measurement of the maxillary sinus. On each side, the maxillary sinus was identified as the integral part of the air cavity within the sinus walls in the maxillary bone on reformatted axial, sagittal, and coronal images. The maximum distance between the most lateral and medial points of each sinus was identified as the width. The height was defined as the maximum distance between the bottom and the highest points of the sinus on each side. The maximum breadth between the most prominent points of the anterior and posterior parts of the sinus was measured as the sinus breadth.

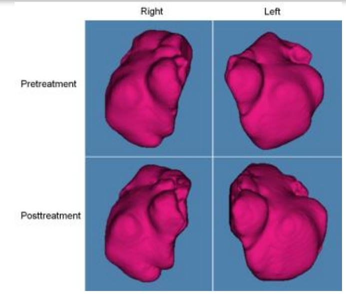

Figure 1. Representative images of the maxillary sinuses.

Results

Participants

The participants consisted of 15 females with skeletal Class I group ranging from 19 to 29 years (mean age ± SD, 24.5 ± 3.7 years); 15 females with skeletal Class II group ranging from 18 to 28 years (23.4 ± 3.6 years); and 15 females with skeletal Class III group ranging from 18 to 26 years (23.8 ± 3.1 years). There were no significant differences in age among the three subgroups (p =0.704, one-way ANOVA). The treatment duration was 3.7 ± 1.1 years.

Volumetric and geometric measurements of the maxillary sinus

For all participants, no significant differences in the maxillary sinus dimensions were found between the left and right sides (p > 0.145), and the average values of the bilateral maxillary sinuses were adopted (**Table 1**). The pretreatment sinus width, height, and length in skeletal Class I were 32.2 ± 3.9 mm (mean ± SD), 39.5 ± 3.8 mm, and 38.6 ± 2.4 mm, respectively. In skeletal Class II, the sinus width, height, and length were 33.9 ± 6.2 mm, 37.3 ± 3.5 mm, and 38.6 ± 2.4 mm, respectively. In skeletal Class III, the width was 32.0 ± 4.3 mm, the height was 41.8 ± 5.0 mm, and the length was 38.0 ± 2.8 mm. The total volumes of the left and right maxillary sinus were 36179.3 ± 5454.0 mm^3 in the skeletal Class I, 34729.8 ± 6686.6 mm^3 in the skeletal Class II, and 35592.3 ± 10334.3 mm^3 in the skeletal Class III. The values for width, length, and volume of the sinuses were almost similar among the three groups (p > 0.508); however, the skeletal Class II group had significantly lower height of the maxillary sinus compared to the skeletal Class III group (p = 0.017). Comparing the pretreatment and posttreatment measurements, the sinus width and length showed no significant changes during orthodontic treatment regardless of the skeletal pattern, whereas the posttreatment sinus height and volume were significantly greater than the pretreatment values, regardless of the skeletal classification (p < 0.01).

Table 1. CT parameters of the maxillary sinus size for classified skeletal type.

		Pretreatment	Posttreatment	p-Value		
				Interaction	Time	Class
Width	Class I	32.2 ± 3.9	32.1 ± 3.9	0.344	0.722	0.508
	Class II	33.9 ± 6.2	33.9 ± 6.2			
	Class III	32.0 ± 4.3	32.0 ± 4.1			
Height	Class I	39.5 ± 3.8	39.6 ± 3.7	0.099	< 0.001	0.020
	Class II	37.3 ± 3.5	37.8 ± 3.5			
	Class III	41.8 ± 5.0	42.2 ± 5.1			
Length	Class I	38.6 ± 1.8	38.7 ± 1.8	0.088	0.231	0.771
	Class II	38.6 ± 2.4	38.5 ± 2.5			
	Class III	38.0 ± 2.8	38.2 ± 2.8			
Volume	Class I	36179.3 ± 5454.0	36716.7 ± 5424.2	0.481	< 0.001	0.858
	Class II	34729.8 ± 6686.6	35136.2 ± 6825.4			
	Class III	35592.3 ± 10334.3	36414.6 ± 9983.0			

Unit: mm for the width, height, and depth; mm^3 for the volume

Table 2. Multiple regression analysis for the association of maxillary sinus dimensions with cephalometric parameters before and after orthodontic treatment.

(1) Pretreatment	Model summary	
Multiple regression equation	Prob. - F	R^2
Width = 2.201 x (Class II) + 0.67 x (Class III) + 0.852** x (Overbite) + 0.158* x (U1-SN) + 12.705	0.030	0.230
Height = - 2.851 x (Class II) + 0.437 x (Class III) + 0.410* x (Ar-Me) - 0.425* x (SNB) + 28.531	0.005	0.305
Length = 0.413 x (Class II) - 1.808 x (Class III) - 0.168 x (Occ Plane to SN) + 0.12 x (Ar-Me) + 28.925**	0.045	0.211
Volume = - 683.899 x (Class II) + 1724.558 x (Class III) + 1102.423* x (Overbite) + 624.838 x (S-N) - 10643.691	0.068	0.192
(2) Posttreatment	**Model summary**	
Multiple regression equation	Prob. - F	R^2
Width = 0.001 x (Class II) + 3.988 x (Class III) - 1.005** x (U1-NA) + 2.909** x (Overjet) + 26.967**	0.016	0.258
Height = - 1.715 x (Class II) + 0.573 x (Class III) + 0.217 x (Ar-Me) + 16.555	0.016	0.221
Length = - 0.167 x (Class II) + 0.281 x (Class III) - 0.195* x (Occ Plane to SN) - 0.308 x (U1-NA) + 43.856**	0.094	0.176
Volume = - 1292.379 x (Class II) - 4235.445 x (Class III) + 432.232 x (Ar-Me) - 9171.899	0.307	0.083

*: p < 0.05, **: p < 0.01, In yellow: explanatory variable with a significant effect against the response variable
Prob: F: probability level of F-value; R^2: coefficient of determination.

The relationship between the craniofacial morphology and the maxillary sinus morphology

Multiple regression analysis was used to analyze the correlations of maxillary sinus dimensions with 20 cephalometric variables, and multiple regression equations were calculated (Table 2). The effectiveness of each multiple regression equation was determined based on the probability level of the F-value. Pretreatment, the width, height, and length of the maxillary sinus were significantly related (probability level of F-value = 0.030, 0.005, and 0.045, respectively). In particular, overbite and U1-SN significantly were related to the maxillary sinus width (p = 0.007 and p = 0.044, respectively), which are regarded as response variables. Moreover, Ar-Me and SNB significantly affected maxillary sinus height (p = 0.010 and p = 0.041, respectively). Posttreatment, the maxillary sinus width and height were significantly improved (probability level of F-value = 0.016 and 0.016, respectively). In the multiple regression equation of maxillary sinus width, U1-NA and overjet were significantly affected (p = 0.006 and p = 0.009, respectively).

Conclusions

Comparing the pretreatment and posttreatment measurements, the posttreatment sinus height and volume were significantly greater than the pretreatment values, although the sinus width and length showed no significant changes during orthodontic treatment. This implies that orthodontic treatment may facilitate the enlargement of the maxillary sinus even after physical growth. Furthermore, the maxillary sinus dimensions may be associated with craniofacial skeletal patterns and anterior occlusion.

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