Assessment of Maxillary Sinus Septa Using Cone-Beam Computed Tomography: Etiological Consideration

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ABSTRACT

Background: Septum presence in the maxillary sinus complicates sinus floor elevation surgery, and so it is important that septa are accurately diagnosed on preoperative imaging.

Purpose: Septa were observed regarding their relationship with the bony palate using cone-beam computed tomography (CT).

Materials and Methods: Thirty maxillary sinuses with dentate jaws of 15 dry skulls and a cone-beam CT unit were used. A septum was defined as a pointed bone structure, and an exostosis was defined as a rounded bone structure. The occurrence and locations of maxillary sinus septa and exostoses of more than 2 mm in height were evaluated. Also, angles between the direction of septum and median palatine suture were measured on axial images.

Results: Twelve septa of 11 maxillary sinuses (37%) and nine exostoses of nine maxillary sinuses (30%) were observed. Also, 42% of septa and 67% of exostoses were antero-posteriorly aligned according to the transverse palatine suture. Moreover, the mean septum angle was 57.9 degrees in the anterior maxillary sinus region, and 101.8 degrees in the transverse palatine suture region, and significant differences were noted between them.

Conclusion: Maxillary sinus septa and exostoses could be clarified regarding their relationship with the bony palate using cone-beam CT.

KEY WORDS: bony palate, cone-beam computed tomography, exostosis, maxillary sinus, septum, transverse palatine suture

Septum presence in the maxillary sinus, especially the inferior wall, complicates sinus floor elevation surgery.[1] Therefore, it is important for septa to be accurately diagnosed on preoperative imaging. The occurrence and location of maxillary sinus septa have been evaluated using panoramic radiography and computed tomography (CT).[2–7] Maxillary sinus septa could be accurately diagnosed using CT. However, the relationship between maxillary sinus septa and the bony palate was not investigated.

Recently, cone-beam CT was developed with a spatial resolution higher than that of multislice CT.[8] Using cone-beam CT images, the bifid mandibular canal in the mandibular ramus was observed in 65% of subjects, and the accessory mental foramen in 7% of subjects.[9,10]

In the present investigation, we observed the maxillary sinus septa to clarify the relationship with the bony palate using cone-beam CT images of dry skulls. Further, a hypothesis regarding the etiology of maxillary sinus septa was proposed from the results.

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MATERIALS AND METHODS

Cone-Beam CT Images

Cone-beam CT using Alphard VEGA (Asahi Roentgen Ind., Kyoto, Japan) was performed using 30 maxillary sinuses of 15 dry skulls with a dentate jaw. The palatal plane of each dry skull was set parallel to the floor base. The exposure volume was set at 50 mm in diameter and 50 mm in height (D-mode), and the voxel size was $0.1 \times 0.1 \times 0.1$ mm. The DICOM files of axial images were saved to a portable hard disk.

Assessment of Septa and Exostoses

Cone-beam CT images were analyzed using two DICOM viewer software packages (OsiriX Imaging Software: The OsiriX Foundation, Geneva, Switzerland, http://www.osirix-viewer.com,[11] and INTAGE Realia: KGT, Tokyo, Japan). OsiriX software was used for measurements of two-dimensional images, and INTAGE Realia software was employed for the reconstruction of three-dimensional images. Maxillary sinus walls were observed between the most inferior site of the maxillary sinus and 10 mm superiorly. A septum was defined as a pointed bone structure, and an exostosis was defined as a rounded bone structure (Figures 1–3). Further, any septum/exostosis less than 2 mm in height was excluded from the evaluation. One oral and maxillofacial radiologist with experience of 25 years (M.N.) and one general practitioner with experience of 15 years and dental implant treatment (Y.S.), reconstructed and observed images in consultation.

Firstly, we recorded whether the septum/exostosis originated from any maxillary sinus wall. The location of the septum/exostosis was antero-posteriorly classified into three regions, in relation to the transverse palatine suture: anterior maxillary sinus region, 3 mm anterior and posterior region from the transverse palatine suture, and the posterior maxillary sinus region. (Figure 4) Subsequently, the height of each septum/exostosis was measured in accordance with the method of Velasquez-Plata and colleagues.[5] In septum/exostosis measurement, originating from the inferior wall, the distance between the base and top of the septum/exostosis was measured using an intero-laterally middle longitudinal image of the septum/exostosis. Also, for septa/exostoses originating from interior, anterior, or posterior wall, the distance between the base and top was measured in a central septum/exostosis using an axial image. Moreover, the distance between the base of the septum/exostosis and bony palate, which was related to the inferior or interior walls, was supero-inferiorly measured (Figure 5). The angle between the direction of the septum and median palatine suture was measured using axial images (Figure 6). In each measurement, one of author (M.N.) performed five times, and repeated in the same way after 6 weeks. The measurements were averaged.

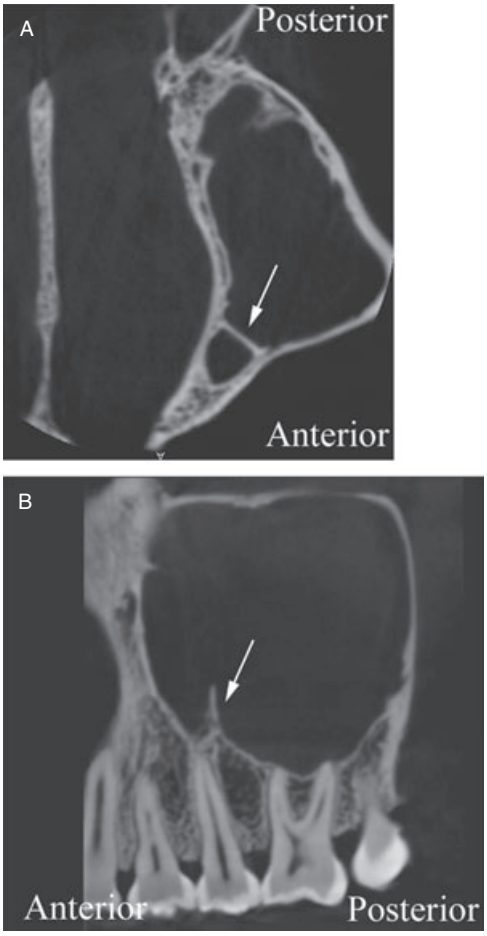

Figure 1 Septum in a left maxillary sinus. *A,* Axial image. A septum, which connected the interior and frontal walls, was observed. *B,* Longitudinal image. A septum, which originated from the inferior wall, was observed. White arrow: maxillary sinus septum.

Statistical Analysis

Differences in height, distances from the bony palate, and angles between locations of the septum/exostosis were evaluated using the Mann-Whitney *U*-test. Differences were considered significant at p of less than .05.

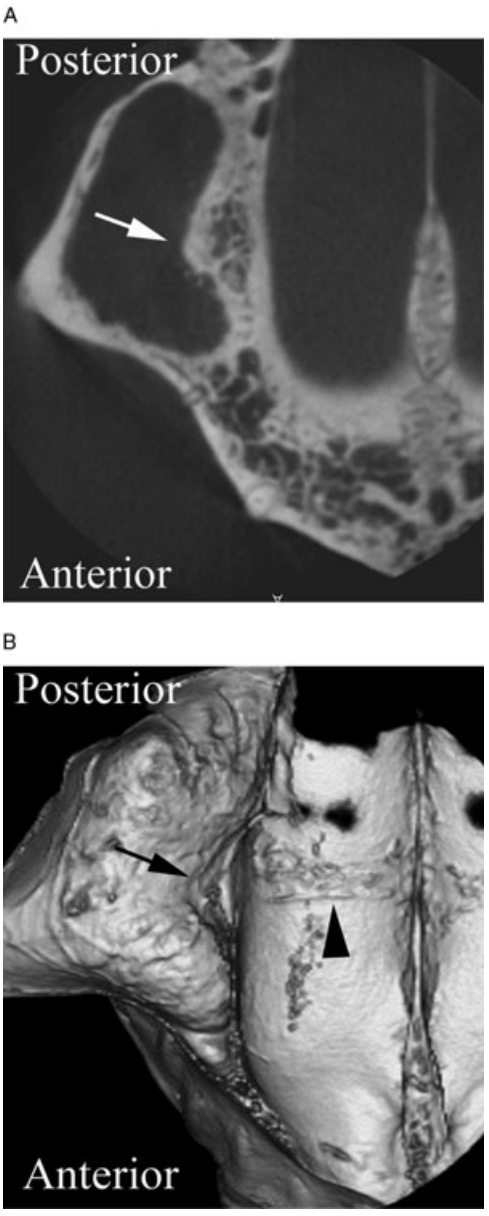

Figure 2 Exostosis in a right maxillary sinus. *A,* Axial image. An exostosis, which was originated from the interior wall, was observed. *B,* Three-dimensional image using INTAGE Realia software. An exostosis, which originated from the interior wall, was observed. Black and white arrows: maxillary sinus exostosis; black arrowhead: transverse palatine suture.

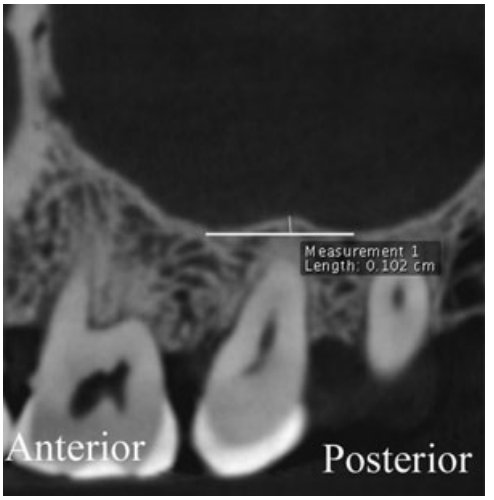

Figure 3 Exostosis in a right maxillary sinus. An exostosis, which was originated from the inferior wall, was less than 2 mm in height, and it was excluded from the evaluation.

RESULTS

Septa

Twelve septa were observed in 11 maxillary sinuses (36.7%) of seven dry skulls (47%). One septum in 10 sinuses, and two septa in one sinus were observed. All septa originated from the interior wall, passed through the inferior wall, and extend to the anterior or posterior wall. Seven septa (58.3%) were located in the anterior maxillary sinus region, and five septa (41.7%) were located within 3 mm from the transverse palatine suture (Figure 7). No septa were located in the posterior maxillary sinus region. The height of septa ranged from 2.1 to 7.7 mm, with a mean of 3.8 mm (SD 1.8 mm). Also, the supero-inferior distance between the base of the septum and bony palate ranged from −7.1 to 2.2 mm, with a mean of −1.0 mm (SD 3.1 mm) (Table 1). Moreover, angle of the septum in the anterior maxillary sinus region ranged from 40.6 to 86.8 degrees, with a mean of 57.9 degrees (SD 15.7 degrees), and the angle of the septum within 3 mm from the transverse palatine suture

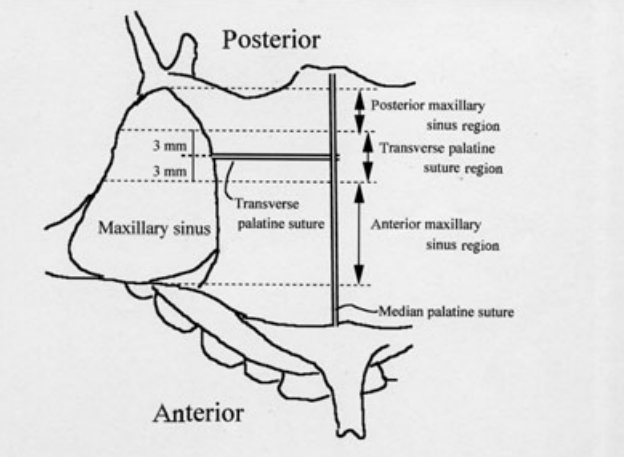

Figure 4 Schematic drawing septum/exostosis location. Maxillary sinuses were antero-posteriorly classified into three regions: anterior maxillary sinus portion, transverse suture portion, and posterior maxillary sinus portion.

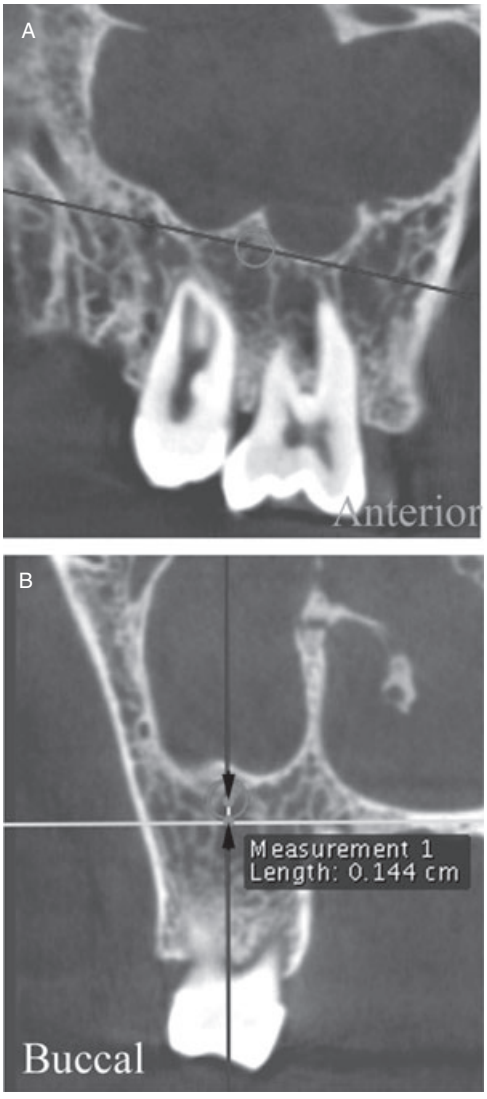

Figure 5 Measurement between the base of the septum/exostosis and bony palate. *A,* Longitudinal image. *B,* Coronal image. At first, the base of the septum/exostosis was decided on using a longitudinal image. Subsequently, the distance between the base and the bony palate was supero-inferiorly measured using a coronal image.

ranged from 49.8 to 127.3 degrees, with a mean of 101.8 degrees (SD 32.1 degrees). Significant differences in the angle of the septum were noted between the anterior maxillary sinus region and transverse palatine suture region.

Exostosis

Nine exostoses were observed in nine maxillary sinuses (30.0%) of six dry skulls (40.0%). Five exostoses (55.6%) originated from an interior wall, and four exostoses (44.4%) from an inferior wall. Also, three exostoses (33.3%) were located in the anterior maxillary sinus region, and six exostoses (66.7%) within 3 mm of the transverse palatine suture. Moreover, a height of exostosis ranged from 2.0 to 4.6 mm, with a mean of 3.0 mm (SD 0.9 mm). The supero-inferior distance between the base of the exostosis and bony palate ranged from −4.1 to 1.4 mm, with a mean of −0.7 mm (SD 2.1 mm) (Table 2).

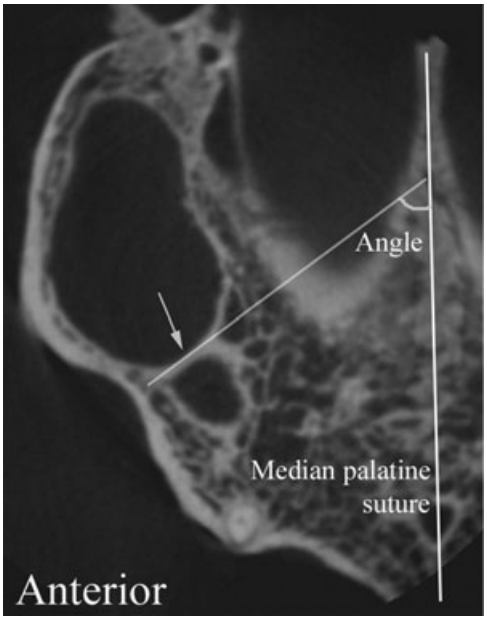

Figure 6 Angle between the direction of the septum and median palatine suture. The angle between the direction of the septum and median palatine suture was measured using an axial image. White arrow: maxillary sinus septum.

DISCUSSION

Various surgical procedures for dental implant treatment, such as sinus lift procedures, osteotome techniques, and inclined dental implant insertion, were proposed for the maxilla.[12–14] When the alveolar bone height was insufficient for the insertion of a dental implant in the posterior region, the sinus floor elevation technique would be applied. Also, modified techniques, such as the double window technique, were proposed in maxillary sinus lift procedures involving septa.[15,16] The diagnosis of septum presence was important in the presurgical imaging of sinus floor elevation techniques.

In this study, maxillary sinus walls were observed between the most inferior site and 10 mm superior of the maxillary sinus. In previous studies, a range of maxillary sinus walls observed using CT images, was not described. Boyne and James[12] reported that septum presence in the region of the sinus floor could cause

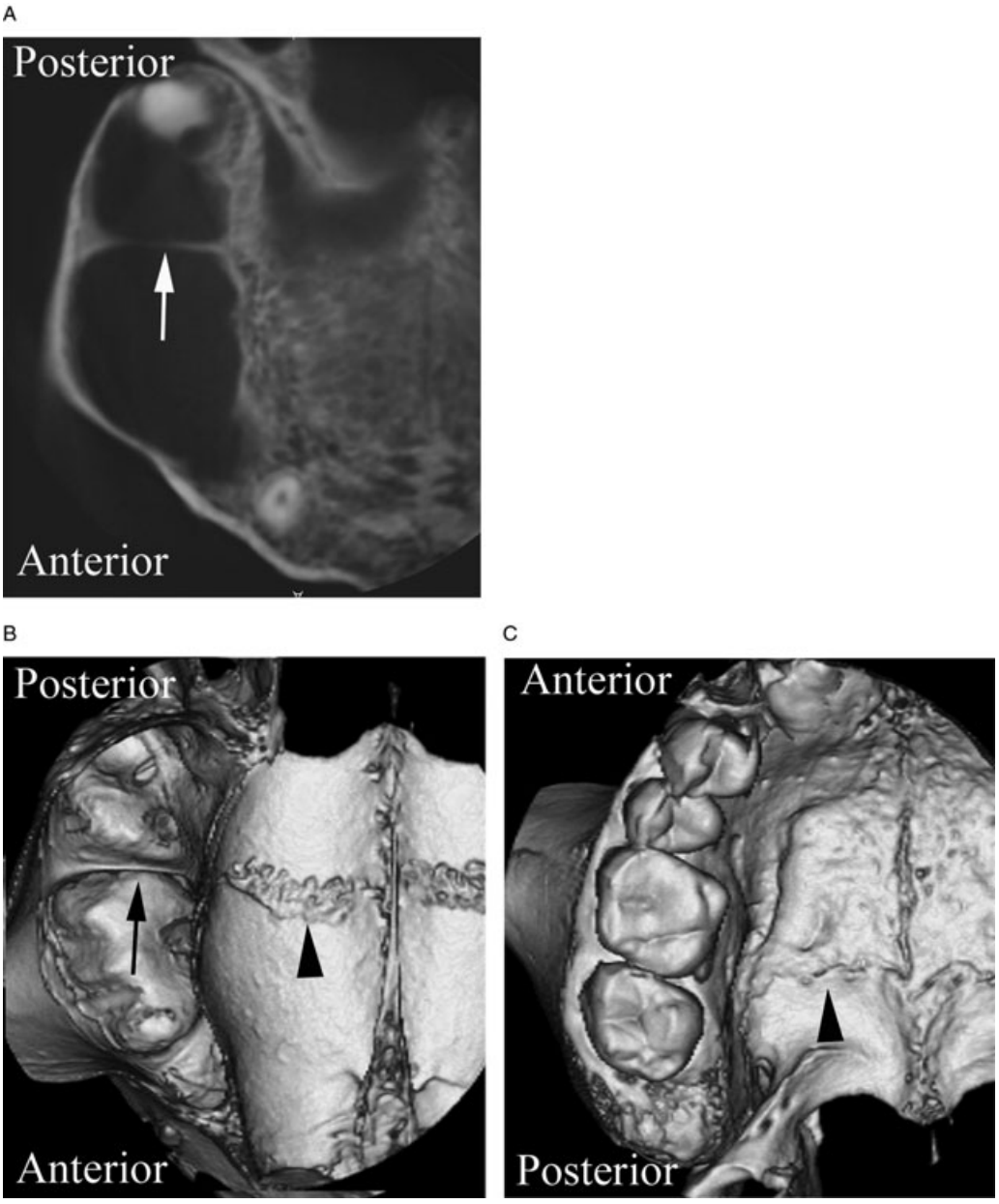

Figure 7 Septum in a right maxillary sinus. *A,* Axial image. *B,* Three-dimensional image viewed from the nasal cavity. *C,* Three-dimensional image viewed from the oral cavity. Septum location was antero-posteriorly recorded according to the transverse palatine suture. Three-dimensional images were reconstructed using INTAGE Realia software. Black and white arrows: maxillary sinus septum; black arrowhead: transverse palatine suture.

complication during sinus floor elevation surgery. Also, septa of more than 2 mm in height, most important regarding the sinus floor elevation technique, were registered. Septa of at least 2.5 mm in height were evaluated in previous studies.[1,4,6] In this study, septa of less than 2 mm in height were excluded from evaluation. The rate of a dentate maxillary sinus with a septum was 37%. This was similar to that reported in some previous studies, in which septa occurred in over 30% of sinuses.[1,4] Also, Krennmair and colleagues[2] reported a significant difference between dentate (13.2%) and edentulous (26.8%) maxillae using CT examination. Further studies involving many subjects might be needed to accurately assess septa occurrence.

The mean septal height was reported to be from 3.55 to 9.2 mm on CT examination.[2,5,6] The mean height (3.8 mm) was close to that of previous studies. Also, the mean height of exostoses was close to that of the septa.

The mesio-distal location of the septum was assessed on the basis of dental formula in previous

TABLE 1 Measurements of Septa

Site	Number	Height (mm) Range Average, SD	Distance from Bony Palate (mm) Range Average, SD	Angle Range Average, SD
Anterior maxillary sinus	7	2.4–7.7	−4.7 to 2.6	40.6–86.8
		4.0, 1.9	−1.3, 2.7	57.9, 15.7
Transverse palatine suture	5	2.1–5.7	−7.1 to 2.2	45.1–126.9
		3.6, 1.6	−0.5, 3.8	101.8, 32.1
Posterior maxillary sinus	0	—	—	—
		—	—	—

Distance from bony palate: −, the base of the septum was inferior to the bony palate; +, the base of the septum was superior to the bony palate.

studies.[1,5,6] Also, the etiology of the maxillary sinus septum has been hypothesized by several authors.[3,17,18] Underwood[17] described septa as arising between areas of two adjacent teeth and usually presenting in three specific regions of the sinus floor, thus dividing the floor into three regions: anterior, middle, and posterior. Further, Krennmair and colleagues[3] observed septa at rate from 26.6% to 42.9% in the molar region, and Velasquez-Plata and colleagues[5] reported that 41% of septa occurred between the second premolar and second molar. Also, Uemura[18] considered that maxillary sinus septa were formed by pressure, such as that generated by chewing.

In this study, the location was classified on the basis of the transverse palatine suture. The bony palate consists of two bones: the palatal processes of the maxillae from the anterior two-thirds of the palate, and the palatal processes of the palatine bones from the posterior third.[19] The transverse palatine suture crosses bony palate between the palatal processes of the maxillae and those of the palatine bones, and runs parallel to the maxillary alveolar process after the crook. Forty-two percent of septa and 67% of exostoses were antero-posteriorly close to transverse palatine suture. Also, the mean supero-inferior distance between the base of the septum and bony palate was −1.0 mm (SD 3.1 mm), and the base of the maxillary sinus septa was positioned according to the level of the bony palate.

The growth of maxillae and palatine bones was complicated.[20] The median and transverse palatine sutures enlarged, and bone deposition appeared on the palatal surface of the maxillary alveolar process. Also, bone resorption appeared on the inner surface of the maxillary sinus. When disharmony due to be enlargement of sutures, and deposition and resorption of the bone surface in the alveolar process and maxillary sinus occur, a maxillary sinus septum might be formed as a buttress to retain the volume and form of the maxillary

TABLE 2 Measurements of Exostoses

Site	Number	Height (mm) Range Average, SD	Distance from Bony Palate (mm) Range Average, SD
Anterior maxillary sinus	3	2.0–4.6	−1.4 to 1.4
		3.2, 1.3	0.4, 1.6
Transverse palatine suture	6	2.0–3.8	−4.1 to 0.8
		2.9, 0.7	−1.2, 2.2
Posterior maxillary sinus	0	—	—
		—	—

Distance from bony palate: −, the base of the exostosis was inferior to the bony palate; +, the base of the exostosis was superior to the bony palate.

sinus. Moreover, significant differences in the angle of the septum were noted between the anterior maxillary sinus and transverse palatine suture regions. Most of the septa in anterior maxillary sinus region were anterolaterally directed from the interior wall, and most of the septa in the transverse palatine suture region were laterally directed from the interior wall. The direction of septa might be influenced by the growth of maxillae and palatine bones.

To validate our hypothesis regarding the formation of maxillary sinus septa, further studies, such as assessment of the location and aging of maxillary sinus septa, are needed involving many subjects.

CONCLUSION

Maxillary sinus septa were observed in 37% of dentate maxillae, and exostoses were noted in 30% using dry skulls and cone-beam CT. Also, 42% of septa and 67% of exostoses were antero-posteriorly positioned according to the transverse palatine suture.

CONFLICTS OF INTEREST STATEMENT

The authors have declared no conflicts of interest. [Correction added after online publication 23 October 2009: Conflicts of Interest Statement added.]

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