Oral and Maxillofacial Surgery (2019) 23:233–237
https://doi.org/10.1007/s10006-019-00773-2

ORIGINAL ARTICLE

A radiologic evaluation of the incidence and morphology of maxillary sinus septa in Japanese dentate maxillae

Daisuke Takeda[1] · Takumi Hasegawa[1] · Izumi Saito[1] · Satomi Arimoto[1] · Masaya Akashi[1] · Takahide Komori[1]

Received: 7 May 2018 / Accepted: 2 May 2019 / Published online: 14 May 2019

Abstract

Purpose Evaluation of the inner aspect of the maxillary sinus is important for the success of a sinus lift procedure. The most common surgical complication is perforation of the Schneiderian membrane, which is thought to occur because of the presence of maxillary sinus septa. Therefore, we retrospectively investigated the incidence and morphology of maxillary sinus septa using multiplanar reformatted computed tomographic (CT) images from dentate Japanese patients.

Methods A total of 276 patients and 552 maxillary sinus segments were evaluated. The maxillary sinus septa were divided into four locations: forefront, anterior, middle, and posterior. The heights of the septa were measured at three sites from the deepest point of the sinus floor: lateral, mid-point, and medial.

Results Sinus septa were identified in 191 of 552 (34.6%) maxillary sinus segments obtained from 111 of 276 (40.2%) patients. One unilateral septum was most commonly detected, and the sinus septa were most often located in the middle of the maxillary sinus. The average height of the identified septa was 8.69 ± 4.68 mm (mean ± standard deviation).

Conclusion Multiplanar reformatted CT images can identify maxillary sinus septa in any plane. The height of maxillary sinus septa in the dentate maxillae was higher than detected in previous studies. Appropriate treatment planning using CT images should be considered to prevent surgical complications.

Keywords Maxillary sinus septa · Maxillary sinus · Multiplanar reformatted computed tomographic images · Dentate maxillae · Sinus lift procedure

Introduction

Internal augmentation of the maxillary sinus, formally known as sinus floor elevation or sinus lift, was conceived and introduced by Tatum [1] and was first published by Boyne and James [2]. The technique is well known and often used to aid the placement of dental implants in the posterior atrophic maxillae. The most common surgical complication is perforation of the Schneiderian membrane [3]. This is most likely to occur because of sharp angles or ridge lines, septa, or spines in the maxillary sinus [4, 5]. However, the morphology of the maxillary sinus varies between individuals, and even bilaterally in an individual skull [5, 6]. Therefore, the evaluation of the inner aspect of the maxillary sinus is important for the success of this procedure. According to the most recent systematic review and meta-analysis, sinus septa were present in 28.4% of 8923 maxillary sinuses investigated across 33 studies [7]. These studies included dentate, as well as partially or totally edentulous patients. It has been reported that sinus septa in edentulous atrophic maxillae are shorter and more common than those found in dentate maxillae [8, 9]. This is thought to be related to atrophy of the surrounding alveolar process and excavation of the alveolar process from the cranial aspect by sinus pneumatization following tooth loss [10]. However, the influence of duration since tooth loss was not considered in these studies. If a sinus lift procedure is conducted soon after tooth extraction, higher maxillary sinus septa may be present, which might require modification of the lateral window design to avoid fracturing the septa and perforating the Schneiderian membrane. Furthermore, this systematic review did not include Japanese research, except for one study using 15 dry skulls [11]. Therefore, in the present study,

✉ Daisuke Takeda
dsktkd@med.kobe-u.ac.jp

[1] Departments of Oral and Maxillofacial Surgery, Kobe University Graduate School of Medicine, 7-5-1 Kusunoki-cho, Chuo-ku, Kobe 650-0017, Japan

we retrospectively investigated the incidence and morphology of maxillary sinus septa using multiplanar reformatted computed tomographic (CT) images in dentate Japanese patients.

Materials and methods

Participants

This study was based on an analysis of maxillary sinus CT images that were obtained from patients who underwent local and general oral surgery at the Kobe University Hospital between January 2008 and December 2012. We set exclusion criteria to compare normal maxillary sinus morphology bilaterally where skeletal growth was completed: (i) patients with a history of surgical operations over the maxillae, (ii) patients with maxillary bone cysts and malignant tumors, (iii) patients less than 18 years old, and (iv) patients with single or multiple molar tooth loss, to eliminate atrophy of the surrounding alveolar process by tooth loss and ensure precise tooth location. A total of 276 patients were included in this study. This retrospective study was conducted in accordance with the World Medical Association Declaration of Helsinki and was approved by the Institutional Review Board of Kobe University Graduate School of Medicine.

CT measurement procedure

The CT examinations were performed at the time of diagnosis using the Aquilion64^{R} system (Toshiba Medical Systems, Tokyo, Japan) at the Kobe University Hospital (tube voltage 120 kVp, tube current 150 mA, slice thickness 0.5 mm, field of view 150 mm) and Wakaba Imaging Support Center (tube voltage 120 kVp, tube current 100 mA, slice thickness 0.5 mm, field of view 170 mm). The slice plane was parallel to the occlusal plane and the scanned area extended from the floor of the orbit to the inferior border of the mandible. Panoramic images with a cross-section of 1 mm were obtained to detect septa and/or spines in the maxillary sinus, and then complete septa that divide the maxillary sinus into two or more segments were distinguished using axial images. The measurement points and methods were based on and modified according to previous studies [6, 12, 13]. To reduce data variation, a single author (D.T.) measured the CT images in this study. Each antral cavity exhibiting a septum was divided into four locations: forefront (mesial aspect of the second premolar), anterior (mesial to distal aspect of the second premolar), middle (distal aspect of the second premolar to distal aspect of the second molar), and posterior (distal aspect of the second molar). Moreover, reformatted multiplanar reconstruction CT images (slice thickness 0.5 mm) were used to assess the complete course of the septa using ShadeQuest/ViewR (Yokogawa Medical Solutions Corporation, Tokyo, Japan) from axial images (Fig. 1). The heights of the maxillary sinus septa were measured at three sites (lateral, mid-point, and medial) from the deepest point of the sinus floor using coronal images (Fig. 2).

Results

Incidence of maxillary sinus septa

Sinus septa were found in 191 of 552 (34.6%) maxillary sinus segments (276 left and 276 right segments) obtained from 111 of 276 (40.2%) patients. There were 60 males and 51 females with a mean age of 37.1 ± 15.6 years (mean ± standard deviation) ranging between 18 and 81 years. Ninety-one of 191 (47.6%) sinus septa were localized to the left maxillary sinus segment, and 100/191 (52.4%) sinus septa were localized to the right maxillary sinus segment. At most, two sinus septa were detected in either side of a maxillary sinus segment, and sinus septa varied unilaterally or bilaterally in the maxillary sinus segments. Sixty-one of 111 (55.0%) patients had sinus septa unilaterally, and 50/111 (45.0%) had sinus septa bilaterally. In the left maxillary sinus segment, 35/111 (31.5%) patients had no sinus septum, 61/111 (55.0%) had one sinus septum, and 15/111 (13.5%) had two sinus septa. Conversely, in the right maxillary sinus segment, 26/111 (23.4%) patients had no sinus septum, 70/111 (63.1%) had one sinus septum, and 15/111 (13.5%) had two sinus septa. The overall distribution of the 191 identified maxillary sinus septa was as follows: 55 patients had one sinus septum, 36 patients had two sinus septa, 16 patients had three sinus septa, and four patients had four sinus septa (Table 1).

Position of maxillary sinus septa

In the left maxillary sinus segment, sinus septa were detected as follows: four sinus septa in the forefront, 22 sinus septa in the anterior, 42 sinus septa in the middle, and 23 sinus septa in the posterior. Conversely, in the right maxillary sinus segment, sinus septa were detected as follows: six sinus septa in the forefront, 21 sinus septa in the anterior, 46 sinus septa in the middle, and 27 sinus septa in the posterior (Table 2). These findings indicated that sinus septa were most often located in the middle of the maxillary sinus.

Height of maxillary sinus septa

The average height of the identified maxillary septa was 8.69 ± 4.68 mm (mean ± standard deviation). Among the four regions, sinus septa in the forefront were higher than other locations in the maxillary sinus (Fig. 3).

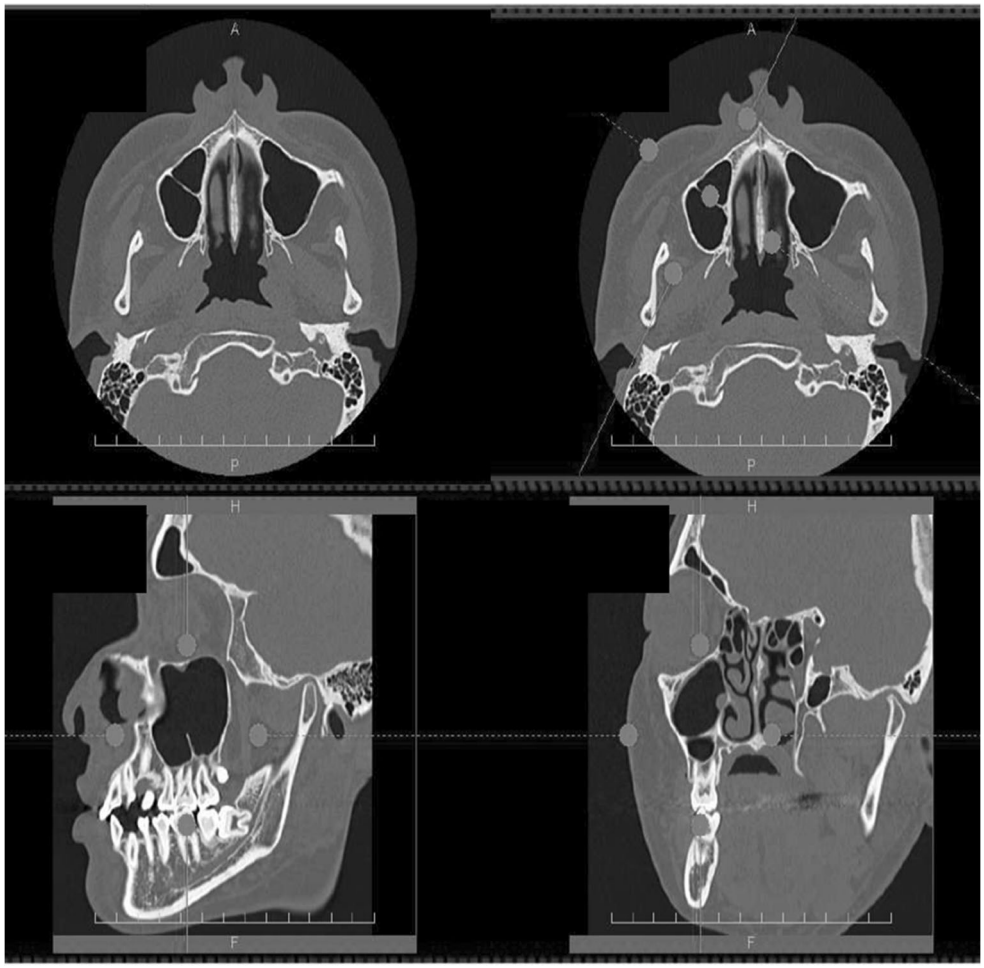

Fig. 1 Axial images were used for identification of Underwood's septa and were reformatted to multiplanar reconstructed CT images

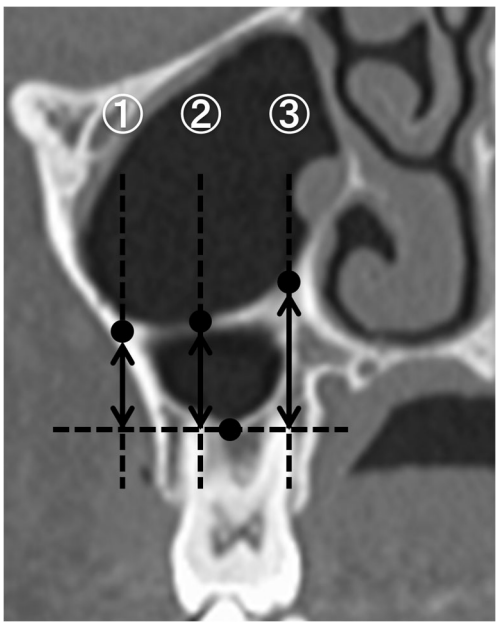

Fig. 2 The heights of the maxillary sinus septa were measured at three sites from the deepest point of the sinus floor: (1) lateral, (2) mid-point, and (3) medial

Table 1 Incidence of maxillary sinus septa ($n = 111$)

Variables	No. of patients	%
Sample size	111	100.0
Bilateral	50	45.0
Unilateral	61	55.0
Side of maxillary sinus septa		
Left sinus segment	111	100.0
No sinus septum	35	31.5
One sinus septum	61	55.0
Two sinus septa	15	13.5
Right sinus segment	111	100.0
No sinus septum	26	23.4
One sinus septum	70	63.1
Two sinus septa	15	13.5
No. of maxillary sinus septa per patient	111	100.0
One sinus septum	55	49.6
Two sinus septa	36	32.4
Three sinus septa	16	14.4
Four sinus septa	4	3.6

Table 2 Locations of sinus septa in the left and right maxillary sinus segments ($n = 191$)

Variables	No. of sinus septa	%
Sample size	191	
Left maxillary sinus segment	91	100.0
Forefront	4	4.3
Anterior	22	24.2
Middle	42	46.2
Posterior	23	25.3
Right maxillary sinus segment	100	100.0
Forefront	6	6.0
Anterior	21	21.0
Middle	46	46.0
Posterior	27	27.0

Discussion

The aim of this study was to examine the incidence, location, and height of maxillary sinus septa using multiplanar reformatted CT images of dentate patients. Maxillary sinus septa were first described by Underwood in 1910 [14] and for decades were thought to be clinically insignificant anatomical variations. They have been divided into two different types depending on their origin [8–10]. The primary type is congenital and arises during development of the maxillae, corresponding to the septa first described by Underwood [10]. These are thought to act as masticatory force-carrying struts during the dentate phase of life [5]. Maxillary sinus volume appears to continue increasing until the third decade in males and the second decade in females [15]. Then, tooth loss causes remodeling and resorption of the surrounding alveolar process. Atrophy of the alveolar process, especially in the posterior maxillae, results in a vertical loss of bone volume, while progressive sinus pneumatization leads to an excavation of the alveolar process from the cranial aspect. The secondary type arises from these excavations and therefore may vary in appearance in different areas of the alveolar process [10]. However, it is not possible to classify septa as either primary or secondary without a radiographic history when they are located over an edentulous region [16]. Therefore, in this study, we focused on dentate patients, so we mostly detected primary maxillary sinus septa ("Underwood's septa"). Correlation between Underwood's septa and Schneiderian membrane thickness has been suggested, so the risk of membrane perforation might be higher when Underwood's septa are present [17]. Conversely, another study found no statistically significant correlation between primary or secondary septa and the Schneiderian membrane thickness [18]. However, consideration must still be given to the design of the lateral window to avoid fracturing maxillary sinus septa and perforating the Schneiderian membrane. Cutting the maxillary sinus septa with a chisel and removing them with hemostatic forceps has been suggested [2]. If the septa are located high in the sinus, two windows can be made (one on each side); if the septa are low in the sinus, one *w*-shaped window can be used for access [5].

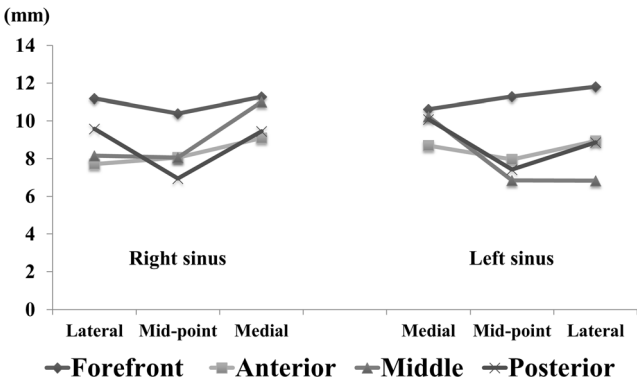

Fig. 3 The average height of the identified maxillary sinus septa at each measuring point

In the latest systematic review, primary and secondary maxillary sinus septa were mostly located in the first or second molar region and had a mean size of 7.5 mm [7]. A previous study also reported that maxillary sinus septa tended to be positioned antero-posteriorly, in accordance with the transverse palatine suture [11]. These results are consistent with our study. It is reasonable that the height of the primary maxillary sinus septa in our study was higher than in studies that included secondary maxillary sinus septa. Recently, cone-beam CT (CBCT) has been developed with a spatial resolution higher than that of multislice CT, which has the advantage of exposing the patient to a lower dose of radiation. In a systematic review using only CBCT, the prevalence of maxillary sinus septa ranged from 33.2–58% across five studies, but there was no meta-analysis on the height of the septa [19]. Another study evaluated the posterior superior alveolar artery using CBCT [20]. It is important to be aware of this significant anatomical landmark in the maxillae to prevent intra- and postoperative complications. We will focus on this measurement in a future study.

In conclusion, maxillary sinus septa were detected in 34.6% of the maxillary sinus segments obtained from 40.2% of dentate patients in our study. Most commonly, one unilateral septum was found per patient, the molar region was the most common site, and the average height of the identified maxillary sinus septa was 8.69 ± 4.68 mm (mean ± standard deviation). The variety of anatomical morphologies on the inner aspect of the maxillary sinus defines the surgical approach. Multiplanar reformatted CT images can show maxillary sinus septa in any plane. The height of maxillary sinus septa in a dentate region might be higher than detected in previous studies. We should consider appropriate treatment

planning, including the anatomy of maxillary sinus septa, using CT images to prevent surgical complications.

Acknowledgments We thank Wakiko Tani from the Center for Radiology and Radiation Oncology at our hospital for their expert analytic advice. We thank Angie Smaranda, M (Dent), from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Tatum H, Jr. (1986) Maxillary and sinus implant reconstructions. Dent Clin N Am 30 (2):207–229
2. Boyne PJ, James RA (1980) Grafting of the maxillary sinus floor with autogenous marrow and bone. Journal of oral surgery (American Dental Association : 1965) 38(8):613–616
3. Ardekian L, Oved-Peleg E, Mactei EE, Peled M (2006) The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons 64(2):277–282. https://doi.org/10.1016/j.joms.2005.10.031
4. Chanavaz M (1990) Maxillary sinus: anatomy, physiology, surgery, and bone grafting related to implantology–eleven years of surgical experience (1979-1990). The Journal of oral implantology 16(3): 199–209
5. van den Bergh JP, ten Bruggenkate CM, Disch FJ, Tuinzing DB (2000) Anatomical aspects of sinus floor elevations. Clin Oral Implants Res 11(3):256–265
6. Koymen R, Gocmen-Mas N, Karacayli U, Ortakoglu K, Ozen T, Yazici AC (2009) Anatomic evaluation of maxillary sinus septa: surgery and radiology. Clinical anatomy (New York, NY) 22(5): 563–570. https://doi.org/10.1002/ca.20813
7. Pommer B, Ulm C, Lorenzoni M, Palmer R, Watzek G, Zechner W (2012) Prevalence, location and morphology of maxillary sinus septa: systematic review and meta-analysis. J Clin Periodontol 39(8):769–773. https://doi.org/10.1111/j.1600-051X.2012.01897.x
8. Krennmair G, Ulm CW, Lugmayr H, Solar P (1999) The incidence, location, and height of maxillary sinus septa in the edentulous and dentate maxilla. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons 57(6):667–671; discussion 671-662
9. Maestre-Ferrin L, Galan-Gil S, Rubio-Serrano M, Penarrocha-Diago M, Penarrocha-Oltra D (2010) Maxillary sinus septa: a systematic review. Medicina oral, patologia oral y cirugia bucal 15(2): e383–e386
10. Vinter I, Krmpotic-Nemanic J, Hat J, Jalsovec D (1993) [Does the alveolar process of the maxilla always disappear after tooth loss?]. Laryngorhinootologie 72 (12):605–607. doi:https://doi.org/10.1055/s-2007-997963
11. Naitoh M, Suenaga Y, Kondo S, Gotoh K, Ariji E (2009) Assessment of maxillary sinus septa using cone-beam computed tomography: etiological consideration. Clin Implant Dent Relat Res 11 Suppl 1:e52–58. doi:https://doi.org/10.1111/j.1708-8208.2009.00194.x, e58
12. Lee WJ, Lee SJ, Kim HS (2010) Analysis of location and prevalence of maxillary sinus septa. Journal of periodontal & implant science 40(2):56–60. https://doi.org/10.5051/jpis.2010.40.2.56
13. Park YB, Jeon HS, Shim JS, Lee KW, Moon HS (2011) Analysis of the anatomy of the maxillary sinus septum using 3-dimensional computed tomography. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons 69(4):1070–1078. https://doi.org/10.1016/j.joms.2010.07.020
14. Underwood AS (1910) An inquiry into the anatomy and pathology of the maxillary sinus. J Anat Physiol 44 (Pt 4:354–369
15. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH (2005) The analysis of maxillary sinus aeration according to aging process; volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. Otolaryngol Head Neck Surg 132(3): 429–434. https://doi.org/10.1016/j.otohns.2004.11.012
16. Krennmair G, Ulm C, Lugmayr H (1997) Maxillary sinus septa: incidence, morphology and clinical implications. J Craniomaxillofac Surg 25(5):261–265
17. Cakur B, Sumbullu MA, Durna D (2013) Relationship among Schneiderian membrane, Underwood's septa, and the maxillary sinus inferior border. Clin Implant Dent Relat Res 15(1):83–87. https://doi.org/10.1111/j.1708-8208.2011.00336.x
18. Rancitelli D, Borgonovo AE, Cicciu M, Re D, Rizza F, Frigo AC, Maiorana C (2015) Maxillary sinus septa and anatomic correlation with the Schneiderian membrane. J Craniofac Surg 26(4):1394–1398. https://doi.org/10.1097/scs.0000000000001725
19. Ata-Ali J, Diago-Vilalta JV, Melo M, Bagan L, Soldini MC, Di-Nardo C, Ata-Ali F, Manes-Ferrer JF (2017) What is the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to maxillofacial cone beam computed tomography? A systematic review. Medicina oral. patologia oral y cirugia bucal 22(4):e400–e409
20. Lozano-Carrascal N, Salomo-Coll O, Gehrke SA, Calvo-Guirado JL, Hernandez-Alfaro F, Gargallo-Albiol J (2017) Radiological evaluation of maxillary sinus anatomy: a cross-sectional study of 300 patients. Annals of anatomy = Anatomischer Anzeiger : official organ of the Anatomische Gesellschaft 214:1–8. https://doi.org/10.1016/j.aanat.2017.06.002