Maxillary Sinus Septa: A 3-Dimensional Computerized Tomographic Scan Analysis

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Purpose: *The purpose of this study was to determine the prevalence, size, location, and morphology of maxillary sinus septa in dentate, partially dentate, and edentulous maxillae.* ***Materials and Methods:*** *Data from 312 sinuses were analyzed from reformatted computerized tomograms utilizing SIM/Plant software. The sample consisted of 156 patients (106 women and 50 men, with ages ranging between 24 and 86 years and a mean age of 55.4 years) who were being treatment-planned to receive implant-supported restorations.* ***Results:*** *A total of 75 septa were found in 312 maxillary sinuses (24%), which corresponded to 32.7% of the patients (51 of 156). Completely edentulous patients presented with 33.3% of the total septa, while 66.7% of the septa were identified in partially edentulous patients. Analysis of the anatomic location of the septa within the sinus revealed that 18 (24.0%) septa were located in the anterior region, 31 (41.0%) were in the middle, and 26 (35.0%) were in the posterior region. Measurements of height of the septa varied among different areas. The lateral area ranged from 0 to 15.7 mm (with a mean of 3.54 ± 3.35 mm), the middle area ranged from 0 to 17.3 mm (with a mean of 5.89 ± 3.14 mm), and the medial area ranged from 0 to 20.6 mm (with a mean of 7.59 ± 3.76 mm). A total of 20 septa (26.7%) were located in the immediate apical region of teeth. The remaining 55 septa (73.3%) were related to edentulous areas.* ***Discussion:*** *Septa may arise in any of the 3 regions of the maxillary sinus irrespective of the degree of dentulism or edentulism present.* ***Conclusion:*** *To avoid unnecessary complications during sinus augmentation procedures, adequate and timely identification of the anatomic structures inherent to the maxillary sinus are required.* (Int J Oral Maxillofac Implants 2002;17:854–860)

Key words: *antral septa, computed tomography, dental implants, dental radiography, maxillary sinus*

The sinus floor elevation procedure was initially developed to increase maxillary osseous height to provide an adequate base for prosthetic reconstruction.[1] This procedure was first conceived by Tatum in 1976, although the first publication describing it did not appear until 1980.[2] Since then, several articles have been published documenting the utilization of this technique to provide adequate vertical bone height for the placement of endosteal dental implants.[3–8]

Reported complications for this procedure include soft tissue perforation, hemosinus, oroantral fistulae, and sinusitis.[8–14] Factors that contribute to the development of infection in the maxillary sinus include perforation of the sinus mucosa, inoculation of the graft with saliva, dehiscence of the incision line, or lack of aseptic conditions during graft and/or implant placement.[15] The prevalence of sinus perforation during sinus elevation procedures is approximately 35%.[7,9,13] Results of a failure analysis by the Sinus Consensus Conference in 1996

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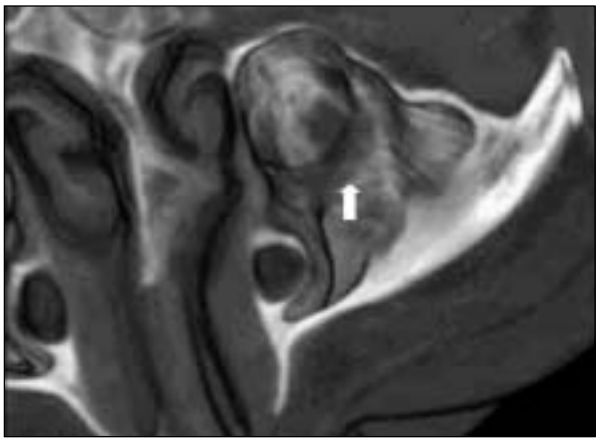
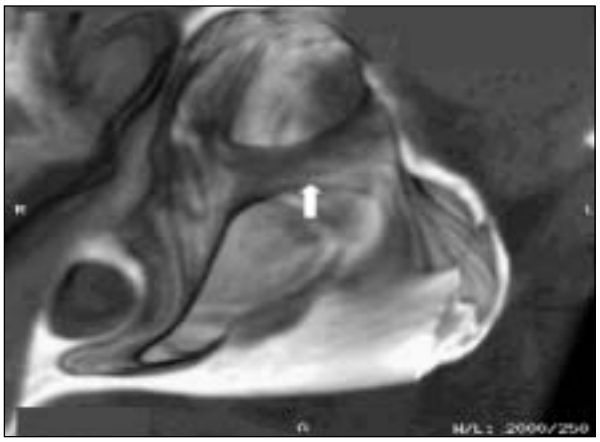
Fig 1 Panoramic radiograph of a partially edentulous patient. Arrow indicates antral septa in the maxillary left sinus.





Figs 2a and 2b Three-dimensional axial reconstruction of the same maxillary sinus shown in Fig 1. Arrows indicate antral septa.

demonstrated that of 164 failures analyzed, 79 (48%) could be attributed to perioperative complications, 38 (48%) of which were associated with sinus membrane perforations.[8]

The presence of anatomic variations within the maxillary sinus, such as septa, have been reported to increase the risk of sinus membrane perforation during sinus elevation procedures.[2,3,10,16–18] This anatomic variation was first described by Underwood in 1910.[18] The shape of septa has been described as resembling an inverted gothic arch arising from the inferior and lateral walls of the sinus and coming to a sharp edge along its most apical border.[17,19] They tend to partially—or, in some cases, completely—divide the floor of the sinus into 2 or more compartments radiating out from the medial wall toward the lateral wall of the sinus (Figs 1 and 2).[18,20]

The etiology of the maxillary septum has been hypothesized by several authors.[17,18,21,22] Underwood[18] described septa as arising between areas of 2 adjacent teeth and usually presenting in 3 specific regions of the sinus floor, thus dividing the floor into 3 basins: anterior, between the second premolar and first molar roots; middle, between the first and second molar roots; and posterior, distal to the third molar roots. Each basin corresponds to 3 defined periods of tooth development and eruption separated by intervals of time. This same author mentioned that septa were most commonly observed in the posterior region, supposedly because of the later occurrence of eruption. He also noted that the size of septa could be accentuated by further pneumatization of the alveolar process. Neivert[21] proposed that septa were derived from the fingerlike projections produced by the embryologic out-pouching of the ethmoid infundibulum in which contiguous walls did not resorb. Krennmair and coworkers[17] further classified septa into primary septa (which arise from development of the maxilla) and secondary septa (which arise from irregular pneumatization of the sinus floor following tooth loss).

Other authors have also reported on the prevalence of septa.[17,18,23] Underwood[18] found 30 septa in

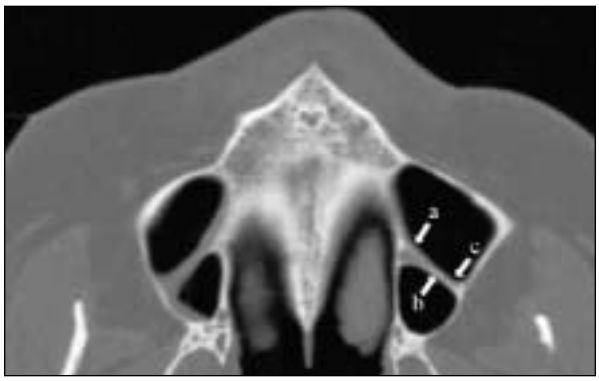


Fig 3 Points of septal height measurements. a = medial; b = middle; c = lateral.

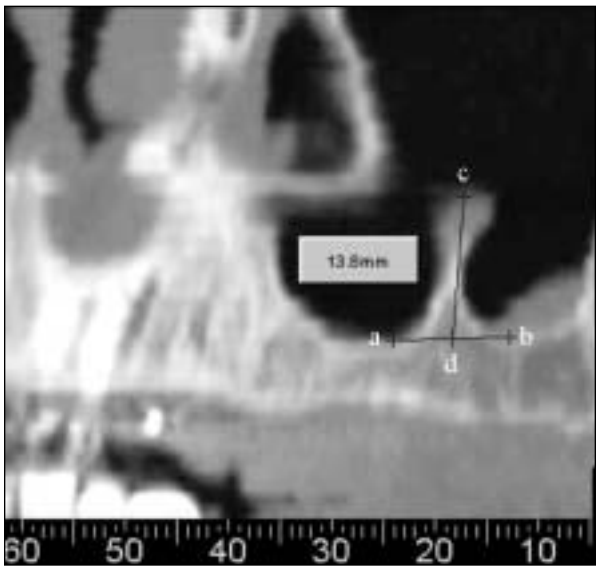


Fig 4 *(Right)* Measurement of vertical dimension of antral septa at middle aspect. A line drawn at the approximate base of the septa is established (a-b), and its height is measured using a line extending from this base to the most coronal portion of the septa (c-d).

45 skulls (90 maxillary sinuses), demonstrating a 33% prevalence. Krennmair and coworkers[17] reported a prevalence ranging from 14% to 31.7%, depending on patient age and tooth loss. The height of septa has also been measured. Underwood[18] reported an average height of 0.25 to 0.5 inches (6.4 to 12.7 mm). Two cases of complete septa demonstrating union with the antral roof were also described. Krennmair and coworkers[17] observed a mean height of 7.7 mm for septa identified in edentulous maxillae and 12.2 mm for septa in dentate maxillae.

The common location for septa described by Underwood[18] was the posterior, as stated earlier; however, Krennmair and coworkers[17] observed a majority of septa in the anterior/premolar region of edentulous maxillae (75%) and dentate maxillae (57.1%). The remaining septa were located in the middle/first molar region, with only 1 septum identified in the posterior region of all specimens examined. These same authors also presented important information regarding the ability to detect the presence of septa with panoramic radiography. They demonstrated the limitations of the orthopantomograph by showing an inability to correctly identify the absence or presence of septa in 21.3% of the cases examined. Thus, computerized tomography (CT) and subsequent reconstruction of axial sections allow a more accurate visualization of anatomic variations within the maxillary sinus.[24,25]

The purpose of this study was to examine a cross-sectional sample of 312 sinuses in 156 patients using preoperative axial CT scans serially processed and analyzed using a software program to determine the prevalence, size, location, and morphology of septa in dentate, partially dentate, and edentulous maxillae.

MATERIALS AND METHODS

Data from 312 sinuses were analyzed from reformatted CT images utilizing SIM/Plant software (Columbia Scientific, Columbia, MD). The protocol utilized 1.25-mm-thick reconstruction algorithms. The sample consisted of 156 patients (106 women and 50 men, with an age range of 24 to 86 years and a mean age of 55.4 years) who were being treatment-planned to receive implant-supported restorations. Forty-one patients (26.3%) were completely edentulous and the remaining population was partially edentulous (73.7%). Partial edentulism was classified according to Kennedy,[26] and the location and extent of the edentulous space(s) were identified.

The CT images were examined for the presence of antral septa using axial planes of section. The "panoramic" reconstructions of SIM/Plant were used to assess the height of the septa. Axial plane images were utilized to locate the segment to be measured in the lateral, middle, and medial aspects of the septa (Fig 3). Vertical measurements were accomplished with the SIM/Plant measuring tool, as shown in Fig 4. Each antral cavity exhibiting a septum was divided into 3 portions: anterior (mesial to distal aspect of second premolar), middle (from distal aspect of second premolar to distal aspect of second molar), and posterior (distal aspect of second molar region). The height of each septa identified

Table 1 Summary of Septa Location Data

Septa identified	No. of septa	Location prevalence*		
		Anterior region	Middle region	Posterior region
CE	25	7 (28%)	9 (36%)	9 (36%)
PE	50	11 (22%)	22 (44%)	17 (34%)
PE, primary septa	20	6 (30%)	9 (45%)	5 (25%)
PE, other septa	30	5 (17%)	14 (47%)	11 (36%)
Total	75	18 (24%)	31 (41%)	26 (35%)

*All differences were statistically significant ($P < .0001$; paired Student t test).
CE = completely edentulous patients; PE = partially edentulous patients; primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge.

Table 2 Summary of Septa Height Measurements

Septa identified	No. of septa	Height (mm ± SD)*		
		Lateral	Midpoint	Medial
CE	25	2.79 ± 1.68	4.87 ± 1.99	6.82 ± 3.48
PE	50	3.91 ± 3.90	6.39 ± 3.48	7.98 ± 3.87
PE, primary septa	20	3.33 ± 2.16	6.11 ± 2.16	7.38 ± 3.38
PE, other septa	30	4.30 ± 4.71	6.58 ± 4.16	8.37 ± 4.16
Total	75	3.54 ± 3.35	5.89 ± 3.14	7.59 ± 3.76

*All differences were statistically significant ($P < .0001$; paired Student t test).
CE = completely edentulous patients; PE = partially edentulous patients; primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge.

was measured at 3 regions selected along its course across the sinus floor: the lateral, the middle, and the medial aspects. Septa measuring more than 2.5 mm in height at 1 of 3 positions measured were included in the analysis. Not all septa demonstrated a measurable component at each aspect; a value of zero was recorded for such regions.

Statistical analysis was performed using a paired Student t test to determine whether there was a significant difference in the size and location of septa identified in completely and partially edentulous areas.

RESULTS

A total of 75 septa were found in 312 maxillary sinuses (24%), which corresponds to 51 (32.7%) of 156 patients. Septa were found unilaterally in 33 patients (64.7%) and bilaterally in 18 patients (35.3%). Completely edentulous patients presented 33.3% of the total septa, while 66.7% of the septa were identified in partially edentulous patients. Thirty-six antral septa (48%) were identified on the right side, while 39 septa (52%) were found on the left side. Four patients (2.66%) presented with multiple septa in 5 sinuses (1.6%). Sixty-four sinuses harbored 1 septum, 4 sinuses presented with 2 septa, and 1 sinus had 3 septa.

Analysis of the anatomic location of the septa within the sinus revealed that 18 (24.0%) septa were located in the anterior region, 31 (41.0%) were in the middle region, and 26 (35.0%) were in the posterior region. The location of septa observed in this study population demonstrated a greater prevalence (41.0%) in the middle region (first and second molar), followed by the posterior region (35.0%), and the anterior region (24.0%). This distribution varied when partially and completely edentulous sinuses were compared (Table 1). A closer examination of the partially edentulous population revealed a 40% prevalence of septa located superior to a maxillary tooth (primary septa) and 60% of septa located superior to an edentulous ridge (primary septa, secondary septa, or a combination of both) (Table 1).

Measurements of the height of each individual septum varied among different regions. The lateral region ranged from 0 to 15.7 mm (with a mean of 3.54 ± 3.35 mm), the middle region ranged from 0 to 17.3 mm (with a mean of 5.89 ± 3.14 mm), and the medial region ranged from 0 to 20.6 mm (with a mean of 7.59 ± 3.76 mm) (Table 2). When mean values for septa identified in partially edentulous versus completely edentulous areas were compared, septa found in partially edentulous areas demonstrated statistically significantly higher values at all points of measurement. When septa found in partially edentulous areas were broken down into those

located apically to remaining teeth (primary septa) and those in the proximity of edentulous areas (other septa), primary septa were found to be significantly shorter at all measured points (Table 2).

DISCUSSION

The prevalence of septa in the maxillary sinus found in this study shows agreement with other anatomic studies reported in the literature. Seventy-five septa were found in 312 maxillary sinuses (ie, 24% of the sinuses) evaluated using CT examinations. The prevalence of 1 or more septa per sinus was found to be 69/312 (22%) in the total study population, 22/82 (27%) in the completely edentulous (CE) population, and 47/230 (20%) in the partially edentulous (PE) population. Of the septa identified in the PE population, 20/50 (40%) were located apical to a maxillary root and classified as primary, while the remaining 30/50 (60%) were located apical to an edentulous ridge. In his classic skull study, Underwood[18] found a 33% prevalence of septa (30 septa in 90 maxillary sinuses). In a similarly designed study, Ulm and coworkers[27] reported 15 septa in 82 maxillary sinuses (18.3% prevalence). Krennmair and associates[24] counted 32 antral septa in 200 maxillary sinuses (ie, 16% of sinuses) utilizing CT imaging. Krennmair and associates[17] later reported 19 antral septa in 184 maxillary sinuses (10%) evaluated using CT examinations. It is important to know that the majority of the sinuses in this study harbored only 1 septum, while only 5 sinuses (1.6%) presented multiple septa.

As described previously, all septa demonstrated a medial-lateral orientation. No sagittally oriented septa were observed. The morphology of septa did, however, demonstrate significant variability. This is evident in the results obtained from measuring each septum at 3 aspects along its medial-lateral dimension. A total of 65.3% demonstrated a morphology similar to the classic inverted gothic arch form, with a significant (> 2.5 mm) lateral and medial insertion; however, the average height of the medial insertion was generally greater than the height of the lateral insertion (Table 2). This observation may be the result of the inherent limitations of the radiographic technique employed in this study when detecting fine details of anatomic structures. Other septa demonstrated insignificant height at 1 of the 3 points measured: lateral height (32%), middle height (5.3%), or medial height (2.7%). This demonstrates the wide range of septum morphology identified within a given population. Previous studies have reported on the height of septa but have failed to describe the specific point of measurement. As demonstrated in the 75 septa identified in the 312 examined sinuses, the height and morphology of septa can vary dramatically, depending on the site chosen for measurement.

The location of septa observed in the total study population demonstrated a greater prevalence in the middle region (first and second molar) (41.0%), followed by the posterior region (35.0%), and the anterior region (24.0%). When partially edentulous and completely edentulous patients were compared, this distribution remained relatively similar (Table 1). This is in contrast to a recent study by Krennmair and coworkers,[17] which reported a greater prevalence of septa in the anterior region (70% to 75%) in partially edentulous, edentulous, and atrophic edentulous maxillae. These authors also examined a group of partially or completely dentate maxillae and observed a decreased prevalence in the anterior segment (57%). Of the 51 septa identified, only 9 (18%) were found in the molar region, and 1 (2%) was found in the second molar region. This information was used to make conclusions regarding the etiology of septa—namely, that the increased prevalence of septa in the anterior region of the edentulous maxilla was a result of earlier tooth loss and pneumatization of the posterior maxillary ridge, which resulted in an increased prevalence of septa at the junction between the premolar and molar segments. Stover[22] criticized these conclusions, stating that a greater prevalence of septa in the posterior segments resulting from remnant interradicular bone between adjacent maxillary molars, ie, secondary septa, would be more likely. Underwood[18] actually noted in his study that the majority of septa identified were located in the posterior segment. He hypothesized that septa (primary) formed as a result of different timing of tooth eruption. Thus, since primary posterior septa are the last to develop, they would remain for a longer period of time because of their decreased exposure to resorptive mechanisms proper to the antral cavity. Differences between the results obtained from different studies may reflect variability between methods of measurement, tools utilized to gather data, and variation among populations studied.

Septa appear to develop in either of 2 ways, either primary (developmental) or secondary as a result of tooth loss and remnant interseptal bone. Tooth loss and pneumatization adjacent to either a primary or secondary septum may also exaggerate the height or size of a septum. It is impossible to label a septum located apical to an edentulous ridge as primary or secondary without a radiographic history of the sinus in question. Thus, it can be stated

that septa located apical to dentate regions are primary (developmental), and septa located apical to an edentulous region can be either primary or secondary. Further examination of the 20 primary septa identified within this study demonstrates a distribution similar to that observed in the edentulous population examined (Table 2).

No conclusions can be drawn from this cross-sectional study regarding the etiology of septa in the sinus; however, it is important for the clinician to realize that septa, when present, may arise in any of the 3 regions of the maxillary sinus irrespective of the degree of dentulism or edentulism present.

Diagnosis of the presence or absence of antral septa should be part of any diagnostic workup when sinus elevation procedures are being considered as part of the dental treatment plan. A positive finding may dictate a different approach on the lateral access to the sinus cavity. For example, opening 2 adjacent windows instead of 1 may be necessary to facilitate access and elevation of the Schneiderian membrane.

It has been shown that panoramic radiography can lead to a false diagnosis regarding the positive or negative identification of antral septa in 21.3% of the cases.[18,27] Several authors have suggested that CT images can be useful to the clinician in diagnosis and treatment planning by enhancing the accuracy of diagnostic decisions and the formulation of adequate treatment plans.[28–30] According to Quirynen and coworkers,[31] standard CT reconstruction offered the most reliable cross-sectional images, with a mean absolute deviation of 0.5 mm. This value varies significantly, depending on the technique employed to reformat these images. Such is the degree of variation that other authors recommend making allowances for the potential maximum error related to operator misinterpretation, which would help prevent anatomic complications during surgery.[32,33] The measurements collected in the present study appear to be as accurate as the image reformatting procedures allow. It is important to realize that because of the design of this study, there was no clinical verification of these measurements.

SUMMARY

To avoid unnecessary complications during sinus augmentation procedures, adequate and timely identification of the anatomic structures inherent to the maxillary sinus must be accomplished. Through examination of a cross-sectional sample of 312 sinuses using preoperative axial CT scans, the prevalence, size, location, and morphology of septa in dentate, partially dentate, and edentulous maxillae were determined.

REFERENCES

1. Boyne P, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Maxillofac Surg 1980;17:176–182.
2. Tatum OH. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986;30:207–229.
3. Betts KIT, Miloro M. Modification of the sinus lift procedure for septa in the maxillary antrum. J Oral Maxillofac Surg 1994;52:332–333.
4. Block M, Kent JN. Sinus augmentation for dental implants. The use of autogenous bone. J Oral Maxillofac Surg 1997; 55:1281–1286.
5. Nevins M. The sinus-elevation surgical procedure to support implant prostheses. Dent Econ 1995 April;85(4):88–89.
6. Wheeler SL, Holmes RE, Calhoun CJ. Six-year clinical and histologic study of sinus-lift grafts. Int J Oral Maxillofac Implants 1996;11:26–34.
7. Jensen J, Sindet-Pederson S, Oliver AJ. Varying treatment strategies for reconstruction of maxillary atrophy with implants: Results in 98 patients. J Oral Maxillofac Surg 1994;52:210–216.
8. Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the Sinus Consensus Conference of 1996. Int J Oral Maxillofac Implants 1998;13(suppl):11–12.
9. Bhattacharyya N. Bilateral chronic maxillary sinusitis after the sinus-lift procedure. Am J Otolaryngol 1999;20(2):133–135.
10. Chanavaz M. Maxillary sinus: Anatomy, physiology, surgery, and bone grafting related to implantology—Eleven years of surgical experience (1979–1990). J Oral Implantol 1990;16: 199–209.
11. Misch CE. Maxillary sinus augmentation for endosteal implants: Organized alternative treatment plans. Int J Oral Implantol 1987;4:49–58.
12. Ziccardi VB, Betts NK. Complications of maxillary sinus augmentation. In: Jensen OT (ed). The Sinus Bone Graft. Chicago: Quintessence, 1999:201–208.
13. Timmenga NM, Raghoebar GM, Boering G, Vanweissenbruch R. Maxillary sinus function after sinus lifts for the insertion of dental implants. J Oral Maxillofac Surg 1997;55: 936–939.
14. Regev E, Smith RA, Perrott DH, Pogrel MA. Maxillary sinus complications related to endosseous implants. Int J Oral Maxillofac Implants 1995;10:451–461.
15. Misch CM. The pharmacologic management of maxillary sinus elevation surgery. J Oral Implantol 1992;28(1):15–23.
16. Van den Bergh JPA, ten Bruggenkate CM, Disch FJM, Tuinzing DB. Anatomic aspects of sinus floor elevations. Clin Oral Implants Res 2000;11:256–265.
17. Krennmair G, Ulm GW, Lugmayr H, Solar P. The incidence, location, and height of maxillary sinus septa in the edentulous and dentate maxilla. J Oral Maxillofac Surg 1999; 57:667–671.
18. Underwood AS. An inquiry into the anatomy and pathology of the maxillary sinus. J Anat Physiol 1910;XLIV (3rd ser, Vol V):354–369.
19. McGowan DA, Baxter PW, James J. The Maxillary Sinus and Its Dental Implications. Oxford: Butterworth-Heinemann, 1993:1–25.

20. Miles AEW. The maxillary antrum. Br Dent J 1973;134:61–63.
21. Neivert H. Surgical anatomy of the maxillary sinus. Laryngoscope 1930;40:1–4.
22. Stover JD. Discussion: The incidence, location, and height of maxillary sinus septa in the edentulous and dentate maxilla. J Oral Maxillofac Surg 1999;57:671–672.
23. Betts HJ, Miloro M. Modification of the sinus lift procedure for septa in the maxillary antrum. J Oral Maxillofac Surg 1994;52:332–333.
24. Krennmair G, Ulm C, Lugmayr H. Maxillary sinus septa: Incidence, morphology and clinical implications. J Craniomaxillofac Surg 1997;25:261–265.
25. Mafee MF, Chow JM, Meyers R. Functional endoscopic sinus surgery: Anatomy, CT-screening, indications and complications. Am J Roentgenol 1993;160:735–744.
26. Kennedy E. Partial Denture Construction. New York: Dental Items of Interest, 1928:3–8.
27. Ulm CW, Solar P, Krennmair G, Matejka M, Watzek G. Incidence and suggested surgical management of septa in sinus-lift procedures. Int J Oral Maxillofac Implants 1995; 10:462–465.
28. Alder ME, Deahl ST, Matteson SR. Clinical usefulness of two dimensional reformatted and three dimensionally rendered computerized tomographic images: Literature review and a survey of surgeons' opinions. J Oral Maxillofac Surg 1995;53:375–386.
29. Dula K, Mini R, Van der Stelt PF, Buser D. The radiographic assessment of implant patients: Decision-making criteria. Int J Oral Maxillofac Implants 2001;16:80–89.
30. Schwarz MS, Rothman SLG, Rhodes ML, Chafetz N. Computed tomography: Part II. Preoperative assessment of the maxilla for endosseous implant surgery. Int J Oral Maxillofac Implants 1987;2:143–148.
31. Quirynen M, Lamoral Y, Dekeyser C, et al. The CT scan standard reconstruction technique for reliable jaw bone volume determination. Int J Oral Maxillofac Implants 1990;5: 384–389.
32. Kohavi D, Bar-Ziv J, Marmary Y. Effect of axial plane deviation on cross sectional height in reformatted computed tomography of the mandible. Dentomaxillofac Radiol 1997; 26:189–191.
33. Jacobs R, Adriansens A, Naert I, Quirynen M, Hermans R, van Steenberghe D. Predictability of reformatted computed tomography for preoperative planning of endosseous implants. Dentomaxillofac Radiol 1999;28:37–41.