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Three-Dimensional Evaluation of Implant Positioning in the Maxillary Sinus Septum: A Retrospective Study

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The aim of this study was to simulate implant placement in the maxillary sinus septum, as a potential alternative site to avoid sinus grafting.

Material/Methods: One hundred partially or completely edentulous patients, with their maxillary sinus septum present in the edentulous region, were selected from the database of the Department of Maxillofacial Surgery, Cliniques Universitaires Saint Luc, Bruxelles, Belgium.

Three-dimensional (3D) reconstructions were created using 3D planning software. 3D reconstructions were performed for each maxillary sinus. Using the software implant library, the implants that presented the best fit with the maxillary sinus septum and that followed the established inclusion criteria were selected.

Results: All of the implants were inserted in premolar and molar regions. Most implants were inserted in the position of the second molar (21 of 55) or in the position of the first molar (17 of 55). In all sites the most frequently used implant was 4 mm in diameter and 7 mm in height.

The mean coronal angle for the implant was 80.19±17.13 degrees and the mean sagittal angle was 94.83±9.94 degrees.

The septal height represents 38.13% of the total available bone height (ABH). The mean percentage of the septum used to insert the implants was 47.33±2.47%. The septum increased the available bone height by a mean value of 2.18±1.47 mm.

In 45 cases, the septa did not permit implant placement.

Conclusions: In completely edentulous patients, inserting implants in sinus septa does not exclude the need for sinus grafting, but in partially edentulous patients, this minimally invasive technique is an alternative to subantral augmentation.

MeSH Keywords: Anatomy • Cone-Beam Computed Tomography • Dental Implants

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Background

The successful placement and restoration of dental implants in the edentulous posterior maxilla could potentially be compromised by a lack of adequate vertical dimension of the alveolar bone present between the alveolar crest and the floor of the maxillary sinus. To address these problems, maxillary sinus elevation surgery was developed to increase the height of the bone available for implant placement in the posterior maxilla [1].

Although the complication rate of maxillary sinus bone augmentation is low [2], there exist intra-operative risks of sinus membrane perforation and bleeding [3–9] and postoperative risks of wound infection and sinusitis [2,7,8,10–12], graft or barrier membrane exposure [13], graft infection (warranting its removal) [14], cyst formation [15], and flap dehiscence. In addition to the maxillary sinus bone augmentation procedure, the implant surgery itself, whether performed simultaneously or as a second-stage procedure, may be complicated by implant displacement, implant migration into the sinus, or failure to achieve osseointegration.

As an alternative to maxillary sinus bone augmentation, some publications described positive outcomes for tilted implants [16–22]. The described advantages were as follows: 1) the placement of longer implants, 2) a reduced cantilever length, and 3) increased posterior implant support with avoidance of anatomical structures [17–22].

To overcome the drawbacks of maxillary sinus bone augmentation, some authors have suggested the use of alternative anatomical areas for implant placement [23]. Inserting the implant in the pterygoid process or tangential to the palatal curvature in the area of the first or second molar was proposed in several studies [19,24,25]. For the non-grafted maxilla, Krekmanov placed the implants into the pterygoid plate, palatally tilted, close to and parallel with the posterior sinus wall or close to and parallel with the anterior sinus wall [26].

However, some authors mentioned a risk of severe complications after using the pterygoid area for implant insertion. Reychler and Olszewski reported perforation of the skull base and penetration of the middle cranial fossa after inserting pterygoid implants in the pterygoid process with associated chronic fatigue and severe headaches [27]. Krekmanov reported mobility of 3 of the 14 implants inserted in the pterygoid plate, palatal curvature, and close to the posterior sinus wall [26].

Another alternative area for implant placement, not requiring the use of specific implants, could be maxillary sinus septa. The feasibility of this method was initially described by Fortin; 3 out of 11 implants were placed into maxillary sinus septa with the help of an intra-operative surgical guide [23].

The hypothesis was that maxillary sinus septa are suitable alternative anatomical areas for implant placement to avoid sinus grafting in partially and completely edentulous patients. Therefore, the aims of this simulation study were to assess: 1) the anatomical region of best use for implants within maxillary sinus septa, 2) the type of implant that fits best with maxillary sinus septa, and 3) the added bone height to the available alveolar bony height obtained by using maxillary sinus septa.

Material and Methods

One hundred partially or completely edentulous patients, with maxillary sinus septum present in the region of the edentation, were consecutively identified from the cone beam computed tomography (CBCT) database of the Department of Oral and Maxillofacial Surgery, Cliniques Universitaires Saint Luc, Bruxelles, Belgium.

The study was retrospective, and the CBCT examination was performed for a reason other than for this study. The exclusion criteria included minors, pregnant women, and patients with CBCT images that presented either inadequate information or signs of a previous surgery.

The study received approval from the Comité d'éthique hospitalo-facultaire of the Université Catholique de Louvain, Brussels, Belgium (2014/13MAR/104).

The CBCT (i-CAT) radiological protocol was as follows: 120 KvP, 18 mAs, 0.3 mm voxel size, 21 cm height and 16 cm diameter field of view. The axial images were transferred to the 3D planning software (Nobel Biocare, Göteborg, Sweden). The DICOM files obtained from CBCT were introduced into the software that displays axial, coronal and sagittal images. A 3D reconstruction was also available.

The implant was selected from the library and freehand positioned in 2-dimensional (2D) images and visualized by 3D reconstruction [28]. The presence of maxillary sinus septa was initially evaluated using the axial planes, and then using the reconstructed sagittal and coronal planes. Three-dimensional reconstructions were performed for each patient. For each patient, 1 observer defined the position of the implant according to the available bony crest and to the sinus septal volume. The observer analyzed whether the tilted axis of the implant did not intersect with the adjacent teeth. Reformatted views of the planned implant axis were always reviewed. The simulation was carried out in real time in all 3 planes (Figure 1). The transverse (also known as axial or horizontal) plane is an X-Z plane, parallel to the ground, which separates the superior from the inferior. The coronal (also known as frontal) plane is a Y-X plane, perpendicular to the ground, which separates

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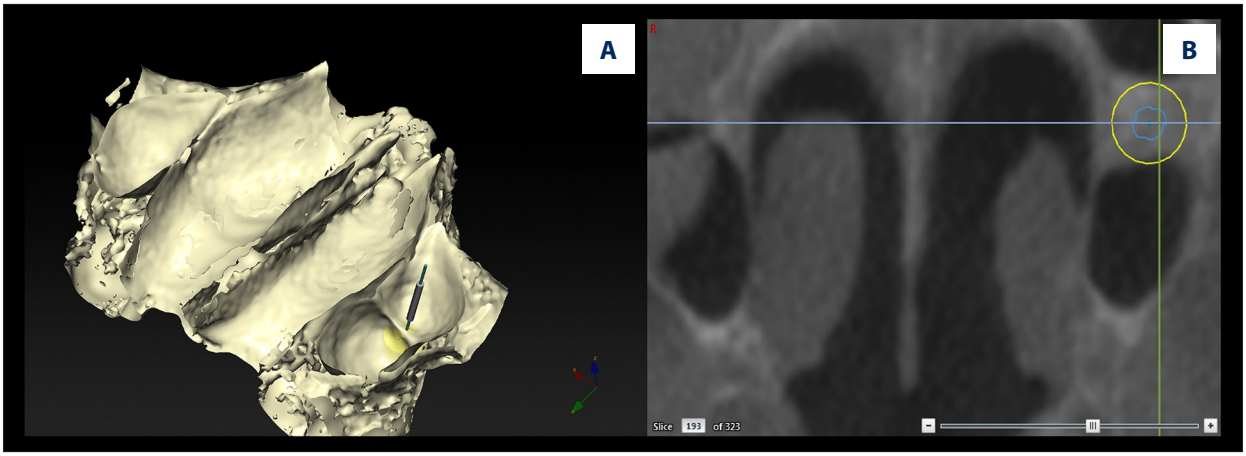

Figure 1. Simulation of implant placement (**A**) and bone assessment around the implant in the axial plane (**B**). The blue circle is the apex of the implant and the semi-transparent yellow zone indicates a by-default tolerance of 1.5 mm.

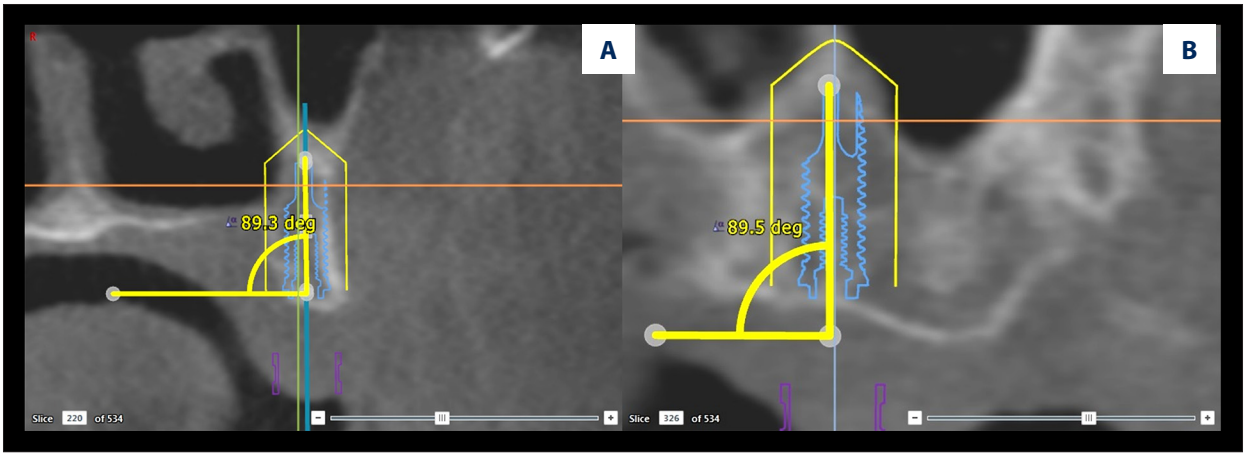

Figure 2. Coronal and sagittal angles (the angle formed by the implant axis (the green vertical line) and the transversal axis (the yellow horizontal line) parallel to the transversal plane (the orange line; the coordinate reference system was automatically proposed by the software) in the coronal (**A**) and sagittal planes (**B**), respectively).

the anterior from the posterior. The sagittal (also known as lateral) plane is a Y-Z plane, perpendicular to the ground, which separates left from right.

Every bony prominence more than 4 mm wide or 4 mm high was considered as a septum [29].

One observer (E.D.) selected the implants with the best fit for each maxillary sinus septum corresponding to the following criteria: 1) the angle between the implant axis and the transversal axis ranged between 45° and 135° and 2) the implant was mesiodistally and buccopalatally surrounded by a minimum of 1.5 mm of bone (Figure 1).

The transversal axis was freehand positioned parallel to the transversal plane. The transversal plane was automatically calculated by the software and displayed on a screen. The angles were evaluated in the coronal and sagittal planes. The coronal angle was the angle formed by the implant axis (automatically generated by the software) and the transversal axis in the coronal plane. The sagittal angle was the angle formed by the implant axis and the transversal axis in the sagittal plane (Figure 2).

The implant library provided 23 types of implants, with diameters ranging from 2.8 mm to 6 mm and lengths ranging from 7 mm to 52.5 mm. The zygomatic implants, 30–52.5 mm length, are not suitable for implant placement in sinus septa.

The implants were represented by their real shapes, to allow the clinician to perform a realistic 3D virtual surgery.

The observer evaluated the crestal height, the septal height, and the percentage of the maxillary sinus septum used for implant insertion (ABH = septal height + crestal height). The heights were measured on 2D reformatted images. The crestal height

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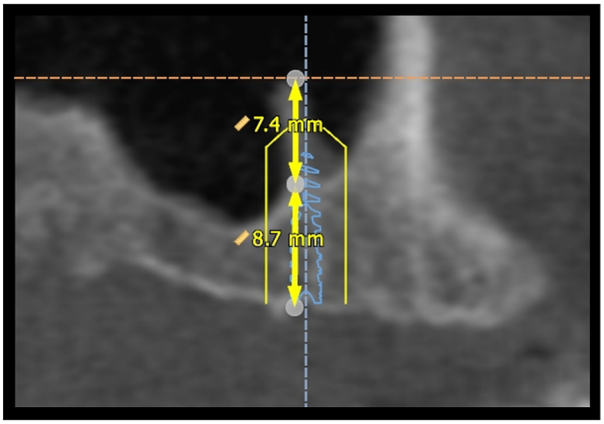

Figure 3. Measurement of crestal and septal heights on 2-dimensional reformatted images.

was defined as the distance between the margin of the alveolar bony crest and the base of the septum. The septal height was defined as the distance between the base of the septum and the top of the septum (Figure 3).

All of the measurements (the sagittal and coronal angles and the crestal and septal heights) were performed twice by 1 observer (E.D.), with a 1-week interval between measurements.

Obtained data and scan data were recorded in an SPSS database (IBM). Statistical analysis was performed using SPSS version 20 for Windows 7 (IBM).

Results

The intraclass correlation coefficient has been advocated as a statistic for assessing agreement or consistency between 2 methods of measurement, in conjunction with a significance test of the difference between means obtained by the 2 methods [30]. The intraclass correlation coefficient (ICC) showed that there was no statistically significant difference between the 2 intra-observer measurements ($p>0.05$).

All of the implants were inserted in premolar and molar regions (Table 1).

In all sites, the most frequently used implant was 4/7 mm (diameter/length) (Table 2).

The range and the mean values of the performed measurements are shown in Table 3. The mean septal height represented 38.13% of the ABH. The mean percentage of sinus septa used to insert the implants was 47.33±2.47%. The highest mean percentage value (53.34%) was encountered in the site of the second premolar. The septum increased the available bone height by a mean value of 2.18±1.47 mm.

Table 1. Implant type and frequency.

Implant diameter	Implant length	Frequency
3	10	7
3	11.5	8
3	13	2
3	15	1
3.75	7	1
3.75	8.5	1
3.75	10	4
3.75	11.5	1
3.75	13	1
4	7	17
4	8.5	2
4	10	2
4	11.5	2
4	13	4
4	15	1
5	8.5	1

Table 2. Distribution of implants and percentage of septal height from ABH according to location.

Location	Implant frequency	Percentage of septal height from ABH
First premolar	4	39.77
Second premolar	13	40.49
First molar	17	37.83
Second molar	21	36.60

In 45 cases, the septa did not allow for implant placement.

Discussion

According to the European Association for Osseointegration guidelines, panoramic radiography is the most commonly used examination for oral implant placement in the upper jaw [31]. Fortin evaluated the degree to which the rate of severely resorbed posterior maxillae requiring sinus lift was overestimated on panoramic radiographs, showing that the use of the panoramic exam for oral implant planning in severely resorbed maxillae overestimates the need for a sinus augmentation procedure when compared with the use of both 3D planning

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Table 3. The range and the mean values of the performed measurements.

	Descriptive statistics				
	N	Minimum	Maximum	Mean	Std. deviation
Coronal angle	55	45	120	80.19	17.133
Sagittal angle	55	74	128	94.83	9.949
Crestal height	55	3	14	7.59	2.313
Septal height	55	2	11	4.69	2.167
Percentage	55	.05	1.00	.4733	.24730

software and strategic implant placement. The author considers that an image-guided procedure allows the surgeon to take advantage of the septa and palatal curvature [32].

Maxillary sinus septa are often described as a potential problematic area during maxillary sinus floor elevation when performing sinus lift surgery because of the risk of membrane perforation. Instead, in this study we tried to use maxillary sinus septa as an alternative source of available bone height to treat partially and completely edentulous patients.

With the mean added bone height (2.18±1.47 mm) we can use a longer implant and can also better angulate the implant axis. The mean coronal angle of 80.19±17.13° and the mean sagittal angle of 94.83±9.94° found in our study are within the range previously described by Malo et al. for tilted implants (45° to 135°) [21].

The most frequently used implant was 4/7 mm. Placement of short implants has been described as a valuable alternative to sinus grafting [33,34]. With the procedure proposed in this paper, implants are often tilted, which does not seem to be a drawback because preliminary studies on tilted implants have indicated a high survival rate [21].

CBCT and 3D virtual planning should become mandatory when using alternative anatomical regions such as sinus septa for implant positioning, for 3 main reasons: 1) to evaluate the anatomy and 3D dimensions of sinus septa, 2) to allow for the precise planning of implant positioning with virtual planning software based on CBCT imaging, and 3) to generate an accurate 3D surgical guide that allows the surgeon to place implants precisely into planned positions [35].

In further studies, the development and experimental validation of surgical guides for implant insertion in sinus septa, using low-cost 3D printers, should be assessed.

A drawback of this study is that this was a simulation study performed on 3D reconstructions and not on real patients; when we determined the implant insertion sites, we did not take into consideration the final prosthetic restoration.

Conclusions

The null hypothesis was accepted; the maxillary sinus septum may partially increase the total bony height in partially and completely edentulous patients. The molar region is the best area to place implants in maxillary sinus septa.

The implant with a 4 mm diameter and 7 mm height had the best fit with maxillary sinus septa.

The septum increased the available bone height by a mean value of 2.18±1.47 mm.

References:

1. Kaufman E: Maxillary sinus elevation surgery: an overview. J Esthet Restor Dent, 2003; 15(5): 272–82
2. Barone A, Santini S, Sbordone L et al: A clinical study of the outcomes and complications associated with maxillary sinus augmentation. Int J Oral Maxillofac Implants, 2006; 21: 81–85
3. Jensen J, Sindet-Pedersen S, Oliver AJ: Varying treatment strategies for reconstruction of maxillary atrophy with implants: results in 98 patients. J Oral Maxillofac Surg, 1994; 52: 210–16
4. Pikos MA: Maxillary sinus membrane repair: report of a technique for large perforations. Implant Dent, 1999; 8: 29–34
5. Maksoud MA: Complications after maxillary sinus augmentation: a case report. Implant Dent, 2001; 10: 168–71
6. Schwartz-Arad D, Herzberg R, Dolev E: The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. J Periodontol, 2004; 75: 511–16
7. Flanagan D: Arterial supply of maxillary sinus and potential for bleeding complication during lateral approach sinus elevation. Implant Dent, 2005; 14: 336–38
8. Elian N, Wallace S, Cho SC et al: Distribution of maxillary artery as it relates to sinus floor augmentation. J Oral Maxillofac Implants, 2005; 20: 784–87

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9. Ardekian L, Oved-Peleg E, Mactei EE, Peled M: The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. J Oral Maxillofac Surg, 2006; 64: 277–82
10. Ueda M, Kaneda T: Maxillary sinusitis caused by dental implants: report of two cases. J Oral Maxillofac Surg, 1992; 50: 285–87
11. Timmenga NM, Raghoebar GM, Boering G, van Weissenbruch R: Maxillary sinus function after sinus lifts for the insertion of dental implants. J Oral Maxillofac Surg, 1997; 55: 936–39
12. Kretzschmar DP, Kretzschmar JL: Rhinosinusitis: review from a dental perspective. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2003; 96: 128–35
13. Regev E, Smith RA, Perrott DH, Pogrel MA: Maxillary sinus complications related to endosseous implants. Int J Oral Maxillofac Implants, 1995; 10: 451–61
14. Goga D, Romieux G, Bonin B et al: Preimplantation iliac graft in the sinus. Retrospective study of the complications encountered in 100 cases. Rev Stomatol Chir Maxillofac, 2000; 101: 303–8
15. Lockhart R, Ceccaldi J, Bertrand JC: Postoperative maxillary cyst following sinus bone graft: report of a case. Int J Oral Maxillofac Implants, 2000; 15: 583–86
16. Spinelli D, Ottria L, Vico de G et al: Full rehabilitation with nobel clinician® and procera implant bridge®: case report. Oral Implantol, 2013; 6(2): 25–36
17. Aparicio C, Perales P, Rangert B: Tilted implants as an alternative to maxillary sinus grafting: a clinical, radiologic, and periotest study. Clin Implant Dent Relat Res, 2001; 3: 39–49
18. Calandriello R, Tomatis M: Simplified treatment of the atrophic posterior maxilla via mmediate/early function and tilted implants: a prospective 1-year clinical study. Clin Implant Dent Relat Res, 2005; 7: S1–S12
19. Krekmanov L, Kahn M, Rangert B, Lindström H: Tilting of posterior mandibular and maxillary implants for improved prosthesis support. Int J Oral Maxillofac Implants, 2000; 15: 405–14
20. Koutouzis T,Wennström JL: Bone level changes at axial- and non-axial-positioned implants supporting fixed partial dentures.A 5-year retrospective longitudinal study. Clin Oral Implants Res, 2007; 18: 585–90
21. Malo P, Rangert B, Nobre M: All-on-4 immediate-function concept with Brånemark system implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res, 2005; 7: S88–94
22. Fortin Y, Sullivan RM, Rangert BR: The Marius implant bridge: surgical and prosthetic rehabilitation for the completely edentulous upper jaw with moderate to severe resorption: a 5-year retrospective clinical study. Clin Implant Dent Relat Res, 2002; 4: 69–77
23. Fortin T, Isidori M, Bouchet H: Placement of posterior maxillary implants in partially edentulous patients with severe bone deficiency using CAD/CAM guidance to avoid sinus grafting: a clinical report of procedure. Int J Oral Maxillofac Implants, 2009; 24(1): 96–102
24. Krekmanov L: A modified method of simultaneous bone grafting and placement of endosseous implants in the severely atrophic maxilla. Int J Oral Maxillofac Implants, 1995; 10(6): 682–88
25. Balshi TJ, Wolfinger GJ, Balshi SF II: Analysis of 356 pterygomaxillary implants in edentulous arches for fixed prosthesis anchorage. Int J Oral Maxillofac Implants, 1999; 14(3): 398–406
26. Krekmanov L: Placement of posterior mandibular and maxillary implants in patients with severe bone deficiency: A clinical report of procedure. Int J Oral Maxillofac Implants, 2000; 15(5): 722–30
27. Reychler H, Olszewski R: Intracerebral penetration of a zygomatic dental implant and consequent therapeutic dilemmas: case report. Int J Oral Maxillofac Implants, 2010; 25(2): 416–18
28. Vasak C, Watzak G, Gahleitner A et al: Computed tomography-based evaluation of template (NobelGuide™)-guided implant positions: a prospective radiological study. Clin Oral Implants Res, 2011; (10): 1157–63
29. White SC: Oral Radiology Principles and Interpretation, 6th Edition, Elsevier, 2009
30. Bland JM, Altman DG: A note on the use of the intraclass correlation coefficient in the evaluation of agreement between two methods of measurement. Comput Biol Med, 1990; 20(5): 337–40
31. Harris D, Buser D, Dula K et al: Guidelines for the use of diagnostic imaging in implant dentistry. Clin Implant Dent Relat Res, 2002; 13: 566–70
32. Fortin T, Camby E, Alik M et al: Panoramic images versus three-dimensional planning software for oral implant planning in atrophied posteriormaxillary: clinical radiological study. Clin Implant Dent Relat Res, 2013; 15(2): 198–204
33. Friberg B: The posterior maxilla: clinical considerations and current concepts using Brånemark system implants. Periodontol 2000, 2008; 47: 67–78
34. Renouard F, Nisand D: Short implants in the severely resorbed maxilla: a 2-year retrospective clinical study. Clin Implant Dent Relat Res, 2005; 7: S104–10
35. Yong LT, Moy PK: Complications of computer-aided-design/computer-aided-machining-guided (NobelGuide) surgical implant placement: an evaluation of early clinical results. Clin Implant Dent Relat Res, 2008; 10(3): 123–27

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