Radiographic Analysis of the Transcrestal Sinus Floor Elevation: Short-Term Observations

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ABSTRACT

Background: There are some limitations for implant placement in the posterior maxilla when there is an extended sinus. Various techniques for sinus floor elevation allow an increase in implant length.

Purpose: The aim of the present radiographic study was to assess the augmented site in the sinus around implants that were installed by means of an osteotome-mediated transcrestal sinus floor elevation.

Materials and Methods: Thirty-three patients with 44 implants were available. In 39% of the implants the sinus floor elevation was performed exclusively with bone chips. Bone fill material (Bio-Oss®, Geistlich Söhne AG, Wolhusen, Switzerland) was additionally used to increase the volume and stability of the lifted area at 61% of the implants. The visibility and morphology of the augmentation were assessed and compared by means of intraoral radiography (long-cone technique).

Results: All implants were stable and were considered to be successful when they were reexamined in the context of the present study. The mean residual bone height was 5.78 ± 1.4 mm. The increase of the implant length as compared to the original bone height resulted in a mean value of 3.87 ± 2.0 mm. The volume and density of the lifted area were more visible if Bio-Oss was added. A shrinkage and/or condensation of the grafted material was visible at 37% of the implants after a minimum loaded period of 200 days. Equally, a decreased visibility of the original sinus floor was noted at 61% of implants. The formation of a cortical bone layer at the apex of the implants was detected at 35% of implants.

Conclusions: The surgical procedure appears to be a safe method with rare complications. Radiographic assessment of the augmentation procedure proved to be difficult, and measurements are not fully reliable.

KEY WORDS: reduced bone height, radiographic analysis, transcrestal sinus floor elevation

Complex surgical techniques have gradually become routine clinical procedures in jaw sites that were previously considered to be contraindicated for implant placement. These techniques include guided bone regeneration by means of membranes[1,2] and various augmentation procedures performed simultaneously with or prior to the installation of the implant in sites with insufficient bone volume. Placement of implants may be limited in the posterior maxilla owing to low bone height and large extension of the sinus. This problem is encountered in patients with a partially or completely edentulous maxillary jaw. An increased failure rate in the maxilla in conjunction with short implants (owing to reduced bone height) has been reported in several clinical studies by various investigators.[3–6] Additionally, low bone quality[7–9] does not contribute to primary implant stability, which is not always easily achieved during the surgical procedure. The minimum length of implants necessary for predictable results is discussed in various studies,[10–14] and implants longer than 10 mm are suggested.

More than 20 years ago various techniques that allow augmentation of the posterior maxillary jawbone by means of the elevation of the sinus floor were described and developed. Access to the sinus cavity was achieved through a lateral fenestration. The sinus floor membrane was elevated, and the space was filled with

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TABLE 1 Number of Implants Placed, by Length and Diameter

	Diameter		
Length (mm)	3.3 mm	4.1 mm	4.8 mm
6	—	1	2
8	1	10	7
9	1	3	—
10	5	8	4
11	—	2	—

autologous bone.[15,16] A simultaneous or staged procedure for implant placement is possible, depending on the residual bone height.[17,18] The method has gained more popularity in the past 15 years. Preliminary reports and short-term and long-term results became available.[19] However, this invasive technique increases the treatment time.

Transcrestal access to the sinus cavity without a lateral fenestration has also been described.[16] In the mid-1990s the transcrestal technique with simultaneous implant placement was suggested by Summers.[20] This technique should be simple and less invasive. The author claimed a remaining minimal bone height of 5 mm. Special osteotome instruments were developed; these instruments are used with a light tapping technique to elevate the sinus membrane and to fill the new space with bone. Today many implant systems have their own instruments for performing the osteotome technique. Nowadays this technique is frequently performed with the addition of various fill materials.[20–27] A recent review reported on the transcrestal technique and summarized short-term observations.[28]

The aim of the present study was to describe and analyze radiographs of ITI Dental Implant System® implants (Straumann AG, Waldenburg, Switzerland) that were placed in combination with the osteotome-mediated transcrestal sinus floor elevation in partially and completely edentulous patients.

MATERIALS AND METHODS

Patients and Implants

Fifty-five consecutive patients received a total of 66 ITI implants in the posterior maxilla by means of an osteotome-mediated transcrestal sinus floor elevation procedure during a period of 1 to 6 years. Exclusion criteria were a history of frequent sinusitis, previous surgical interventions in the sinus, and detection of any pathologic changes on presurgical panoramic radiographs. The technique described by Summers[20] was adopted but was slightly modified. Thirty-three patients (13 men and 20 women) were willing to participate in the present study and to undergo clinical and radiographic reexamination; they also participated at an interview. Parts of these data will be published elsewhere.

The average age of the patients at the time of implant placement was 59.8 ± 7.2 years. They were partially (93%) or completely (7%) edentulous in the maxilla. A total of 44 implants was identified; 11 patients received two implants each, and the remaining 22 patients each received one implant. The two-part ITI implants were placed by a one-stage surgical procedure. All implants had a screw design with a roughened surface and either a TPS (titanium plasma sprayed) or SLA (sandblasted large grit acid etched) surface. The intraosseous implant length ranged from 6 to 11 mm, and the majority of the implants were 8 mm or 10 mm long. Table 1 gives an overview of the diameters and lengths of all 44 implants analyzed in the present study. The mean implant length was 8.9 ± 1.2 mm. The distribution of the implants according to their location in the jaw is shown in Figure 1.

Surgical Procedure

First, panoramic radiography was carried out in all patients to assess the extension and appearance of the sinus. If the patients were admitted to surgery, a presurgical radiograph was taken after placement of a metallic marker (a ball or pin) of known size (Figure 2). This was helpful for verifying (within the limitations of such radiographic techniques) the residual bone

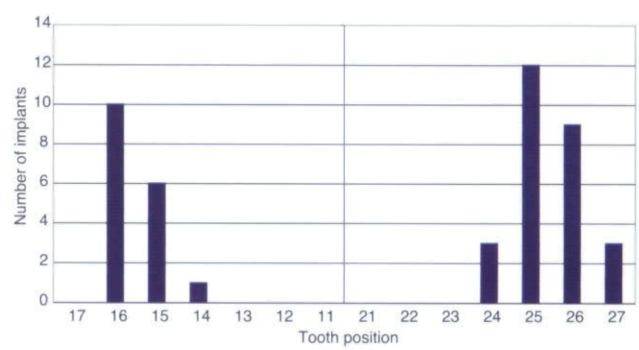


Figure 1 Maxillary distribution of 44 implants placed by means of transcrestal sinus floor elevation.

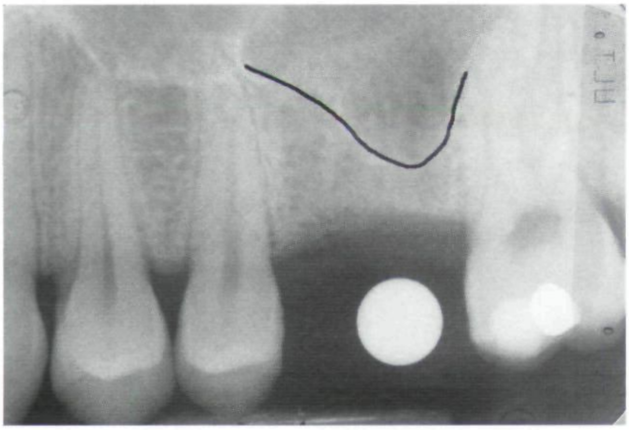


Figure 2 Preoperative radiograph showing a metallic marker of known diameter.

height but also helped verify the prospective implant axis in relation to the topography of the sinus floor and adjacent teeth. The radiographic splint was then adapted as a surgical guide. The prerequisite for implant placement was a residual height of about 4 mm. All implants were placed by one dentist or under that dentist's supervision. The set of osteotome instruments available for specific use with ITI implants was used. As a modification of the technique described by Summers, initial access into the bone was obtained with a small pilot drill. The penetration depth was at least 2 mm less than the remaining residual bone height as calculated from initial radiographs. Augmentation was then performed with the tapping technique. The instruments were introduced step-by-step until the sinus floor could be slightly fractured. The fracture was performed at the end with the largest instrument that corresponded in size to the implant to be placed. Direct contact of the instruments with the sinus membrane was avoided since bone particles or a combination of bone and Bio-Oss fill material was immediately added (on the top of the instruments) to the developing space after fracture of the sinus floor. Again in contrast to the technique described by Summers, fill material was added only after the sinus floor had been fractured and if the sinus membrane appeared to be fully intact. In the early phase when the technique was first applied, small bone particles from the surgical site were harvested and pushed upward. In the later period Bio-Oss was added stepwise in small portions. Altogether, 17 implants were placed exclusively with bone particles, and 27 implants combined with Bio-Oss material were placed. After the surgical procedure radiography was performed.

A healing phase of a minimum of 6 months was maintained before the loading of the suprastructure (mean, 6.7 $\pm$ 0.4 months). The provisional dentures (if worn by the patient) remained without any contact with the implant. When the final prosthesis was delivered at the beginning of the loaded period, radiography was again performed.

Radiographic Analysis

The radiographs used for analysis were taken with the long-cone technique and were all digitized. This allowed measurements on the computer screen to be more accurate. The three variables detailed below were examined by the radiographic analysis.

The first variable was implant length and remaining bone height. The presurgical radiographs served for measurements of the height of remaining bone. The postsurgical radiograph was used for measurements of the implant length above the sinus floor (Figure 3). This length usually was different at mesial and distal implant sites or was not measurable at both sites since implants may be slightly tilted or the sinus floor may be oblique. Therefore in the present study the implant site with the maximum length in the sinus was measured. The measurements were performed in duplicate.

The second variable was the visibility of the graft material and morphology of the augmented site. The postsurgical radiograph was used for measurements of the extent of the grafted material around the apex of the implants above the original sinus floor. The

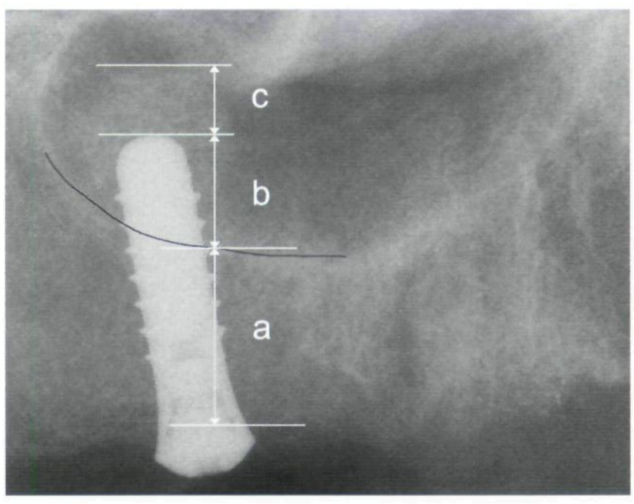


Figure 3 Radiograph showing measurements aimed at describing the augmented site in the sinus; "a" is the presurgical bone height, "b" is the implant length in the sinus, and "c" is a measure of the fill material on top of the implant apex.

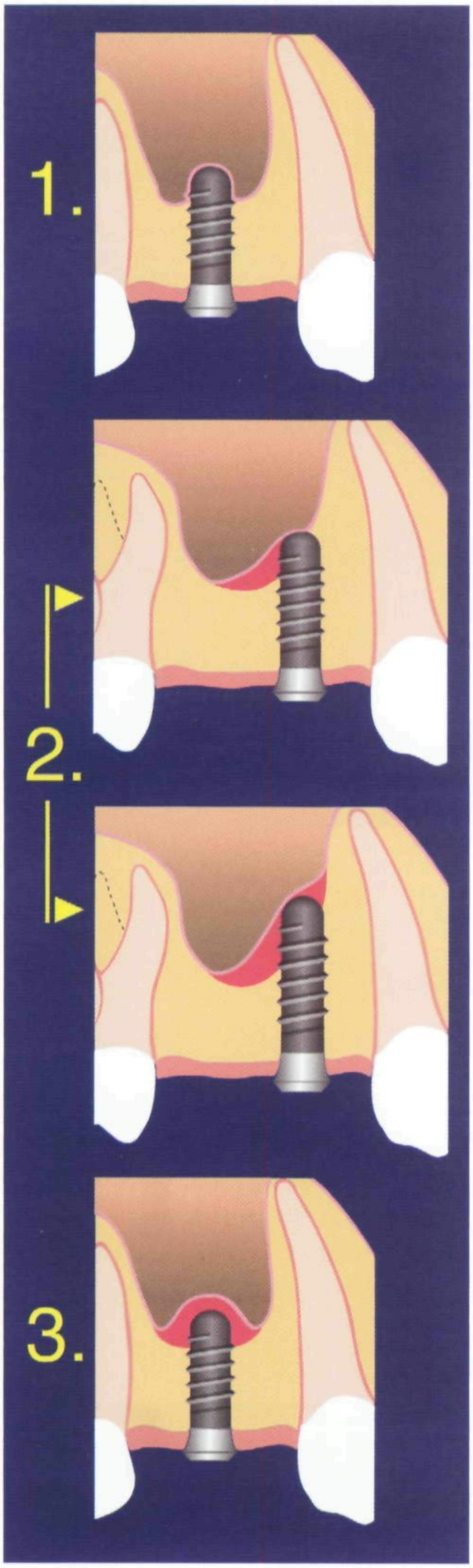


Figure 4 Topography and visibility of fill material around the implants. *1*, Fill material not visible. *2*, Fill material visible at one or two sides of the implant apex. *3*, Fill material visible all around the implant apex.

visibility of the grafted material in size and morphology (Figures 4 and 5) was described by means of three parameters: (1) no graft material visible, (2) graft material visible on one or two sides of the implant, and (3) graft material visible all around the apex of the implant.

The third variable was change after the loaded period. Comparison of the postsurgical radiographs with the actual radiographs taken in the context of the present study enabled researchers to detect changes in the grafted site after the loaded period. The parameters for assessment were (1) the consolidation of the grafted area in terms of increased density and shrinkage and (2) the visibility of the original sinus floor with the formation of a new sinus floor (cortical layer) around the grafted material.

Statistical Analysis

Descriptive statistics was used for patients' demographics, implant distribution, and radiographic analyses.

RESULTS

Forty-four implants were analyzed. All implants were stable in situ, and no problems were observed during the reported mean observation period of 1.2 years. The average increase of the implant length in the sinus was 3.87 ± 2.0 mm (range, 0.5–6.5 mm). Results are given in Table 2.

In regard to the visibility and topography of the grafted site, the results of the radiographic assessment (as described in Figure 4) are shown in Tables 3A and 3B. Nonvisibility or very weak visibility of the grafted material was mostly noted if the implants were placed exclusively with bone chips whereas Bio-Oss fill material could always be detected. Visibility all around the apical portion of the implants was typical for implants placed in the molar region whereas visibility on one or two sides was typical for the region of the first premolar. These implants were mostly located at the mesial wall of the sinus. The visibility of the fill material was better with a deeper penetration depth of the implant in the sinus.

In the analysis of changes after the loaded period, 8% of the radiographs could not be compared owing to insufficient congruence (Table 4). A strongly visible consolidation with shrinkage and higher density of the fill material was observed in 49% of all implants (Figure 6). In terms of changes of the original sinus floor, decreased visibility or no identifiable visibility of

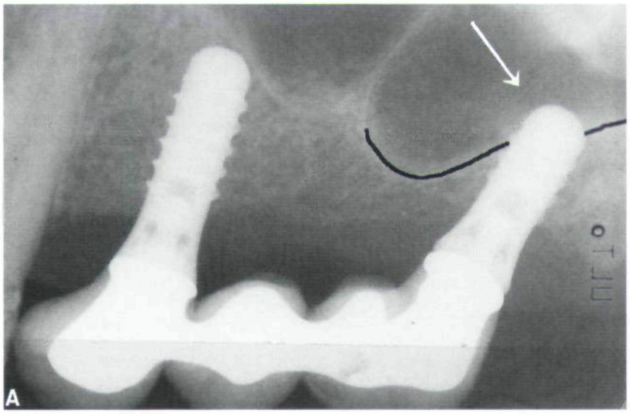
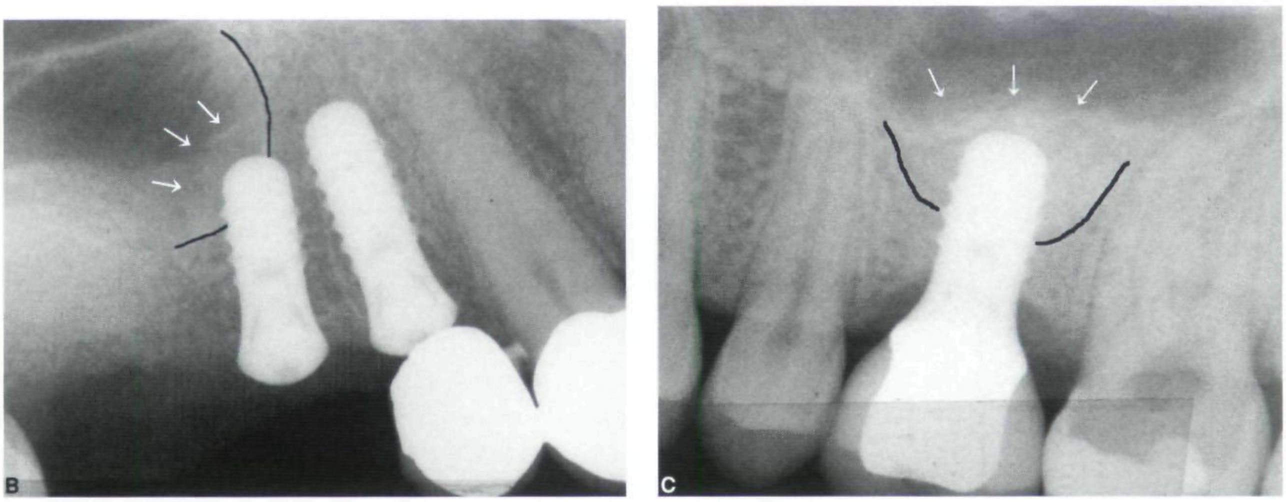


Figure 5 Radiographic examples of the visibility of fill material around implants. *A*, Fill material not visible at any side. *B*, Fill material visible at one or two sides. *C*, Fill material visible all around the implant apex.



the original sinus floor was most typically noted (Figure 7). The formation of a new inferior sinus border (cortical layer) was detected in 35% of the implants (Figure 8). All of these changes were not visible or not well visible at implants that had not been loaded for at least 200 days.

TABLE 2 Pre- and Postsurgical Radiographic Measurements

Variable Measured	Mean Value (mm)	Range (mm)
Presurgical bone height (a)*	5.78 ± 1.4	3.0–7.5
Implant length in sinus (b)*	3.87 ± 2.0	0.5–6.5
Fill material on top of implant apex (c)*	1.39 ± 1.3	0–4.0

*Letters in parentheses refer to measurements as shown in Figure 3.

DISCUSSION

Osteotome-mediated transcrestal sinus floor elevation is nowadays applied with increasing frequency for implant installation in the posterior maxilla. The advantages of this technique are a less invasive procedure, reduced patient morbidity, and a reduction in treatment time and cost when compared with the lateral-fenestration technique. An objection to the technique is that it lacks the control of the surgical procedure.

TABLE 3A Topography of Grafted Material around Apex of Implants

Fill Material	Implants (%)
At any side* not assessed	24
1 or 2 sides	27
All around implant apex	49

*All without Bio-Oss.

TABLE 3B Visibility of Grafted Material Related to the Penetration Depth of Implants

Penetration Depth of Implant in Sinus (mm)	Implants (%)	Visibility of Fill Material (%)	
≤ 2	26	Not visible*	19
		Weak	0
		Strong	7
3–4	39	Not visible*	11
		Weak	7
		Strong	21
≥ 5	35	Not visible*	0
		Weak	14
		Strong	21

*Or not assessed.

Stretching and tearing of the sinus membrane was investigated by means of anatomic sections and endoscopy,[29] and it was shown that elevation up to 10 mm was possible without damage to the membrane.

Currently used clinical and radiographic parameters may not be reliable for assessment of the augmented site in the sinus. Computed tomography (giving a three-dimensional view of the implants and the sinus cavity) and/or histologic specimens obtained from the surgical site could provide more information.[23,27] However, this is not applicable to daily practice because of high cost and invasiveness. Therefore this study tried to analyze periapical radiographs of implants that were placed by means of osteotome-mediated sinus floor elevation.

The mean gain of implant length of 3.87 mm by elevation of the sinus floor is well in keeping with a recent report on 240 loaded implants of various types[28] and is slightly increased as compared to other findings of 2.9 to 3.5 mm.[23,30,31] The mean implant length in the present study was 8.9 mm, and the mean penetration depth into the sinus was about 4 mm. Many investigators still consider this implant length to be short, and a minimum length of 10 mm is often claimed to be necessary.[10–14] This is in contrast to one study that reported successful short implants (about 7 mm in length, with a remaining minimal bone height of only 3 mm) that were placed in combination with the osteotome technique.[26]

In the present study more than 60% of the implants were installed by adding Bio-Oss material. The use of Bio-Oss appears to make it technically simple to create adequate space in the sinus and to obtain higher density of the grafted material; this may contribute to better

TABLE 4 Comparisons of Radiographs

Consolidation of Fill Material	Implants (%)	Changes of Sinus Floor (New Lamina Dura)	Implants (%)
Not visible*/ not assessed	40	Not assessed	8
No changes	23	Visibility of original sinus floor	
		Not decreasing	31
		Decreasing	39
		No longer visible	22
Visible changes	37	New sinus floor	35

*All without Bio-Oss.

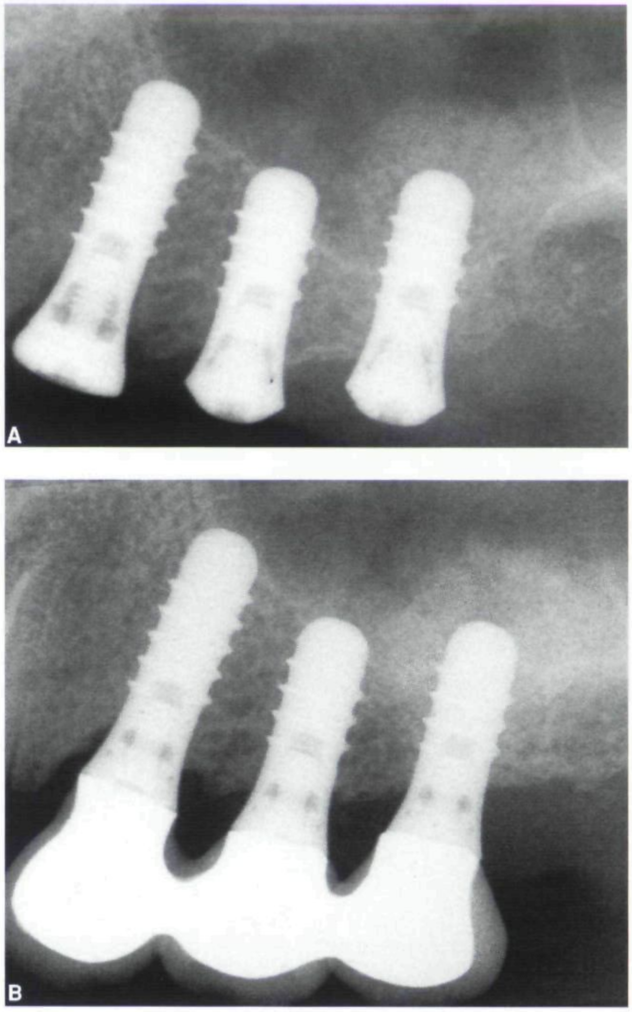


Figure 6 Example of shrinkage and increased density of Bio-Oss material. *A*, Postsurgical radiograph. *B*, Radiograph made 1.5 years after loading.

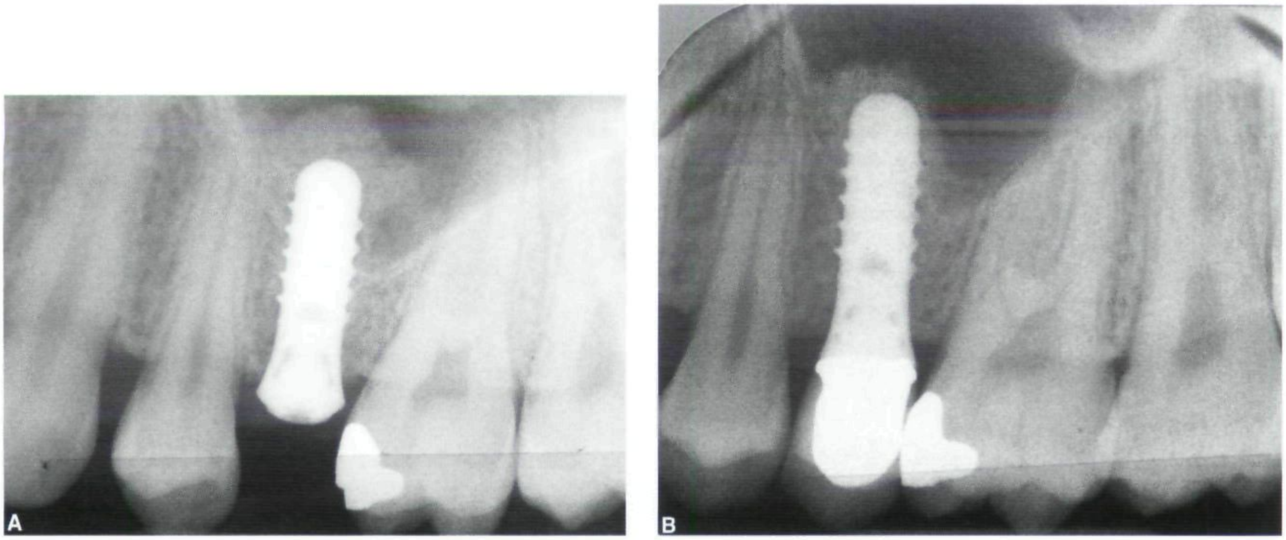


Figure 7 Examples of decreasing visibility of original sinus floor. *A*, Postsurgical radiograph. *B*, Radiograph made 1.5 years after loading.

stability of the implant as well. Further, better visibility of the elevated site in the sinus is achieved on the radiographs, which allows the clinician to get some control and gain information about the performed surgical procedure. Bio-Oss particles could also have a protective function against tearing of the sinus membrane during the surgical procedure since contact with the metal instruments is avoided. The same may be true under the impact of loading forces when the suprastructure is in function. A study reported that when bone chips were exclusively added, no fill material was visible on postsurgical radiographs. Radiopacity could be observed only after 8 months.[30]

It is not known how or whether the Bio-Oss material is transformed into bone. Regeneration of bone in conjunction with Bio-Oss material was shown in histologic specimens,[23,27] and favorable performance of Bio-Oss in the sinus was reported by studies in humans.[32–34] Histomorphometric analyses in one study found no differences of bone formation when autogenous bone, Bio-Oss material, or a combination of both was applied.[32] Some investigators avoided any fill material except for bone chips or suggested the use of collagen sheets and sponges[28,30,31,35] (which, however, are not visible on the radiographs). Single-case reports indicate that a blood clot alone can induce sufficient bone formation around implants in the maxillary sinus.[36]

During the present short-term observation, no implant was lost after loading. A recent report presented the results of a multicenter study of 174 implants in

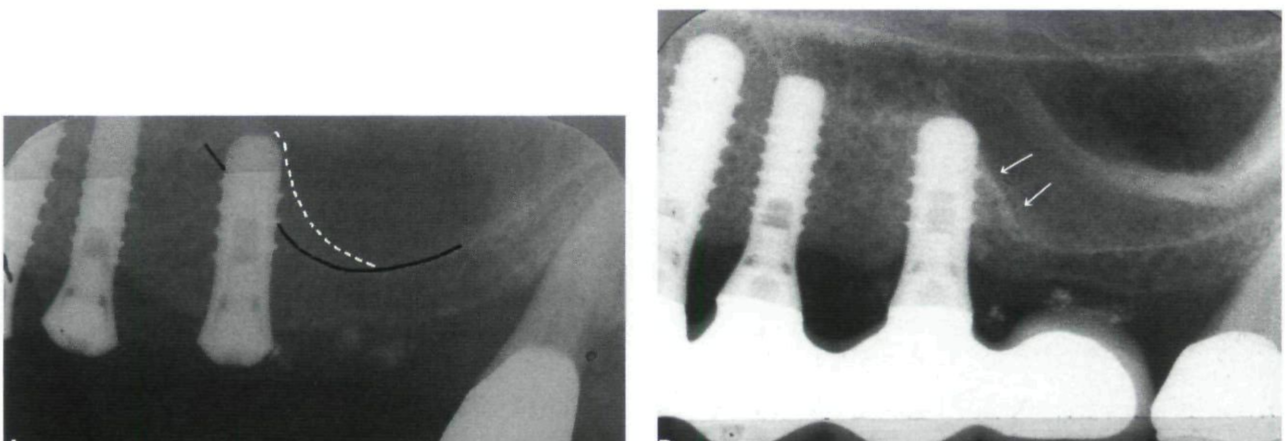


Figure 8 Examples of the formation of a cortical layer. *A*, Postsurgical radiograph. *B*, Radiograph made 1.2 years after loading.

101 patients.[25] A survival rate of 95.4% was recorded with a variety of graft materials and implants. It was concluded that the remaining preoperative bone height, along with the implant's surface characteristics, had the greatest impact on implant survival. More implants failed in patients with a low initial bone height (<4 mm), in patients who were smokers, and in patients with implants that had a smooth polished surface.[28] The type of fill material did not appear to influence the results.

The comparison of the radiographs indicates that a remodeling process of the bone takes place over time. In particular the formation of a new sinus floor with a cortical layer around the grafted area appears to be a favorable observation.[20,22,24,26–28,30,31]

CONCLUSIONS

The radiographic assessment of the transcrestal sinus floor augmentation procedure and the interpretation of the radiographs proved to be difficult in several cases. Measurements may not be fully reliable and a 3-D view of the elevated sinus site cannot be obtained by these simple measurements.

Nevertheless, the surgical procedure of a transcrestal sinus floor elevation appeared to be a safe and successful method. The average gain of implant length of about 4 mm was favorable with respect to the clinical indication. Complications were rare. Compared to a lateral access to the sinus floor, the invasiveness and patient morbidity were low. Adding Bio-Oss material to fill the newly created space improved the visibility of the augmentation on the radiographs. The formation of a new cortical layer around the apex of the implants appeared to be a favorable observation in terms of bone remodeling.

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