Radiographic Monitoring of Changes in Bone Height after Implant Placement in Combination with an Internal Sinus Lift without Graft Material

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ABSTRACT

Purpose: The objective was to investigate changes in bone height after implant placement in combination with simultaneous internal sinus lift (ISL) without graft material.

Materials and Methods: For a retrospective clinical study, 101 implants placed in combination with ISL without graft were selected. The study included 66 patients (mean age 59.6 years) with radiographs from baseline (T0) and two follow-ups after mean times of 7 months (T1) and 17 months (T2). Apical changes in bone height were measured at the mesial and distal aspects of the implant. Correlation analysis was performed to identify factors affecting changes in bone height.

Results: Mean apical bone gains of 1.0 mm (mesial) and 1.7 mm (distal) were observed at T1. At T2, mean apical bone gains were 1.5 mm and 2.1 mm (distal). The change in apical bone height was significant between T0 and T1, between T0 and T2, and between T1 and T2. Rank correlation analysis revealed a significant correlation (Spearman rho: –0.2 to –0.4) between small initial bone height and a greater amount of apical bone gain.

Conclusions: A gain in apical bone height can be expected if implants are placed in combination with ISL without graft material. Variability is high, however.

KEY WORDS: atrophic maxilla, radiographs, sinus floor elevation

INTRODUCTION

For nearly 20 years, elevation of the maxillary sinus floor, by use of a lateral window in combination with sinus grafting, has been performed to overcome reduced bone height in the posterior maxilla.[1,2] The conventional technique is based on elevation of the Schneiderian membrane from the floor of the sinus then introduction of a bone graft or a bone substitute to preserve space for the implant. The procedure is technically demanding and invasive, and is associated with additional morbidity and cost.

The internal sinus lift (ISL) was introduced by Summers as a less invasive approach for sinus floor elevation without ostectomy. After pilot drilling to the sinus floor, the membrane is elevated with a hand osteotome by pushing the graft material forward. If the residual bone height below the sinus ranged between 5 and 7 mm, the ISL technique is an option for simultaneous implant installation.[3–5]

The effect of different graft materials on survival of the implants has been evaluated in several reviews.[6–10] Autogenous bone grafts, graft materials, or a combination of both are recommended methods, but shrinkage

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and a remodeling process associated with a loss of graft height were observed for all types of graft during the first 1 to 3 years after augmentation.[11–13]

In recent years, a modified sinus floor elevation technique has been described in which no graft material is placed in the newly created space underneath the Schneiderian membrane.[14–21] Although there are several reports of acceptable survival of the implants and of apical bone gain after this procedure, only short-term evaluations of the amount of apical bone gain that can be expected have been reported.[16]

The objective of this clinical study was to investigate changes in bone height around maxillary implants placed in combination with an ISL without graft. An attempt was also made to identify predictive factors with possible effect on changes in bone height within the healing period and after 1 year of loading. The null hypothesis was that there would be no change in bone height at the apical aspect of implants placed in combination with an ISL.

TABLE 1 Characteristics of the Implants: Manufacturer, Surgical Aspects, Length, Diameter, Location, and Prosthetic Restoration

Implant	Straumann tissue level	91
	Straumann bone level	6
	Nobel Biocare replace select	4
Perforation	Yes	30
	No	71
Length (mm)	8	8
	10	83
	12/13	10
Diameter (mm)	3.3	1
	4.1/4.3	55
	4.8/5.0	45
Location	Canine	2
	Premolar	39
	Molar	60
Restoration	Single crown	40
	FDP	40
	RDP	21

FDP, fixed dental prosthesis; RDP, removable dental prosthesis.

MATERIALS AND METHODS

Patients

This retrospective study was conducted in accordance with the World Medical Association Declaration of Helsinki and was approved by the regional ethics committee (registration number 229/2005). All participants gave their informed consent. Implant placement and prosthetic treatment were exclusively performed in the Department of Prosthodontics of the University of Heidelberg. Inclusion criteria were implants placed in the posterior maxilla in combination with an ISL without using graft material and radiographs from the time of implant placement (T0) and from at least two follow-ups (T1 and T2).

The study group comprised 66 patients (35 men and 31 women) with a mean age of 59.6 years (range 21–75). All participants underwent implant surgery between December 2003 and September 2009. One hundred one implants were selected – 97 solid-screw implants (Straumann, Waldenburg, Switzerland) with Sandblasted, Large grit, Acid-etched (SLA) surface and four Replace select implants (Nobel Biocare, Gothenborg, Sweden). Further characteristics of the implants are given in Table 1. No graft was used, and primary stability was achieved in all cases.

Surgical Procedure

All patients underwent panoramic radiographic examination before surgery and immediately after implant placement. Bone height of at least 3 mm was required for an implant in the sinus region. After local anesthesia and mid-crestal incision, buccal and palatal full-thickness flaps were reflected. A surgical splint was used to mark the implant position with a round bur, and a pilot drill was used to define the angle of the implant. The pilot drill ended approximately 1 mm below the sinus floor as calculated from the presurgical X-ray. Preparation of the recipient sites was performed stepwise with appropriate spiral drills. Finally, a parallel hand osteotome was used under gentle malleting force to cause initial fracture of the sinus floor. The sinus floor was then elevated, by use of a depth gauge, to displace the Schneiderian membrane apically. The depth gauge had a rounded, smooth tip that enabled safe apical displacement of the sinus membrane. This step was performed manually with special attention devoted to avoiding perforation of the membrane.

To ascertain the integrity of the Schneiderian membrane, the elasticity of the membrane should be felt while manually inserting the Ø = 2.8 mm depth gauge. All implant insertions were performed with a hand ratchet. Even if perforation of the Schneiderian

membrane was detected, the entire implant insertion procedure was accomplished without further treatment.

As a preventive measure, all patients received $3 \times 1{,}000$ mg amoxicillin for 6 to 7 days and analgesics as required. Oral hygiene was performed as normal, except for tooth brushing around the implants for 7 days. Sutures were removed 6 to 9 days after surgery. For 98 implants, surgery was performed by three experienced dentists; another three implants were placed under supervision of one of the experienced dentists. After an unloaded healing period between 7 and 12 months, all implants were restored with 40 single crowns or with 40 fixed and 21 removable dental prostheses (RDPs) (Table 1).

Radiographic Measurement of Bone Height

All panoramic X-rays and single radiographs were taken with digital detectors; SIDEXIS software (Sirona, Bensheim, Germany) was used for measurements and calculation of correction factors. One dentist who was not involved in implant placement and prosthetic restoration evaluated the radiographs taken at T0, T1, and T2 for the presence or absence of bone gain at the apical and coronal aspects of the implants. To assess the reliability of the measurements, they were repeated for 30 implants by a second investigator unaware of the initial results.

The first thread of the implant was used as a reference point for measurement of apical bone height at the mesial and distal aspects of the implants. Because the real length of the implant was recorded, measurements were corrected by the individually determined enlargement factor of the radiograph. The apical bone height was measured from the first thread apically to the bony sinus floor, at the mesial and distal sides of the implant (Figure 1, A and B). Changes in bone height from T0 to T1 and to T2, and between T1 and T2 were assessed by calculating the corrected differences between the absolute values at different times.

Seventy-four implants were analyzed solely by use of panoramic radiographs, and 27 implants were analyzed on the basis of additional dental radiographs. The mean time between T0 and T1 was 7 months; between T0 and T2, it was 17 months. The radiographs at T1 were acquired before prosthetic restoration and the radiographs at T2 at the first follow-up after prosthetic restoration. Consequently, the time between T1 and T2 was the first months of loading.

Statistics

Statistical analysis was performed by use of *SPSS*® Version 14.01S (SPSS Inc., Chicago, IL, USA). Descriptive data were reported as whisker and box plots. Reliability was assessed on the basis of 30 implants with repeated measurements by two investigators unaware of the nature of the study and use of Pearson correlations analysis. Differences between bone heights at different times were compared by use of Wilcoxon tests. Factors with possible effects on the changes in bone height were isolated by use of rank correlation analysis (Spearman rho).

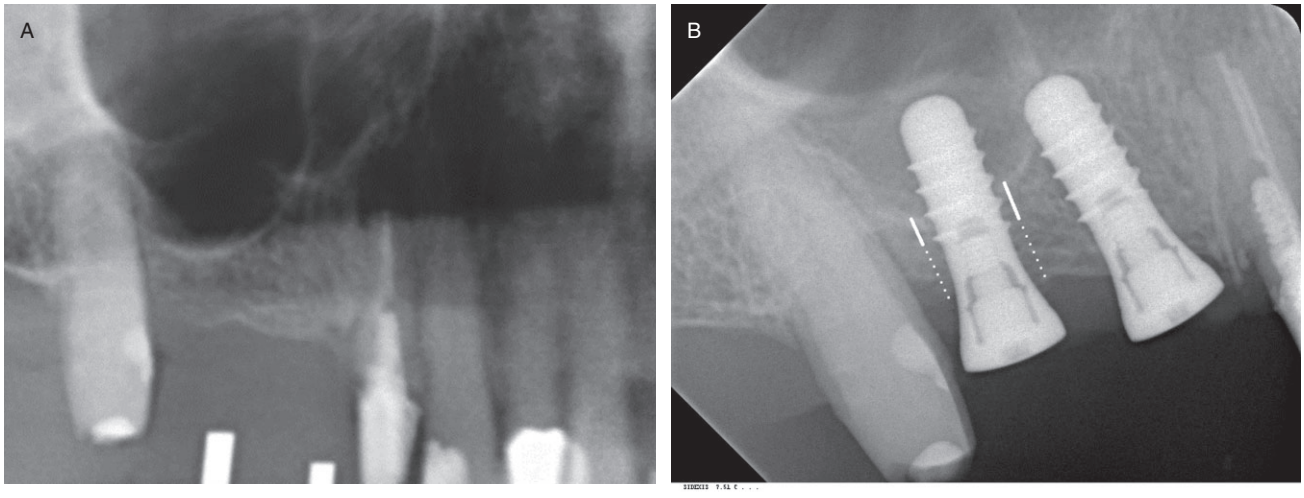

Figure 1 Section of a preoperative panoramic radiograph with an extended sinus in the region of the first molar (A). Postoperative radiograph with measurements of coronal (dotted line) and apical bone height (solid line) with use of the first coronal thread as reference point (B).

RESULTS

Radiographic evaluation revealed the effect of the ISL when the implant preserved the space below the Schneiderian membrane in a manner similar to a tent pole (Figure 2, A and B). After 7 months of unloaded healing, the original margin of the sinus floor was no longer delineated, and after 17 months, the margin of the sinus floor was clearly visible at the apical aspect of the implant (Figure 2, C and D).

Radiographs from 30 implants at T0, T1, and T2 were measured twice at the mesial and distal sides by two investigators unaware of the nature of the study. Correlation analysis revealed significant correlations ($p \leq .001$) for both investigators. Pearson correlation coefficients ranging between 0.860 and 0.865 for T0, between 0.626 and 0.918 for T1, and between 0.822 and 0.823 for T2 indicated the high inter-rater reliability of the measurements.

Initial bone height measured from the first thread of the implants apically to the sinus floor varied substantially (Figure 3), ranging from –0.7 mm to +8.64 mm for the mesial aspect of the implant and from 0 to 8.15 mm for the distal side. The mean values at the mesial aspect of the implant increased from 4.05 (T0) to 5.06 mm at T1 and to 5.52 at T2. At the distal side, the mean values increased from 3.58 (T0) to 4.64 mm at T1 and to 5.03 mm at T2. The differences between the values at all three measurement times were significant (Wilcoxon tests: $p < .001$).

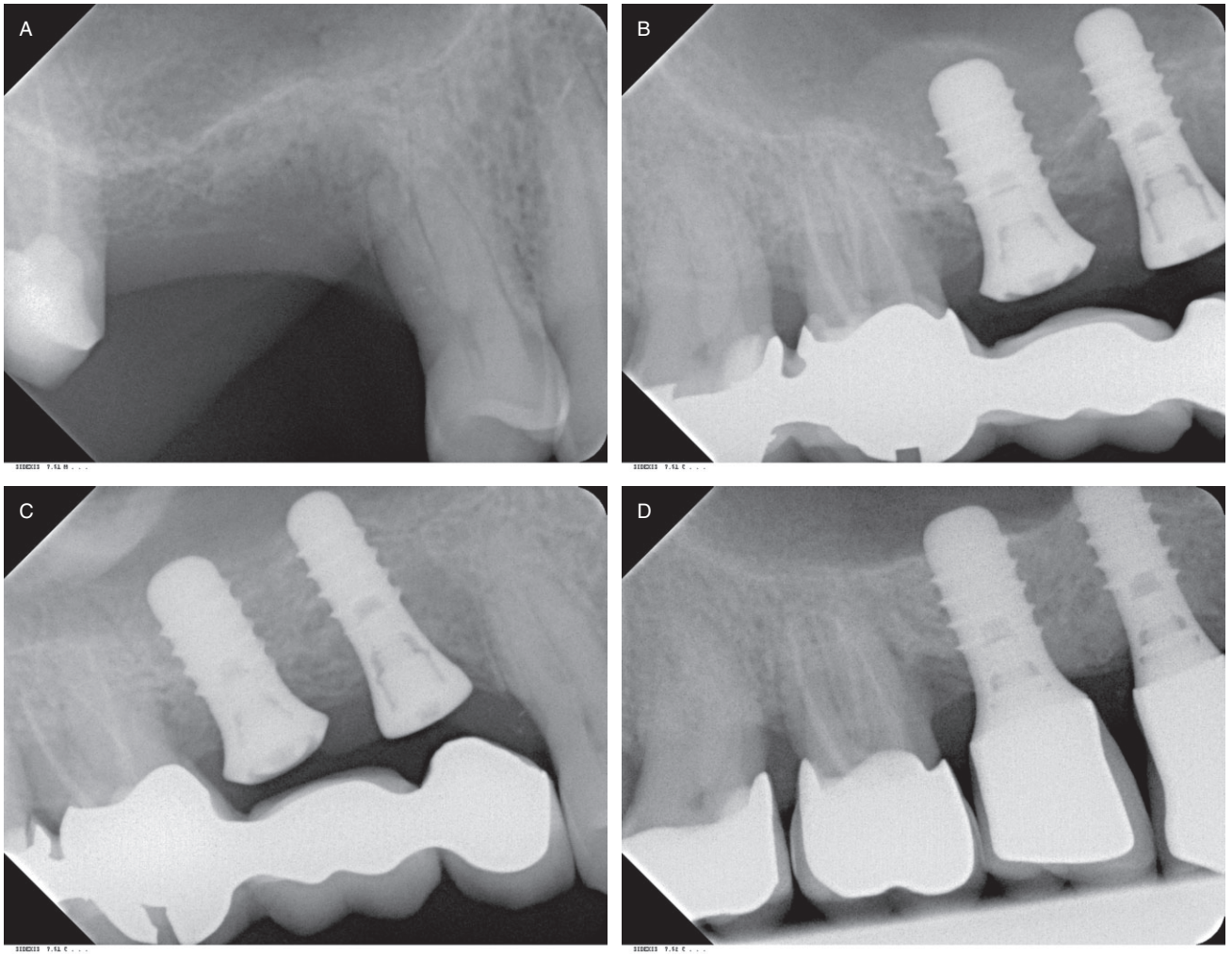

Figure 2 Preoperative radiograph in which the initial bone height of less than 5 mm in the molar region (A). Immediately after implant placement (B), the apical bone ended at the second thread. After 6 months (C) and after 18 months (D), the bone ended mesially and distally at the apical thread of the posterior implant, indicating significant bone gain.

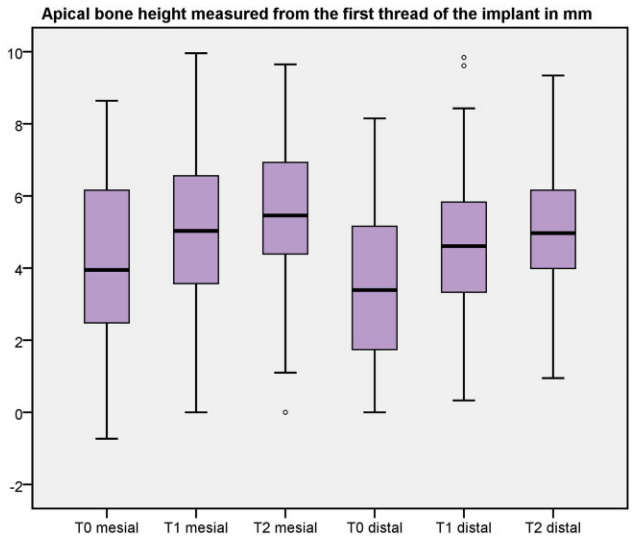

Figure 3 Variation of the apical bone height measured from the first thread of the implant in apical direction from T0 to T2 (T0: baseline; T2: second follow-up).

Calculation of differences between apical bone height at the mesial side between T0, T1, and T2 resulted in mean apical bone gain of 1.0 mm at T1 and 1.5 mm at T2. The mean bone gain between T1 and T2 was 0.5 mm. At the distal aspect of the implant, mean bone height increased by 1.7 mm from T0 to T1 and by 2.1 mm from T0 to T2. Mean bone gain between T1 and T2 was 0.40 mm for the distal side (Figure 4). The whisker and boxplots revealed substantial variation, between −1 and +5.7 mm, in apical bone gain.

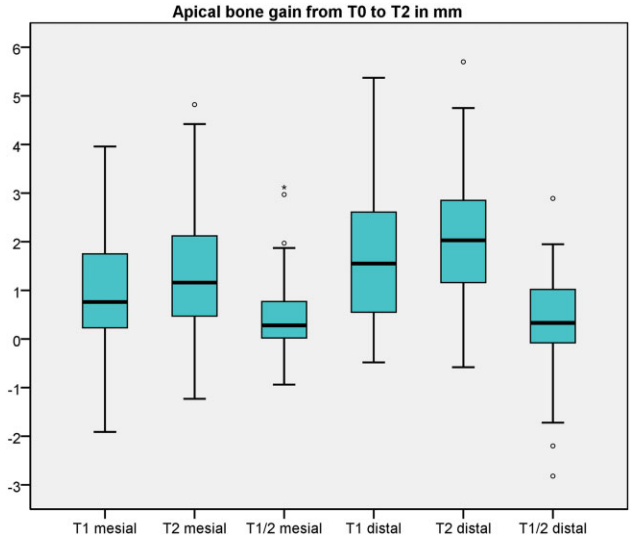

Figure 4 Changes in apical bone height from T0 to T1, T0 to T2, and T1 to T2 at the mesial and distal aspects of the implants (T0: baseline; T1: first follow-up; T2: second follow-up).

Rank correlation analysis was performed to find factors that might be associated with changes in apical bone height. Initial bone height was negatively correlated with the amount of bone gain, with Spearman rho ranging between −0.178 and −0.416 for T2 (Table 2). Negative rank correlation coefficients were also obtained for apical bone gain at T1, although significance was reached for the mesial side of the implant only ($p = .004$). Negative coefficients indicated that a low initial bone height was associated with a greater amount of bone gain. Perforation of the Schneiderian membrane during the sinus lift procedure was the second factor significantly correlated with vertical bone gain at T2. After 17 months, implants placed when the Schneiderian membrane was perforated (30 of 101 implants) had a tendency to more apical bone gain with rank correlation coefficients of 0.231 ($p = .020$) for the mesial side and 0.211 ($p = .034$) for the distal side.

DISCUSSION

Use of two-dimensional radiographs for measurement of bone height had some limitations. The margins of the sinus floor have three-dimensional extensions, whereas the radiographs display only a projection line on the film or sensor plane. As a consequence, changes in bone volume could not be evaluated, and measurements included projection errors. The linear magnification of the radiographs and the panoramic X-rays was, however, corrected by use of real implant length. Controlling the reproducibility of the measurements by comparison of 30 series of radiographs by two independent investigators unaware of the nature of the study revealed that inter-rater reliability was acceptable, with correlation coefficients ranging between 0.626 and 0.918.

Furthermore, the radiographs in this study were not standardized by use of individualized splints to enable reproducible fixation of the sensor on the remaining teeth. In cases of RDPs, no hard tissue remained to fix a splint preoperatively, after surgery, and after prosthetic restoration. For fixed dental prostheses (FDPs), the occlusal situation was significantly changed after prosthetic restoration. As a consequence, standardized fixation of the sensor was not applicable for most of the implants.

Compared with more invasive options for treatment of the atrophic posterior maxilla, the ISL has many advantages. No allografts, xenografts, or membranes are

TABLE 2 Results from Rank Correlation Analysis between Apical Bone Gain and Baseline Characteristics. Spearman Rho and Two-Sided *p* Values Are Given for Each Variable

Apical Bone Gain		Gender	Age	Perforation	Initial Bone Height Mesial	Initial Bone Height Distal
T1 mesial	Rho	.147	−.114	.129	**−.282**	−.188
	p	.144	.257	.199	**.004**	.059
T1 distal	Rho	−.104	.0126	.045	−.055	−.087
	p	.301	.209	.653	.588	.388
T2 mesial	Rho	−.066	−.089	**.231**	**−.416**	**−.212**
	p	.515	.374	**.020**	**.001**	**.033**
T2 distal	Rho	−.125	.170	**.211**	**−.199**	−.178
	p	.213	.090	**.034**	**.047**	.075

Significant rank correlations are marked in bold.

used; therefore, no secondary surgical site, with additional risk of infection and surgical trauma, is needed to harvest autogenous bone. The risk of overfilling the maxillary sinus, which may cause necrosis of the membrane, loss of the graft into the sinus, and, finally, sinusitis, is also avoided.[22,23]

The results of this study led to rejection of the null hypothesis. Significant changes in bone height were found between T0 on the one hand and T1 and T2 on the other, and between T1 and T2. Mean apical bone gain ranged between 1.0 and 2.1 mm, depending on location (mesial or distal) and time. Comparable values with a mean bone gain of 2.5 mm have been reported in a recent study using cone beam computerized tomography for measurement of changes in bone height.[24] The presence of augmentation material was not required to initiate new bone formation around the implant. However, simultaneously placed implants preserved the space between the Schneiderian membrane and the residual bone. In the present study, initial bone gain in the first 7 months was approximately twice that between 7 and 17 months. This result is in contrast with a previous study in which BioOss and autologous bone were used as graft material in combination with a transalveolar sinus lift.[12] In that study, the initial gain in bone height had decreased 3 and 12 months later.

The amount of bone gain varied substantially, leading to the assumption that individual bone gain, in mm, cannot be predicted. Implants placed in bone heights of approximately 8 mm, with only a minimal apical dislocation of the Schneiderian membrane, cannot, however, be associated with extreme values of bone gain, because the length of 83 of 101 implants was 10 mm. A study using a lateral window approach for the sinus lift procedure without graft materials revealed marked bone formation around long implants when the residual bone height below the sinus was small.[25]

All implants in the test group were anchored bicortically, resulting in acceptable primary stability. This is in accordance with a previous study by Ellegaard and colleagues[26] who achieved primary stability even for 3 mm vertical bone height. Rosen and colleagues[5] reported comparable survival of at least 96% for implants in the grafted maxilla when pretreatment bone height was 5 mm or more, but survival dropped to 85.7% when bone height was 4 mm or less. Bruschi and colleagues[14] reported results for 499 single-stage implants placed in a residual bone height of 5 to 7 mm without using membranes or grafts; success was 97.5% after 2 to 5 years of loading. Survival and success could not be calculated for this sample, because implants failing within the first 18 months were not included, owing to missing radiographs from T2 (exclusion criterion). Results from previous studies, however, are indicative of high initial success, approximately 95%, for implants placed in combination with ISL without graft.[21,27] Because additional bone gain was observed between T1 and T2, longer healing periods might be an option in cases of extremely low initial bone heights.

The most commonly described intraoperative complication of sinus floor elevation is perforation of the Schneiderian membrane,[28] which sometimes results in abandoning of the sinus lift procedure.[19] A problem of the described sinus lift technique is that membrane perforation cannot be repaired. In this study, the size of

the perforations occurring during careful displacement of the sinus membrane can be assumed to be small compared with impairments during the Caldwell–Luc approach. In this study, implant treatment was completed at all sites in which membrane perforation was detected, because in cases of minor perforation, the membrane might fold on itself during elevation. The incidence of perforation in this study is consistent with that in other published reports on sinus elevation.[29,30] Our results revealed that perforation during the ISL procedure was not a risk factor for implant survival. Small positive correlation coefficients revealed a slight tendency to more bone gain in these cases. However, this effect was only significant at T2 (see Table 2). Several clinical studies likewise reported no complications for implants penetrating the maxillary sinus or the nasal cavity.[31–33]

This article reports results obtained after a mean period of 7 and 17 months. Because of the substantial interindividual variation in initial bone height and in bone gain, conclusions must be drawn with caution.

CONCLUSIONS

1 The minimally invasive sinus lift technique without graft can be recommended if primary stability of the implant was achieved.

2 Individual amounts of bone gain cannot be predicted because of the substantial variation.

3 A small initial bone height was associated with a greater amount of bone gain.

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