Implants in the Posterior Maxilla: A Comparative Clinical and Radiologic Study

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Purpose: *The aim of this study was to evaluate implants placed according to several methods of sinus floor augmentation.* **Materials and Methods:** *Forty-eight patients (median age of 62 years, range 23 to 89) had been treated at least 3 years prior to examination with screw-type implants in the posterior maxilla. Depending on the vertical dimension of the residual bone, 1 of 3 surgical procedures had been performed: sinus lift by lateral antrostomy (SL) in 13 patients; osteotome technique (OT) in 18 patients; standard implantation in 17 patients (control). In each patient 1 implant was randomly chosen for analysis (48 implants with a mean observation time of 4.6 ± 1.4 years). Examination included probing pocket depth (PPD) measurement and radiographic examination. Radiographs were digitized to assess the marginal bone level. Differences between the groups were tested using analysis of variance, the Student t test and the Kruskal-Wallis test.* **Results:** *Mean PPD was 3.0 mm for the SL, 3.1 mm for OT, and 3.1 mm for control. The mean radiographic bone level was 1.53 mm for SL, 2.40 mm for OT, and 1.96 mm for control. No statistically significant differences were found between the groups for either of these parameters.* **Discussion and Conclusion:** *Clinical examinations as well as radiographically stable bone levels indicated similar biomechanical conditions for prosthetic restorations when applying the 3 surgical procedures tested.* Int J Oral Maxillofac Implants 2005;20:231–237

Key words: *dental implants, maxilla, maxillary sinus, osteotome technique, radiography, sinus floor elevation*

The posterior maxilla often presents specific problems for the placement of dental implants. The generally poor bone quality frequently encountered in this region in conjunction with inadequate bone volume related to both the size of the maxillary sinus and resorption of the alveolar ridge have rendered long-term success rates for implants less favorable here than in other regions of the mouth.[1–4] During the past 25 years, surgical procedures have been developed with the aim of increasing the local bone volume, thus enabling the placement of implants or allowing the placement of implants of more than 8 mm in length.[5]

In situations where the lack of bone volume is related to an enlarged maxillary sinus, elevation of the sinus floor has been advocated to permit implant placement. Among the variety of techniques that have been described, the 3 that are the most widely used are *(1)* the 2-step antrostomy (lateral approach),[6,7] *(2)* the 1-step antrostomy (lateral approach),[8,9] and *(3)* the osteotome technique (crestal approach).[10–12]

The 2-step antrostomy is the treatment of choice when the residual ridge bone height is less than 4 mm.[13] As part of this approach, the implants are usually placed after a healing period of 6 to 18 months

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following sinus floor elevation.[13–15] The 1-step antrostomy is applied when the ridge bone height ranges from 4 to 6 mm. In this situation, implant placement is performed simultaneously with sinus floor elevation.[7,13–16] When the ridge bone height is more than 6 mm, the osteotome technique can be performed. In that case, implant placement is usually carried out simultaneously with elevation of the sinus floor.[10,11,14]

The most commonly utilized method for sinus augmentation is the antrostomy technique, originally presented in 1977[14] and subsequently published in 1980.[17] Access to the sinus was initially achieved through the crest of the ridge.[14] After modifications of the surgical procedure, access was accomplished through the lateral wall of the maxilla.[6]

With respect to the grafting procedure, several grafting materials have successfully been used for elevating and stabilizing the sinus membrane: autogenous bone,[16–19] allografts,[8] xenografts,[20–22] and combinations of these materials.[7,14] Sinus floor elevation by lateral antrostomy has provided good implant survival rates, as reported in several studies.[12,23–25] However, it is a demanding surgical procedure and is quite invasive. The 1-step antrostomy, in which implants are placed during the same surgical visit as elevation of the sinus floor is performed, is similar to the 2-step technique with regard to advantages and disadvantages. The most important difference is that less time elapses before initiation of prosthetic therapy.

The osteotome technique, first described in 1994, has the primary advantage of being less invasive.[10] The narrower range of indications may be seen as a key disadvantage. As with lateral antrostomy, several grafting materials have successfully been used in conjunction with this technique: autogenous bone, allografts, xenografts, and combinations of these materials.[26,27] High implant survival rates have been reported by several authors.[27,28]

The requirements regarding surgical interventions, invasiveness of the procedures, and healing times are very different among the 3 techniques described. In principle, of the various techniques, which lead to the same therapeutic results, the least invasive, the easiest to perform, and the one providing the desired results most quickly should routinely be applied.

To date, no study has been conducted comparing the 1-step antrostomy, the 2-step antrostomy, and the osteotome technique with regard to the success rates of conventionally placed implants at sites where these techniques have been used. Furthermore, no data have been published comparing implants placed in combination with the lateral antrostomy to implants placed with the osteotome technique and/or implants placed in nonaugmented bone.

The aim of this study was to evaluate implants placed in combination with different methods of sinus floor augmentation and to compare the results with implants placed under standard conditions.

MATERIALS AND METHODS

Forty-eight patients who had received implant therapy in the posterior maxilla were included in this retrospective study. The 23 women and 25 men had a median age of 62 years (range 23 to 89 years). All patients had been treated at least 3 years prior to the examination with 1 or more implants in the posterior maxilla in the molar or premolar regions.

Depending on the radiographically determined vertical dimension of the residual bone between the alveolar crest and the maxillary sinus floor, the implants had been placed following 1 of 3 specified surgical procedures:

- Sinus lift by lateral antrostomy (1- or 2-step procedure)[7,8,14,16–22]: Applied in situations where the vertical dimension of the residual bone was 6 mm or less. The area of elevation of the maxillary sinus was filled with deproteinized bovine bone mineral as a grafting material (Bio-Oss, Spongiosa Block; Geistlich, Wolhusen, Switzerland), and the access window was covered with a bioresorbable collagen membrane (Bio-Gide; Geistlich). Implants were placed at the time of sinus floor elevation when performing the 1-step technique, whereas implants were placed following a healing time of 7.5 to 10 months following sinus floor augmentation when the 2-step procedure was used.
- Osteotome technique[10,26,27]: Performed in situations where the vertical dimension of the residual bone was between 6 and 8 mm. Again, the grafting material used was deproteinized bovine bone mineral (Bio-Oss Spongiosa Granulat).
- Standard implantation procedure: Executed in situations where the vertical dimension of the residual bone was more than 8 mm.

The implants evaluated in this study were either Brånemark System implants (Nobel Biocare, Göteburg, Sweden) or 3i implants (Implant Innovations, Palm Beach Gardens, FL). All had a turned (machined) endosseous surface. Thirty-nine were regular platform (RP) and 9 were wide platform (WP).

Clinical and radiographic examinations of all 134 implants were performed 36 to 116 months following implant placement (Table 1). In patients with

Table 1 Description of All Placed Implants

Group/ patient no.	Gender	Age	Implant location	Implant size (diameter × length)	Loading time (mo?)	Observation time (mo?)	Implants not used for statistical analysis*
Control							
2	M	74	14(26)	3.75 × 13	84	93	12(24): 3.75 × 15, C; 13(25): 3.75 × 15, C
4	F	61	4(15)	3.75 × 10	36	45	14(26): 4 × 8.5, C
5	F	69	5(14)	3.75 × 15	49	57	4(15): 4 × 10, C; 12(24): 3.75 × 15, C; 13(25): 3.75 × 10, C
11	M	54	5(14)	4.00 × 13	41	49	
14	M	63	13(25)	3.75 × 10	55	62	5(14): 3.75 × 13, C; 4(15): 3.75 × 13, C; 12(24): 3.75 × 13, C
18	M	71	14(26)	3.75 × 13	59	71	5(14): 3.75 × 15, C; 4(15): 3.75 × 15, C; 12(24): 3.75 × 10, C; 13(25): 3.75 × 13, C
19	M	60	13(25)	4.00 × 13	39	47	
22	M	50	5(14)	3.75 × 15	45	64	12(24): 3.75 × 15, C; 13(25): 3.75 × 15, C
23	F	62	5(14)	3.75 × 15	43	47	14(26): 3.75 × 13, C; 15(27): 3.75 × 13, C
24	F	77	4(15)	3.75 × 13	59	69	3(16): 6 × 10, C; 12(24): 3.75 × 13, C; 13(25): 3.75 × 11.5, C; 14(26): 5 × 10, O
25	F	76	13(25)	3.75 × 13	108	116	12(24): 3.75 × 15, C
26	F	66	5(14)	4.00 × 13	33	44	14(26): 4 × 10, C
28	M	58	4(15)	3.75 × 10	34	43	5(14): 3.75 × 15, C; 3(16): 3.75 × 8.5, C
29	M	42	12(24)	3.75 × 10	45	52	
34	M	77	12(24)	3.75 × 15	62	70	13(25): 4 × 15, S; 14(26): 4 × 15, S
35	M	42	5(14)	3.75 × 15	45	53	4(15): 4 × 11.5, C; 3(16): 5 × 10, O
43	M	63	3(16)	5.50 × 10	35	47	
Sinus lift							
1†	M	68	4(15)	4.00 × 15	36	47	5(14): 3.75 × 15, S; 3(16): 3.75 × 15, C
6†	F	72	3(16)	5.50 × 13	21	44	4(15): 5.5 × 13, S; 13(25): 5 × 13, S; 14(26): 5 × 13, S
12‡	M	83	12(24)	3.75 × 13	45	62	5(14): 3.75 × 15, C; 4(15): 3.75 × 13, O; 13(25): 3.75 × 13, S
16†	F	58	5(14)	4.00 × 10	30	38	3(16): 5 × 13, S; 2(17): 5 × 11.5, S
17†	F	60	13(25)	5.00 × 13	28	37	14(26): 5 × 13, S
20‡	F	54	4(15)	3.75 × 15	31	49	5(14): 3.75 × 13, S; 3(16): 5 × 11.5, S; 12(24): 3.75 × 13, S; 13(25): 4 × 13, S; 14(26): 5 × 13, S
33†	M	55	2(17)	4.00 × 10	44	52	4(15): 4 × 15, S; 3(16): 5 × 11.5, S; 12(24): 3.75 × 13, S; 13(25): 4 × 10, S
36‡	M	60	2(17)	5.00 × 11.5	31	38	3(16): 5 × 11.5, S
40‡	M	57	4(15)	4.00 × 10	26	38	3(16): 5 × 10, S; 13(25): 4 × 11.5, S; 14(26): 5 × 11.5, S
41†	F	78	12(24)	5.00 × 10	26	37	3(16): 3.75 × 10, O
44†	M	69	4(15)	3.75 × 13	26	46	3(16): 5 × 13, S; 13(25): 4 × 10, S; 14(26): 5 × 10, S
46‡	F	56	13(25)	4.00 × 13	33	43	5(14): 3.75 × 11.5, S; 4(15): 3.75 × 13, S; 3(16): 5 × 13, S; 12(24): 4 × 13, S; 14(26): 5 × 10, S
47†	M	23	12(24)	4.00 × 13	27	38	12(24): 4 × 13, S
Osteotome							
3	M	68	13(25)	3.75 × 11.5	37	50	14(26): 3.75 × 11.5, O
7	F	78	12(24)	4.00 × 10	23	43	5(14): 3.75 × 15, C; 4(15): 3.75 × 13, C; 3(16): 4 × 10, O; 13(25): 4 × 10, O
8	M	75	15(27)	6.00 × 10	45	53	
9	M	81	5(14)	3.75 × 10	67	78	
10	F	53	13(25)	3.75 × 11.5	45	52	12(24): 3.75 × 13, C; 14(26): 4 × 10, O
13	F	47	14(26)	3.75 × 10	63	72	5(14): 3.75 × 10, O; 4(15): 3.75 × 10, O; 12(24): 3.75 × 10, O
15	F	60	3(16)	4.00 × 15	38	54	
21	M	89	3(16)	3.75 × 10	9	76	4(15): 3.75 × 13, O; 2(17): 3.75 × 10, O; 12(24): 3.75 × 10, O; 13(25): 3.75 × 13, O; 14(26): 3.75 × 10, O
27	F	70	5(14)	3.75 × 13	48	61	4(15): 5 × 10, O
30	F	52	13(25)	3.75 × 13	71	91	4(15): 3.75 × 13, O; 3(16): 3.75 × 13, O; 14(26): 3.75 × 13, O
31	F	65	3(16)	4.00 × 10	33	41	4(15): 5 × 10, O
32	F	35	13(25)	3.75 × 10	43	51	
37	M	43	12(24)	3.75 × 10	33	40	
38	M	61	13(25)	3.75 × 11.5	28	42	
39	F	66	3(16)	5.00 × 10	33	41	4(15): 4 × 13, O
42	M	65	3(16)	5.00 × 10	32	40	14(26): 5 × 10, O
45	F	60	13(25)	5.00 × 10	39	47	
48	F	67	5(14)	3.75 × 13	80	93	4(15): 3.75 × 10, O

*Location, diameter × length, group; †2 step sinus lift; ‡1 step sinus lift.
C = control; S = sinus lift; O = osteotome.
For each patient, 1 implant was randomly selected and used for statistical analysis. Tooth numbers given are in universal (FDI).

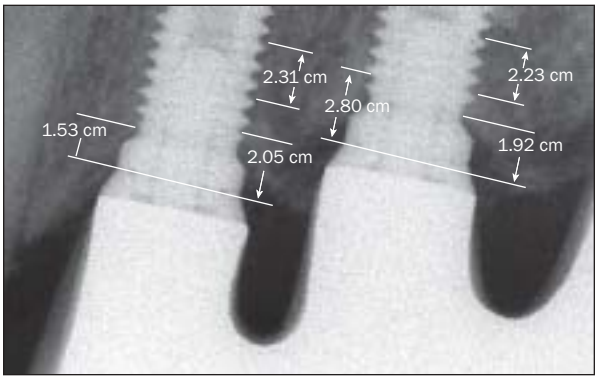

Fig 1 Assessment of the distance from the shoulder to the first bone-to-implant contact on digitized radiographs (original magnification ×12.5). The known distance between 3 implant threads was used for calibration and determination of the exact magnification of the images.

more than 1 implant, 1 implant was randomly chosen for further analysis by assigning the implants in question to the faces of a die before casting it.

During the clinical examination, the state of systemic health of the patients was assessed by obtaining a thorough patient history. Clinical parameters included assessment of the patient's level of oral hygiene (modified Plaque Index [mPI][29]), inflammation of the peri-implant tissues (bleeding on probing [BOP]), probing pocket depth (PPD), and vertical extent of the attached mucosa at the buccal aspect of the implants. In addition, the frequency of supramucosally located crown margins was recorded. Only at sites where the mucosal margin was located apically to the crown-abutment junction was its level measured relative to this junction.

Radiographs were taken using the long-cone paralleling technique with the central beam on the alveolar crest.[30] This technique allows standardization of the exposure geometry. The images were digitalized and the marginal bone level (ie, the distance from the level of the abutment-implant junction to the first bone-to-implant contact) was measured using 10× to 15× magnification (Fig 1). The known distance between 3 implant threads was used for purposes of calibration and determination of the exact magnification of the images. All measurements were performed by 2 examiners. In cases of disagreement, the values were rechecked and discussed until an agreement was reached.

Mean values and standard deviations were calculated for all parameters. Differences between the groups were tested using analysis of variance (ANOVA) and the Student *t* test for normally distributed values and the Kruskal-Wallis test for the remainder. Statistical significance was set at $\alpha = 0.05$.

RESULTS

The sinus lift group comprised 13 patients (median age 60, range 23 to 83) with 13 implants (9 RP, 4 WP); the osteotome group comprised 18 patients (median age 65, range 35 to 89) with 18 implants (14 RP, 4 WP); and the control group comprised 17 patients (median age 63, range 42 to 77) with 17 implants (16 RP, 1 WP) in the control group. There were no statistically significant differences between the 3 groups in regard to the patients' age (ANOVA).

The mean observation periods ± SD after implant placement were recorded: 3.7 ± 0.6 years for the sinus lift group, 4.7 ± 1.4 years for the osteotome group, and 5.0 ± 1.6 years for the control group. The observation period of the sinus lift group was significantly shorter than in the other groups ($P = .0212$; ANOVA).

The results of clinical measurements of mPI, BOP, PPD, recession, attached mucosa, and radiographic height of the marginal bone are presented in Table 2.

With respect to a supramucosal location of the crown-abutment junctions, 22% of the implants in the sinus lift group (mean 0.1 mm, range 0 mm to 0.5 mm), 10% in the osteotome group (mean 0.1 mm, range 0 to 1.0 mm), and 10% in the control group (mean 0.2 mm, range 0 to 3.0 mm) exhibited a supramucosal margin (Table 2). There were no statistically significant differences between the groups regarding the mean values (Kruskal-Wallis test).

When measuring the width of keratinized mucosa buccal to the implants, similar mean values (with large SDs) were recorded for the 3 groups: 3.2 ± 2.4 mm for the sinus lift group, 3.3 ± 1.6 mm for the osteotome group, and 3.3 ± 1.7 mm for the control group (Table 2). No statistically significant differences were noted between the groups.

The radiographically determined marginal bone level, defined as the distance between the level of the abutment-implant junction and the first bone-to-implant contact, amounted to mean values of 1.53 mm for the sinus lift group, 2.40 mm for the osteotome group, and 1.96 mm for the control group (Table 2 and Fig 2). No statistically significant differences were found between the groups.

The mean radiographic marginal bone levels were examined for each type of implant (RP and WP). The mean radiographic marginal bone level was 2.10 ± 2.20 mm for RP and 1.63 ± 0.68 mm for WP. No statistically significant differences were found between the 2 types (unpaired Student *t* test).

Table 2 Clinical Parameters and Radiographic Marginal Bone Level (Means ± SD)

	Group			Statistical test	Significance
	Sinus lift	Osteotome	Control		
Modified Plaque Index	0.3 ± 0.4	0.3 ± 0.5	0.3 ± 0.5	Kruskal-Wallis	No
Bleeding on probing	0.2 ± 0.2	0.5 ± 0.3	0.4 ± 0.3	Kruskal-Wallis	No
Probing pocket depth (mm)	3.0 ± 1.0	3.1 ± 0.9	3.1 ± 0.5	ANOVA	No
Recession (mm)	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.5	Kruskal-Wallis	No
Attached mucosa (mm)	3.2 ± 2.4	3.3 ± 1.6	3.3 ± 1.7	ANOVA	No
Radiographic marginal bone level (mm)	1.53 ± 0.69	2.40 ± 3.03	1.96 ± 1.18	ANOVA	No

DISCUSSION

Comparison of the peri-implant marginal bone levels revealed no difference between implants in grafted sinuses, implants placed using the osteotome technique, and implants placed under standard conditions into pristine bone. This finding would appear to indicate that changes in the level of the marginal bone are independent of the mode of apical anchorage of the implants, ie, anchored in augmented bone by a sinus lift or an osteotome technique or anchored in nonaugmented bone.

In addition, no statistically significant differences were detected between the 3 groups in regard to peri-implant probing depths or the level of the mucosal margins.

Although no differences were found among the groups, the level of the marginal bone was on average 1.5 to 2.4 mm apical to the abutment-implant junction. These values are in accordance with marginal bone levels observed in studies documenting the longitudinal outcomes of implants placed into augmented sinuses.[9,31] These values, however, are somewhat higher than the ones reported in longitudinal studies of implants placed under standard conditions.[32,33]

Interestingly, in the present study the smallest mean loss of marginal bone was found in the sinus lift group (1.5 mm) and the highest in the osteotome group (2.4 mm). The control group was between the two, with a mean value of 2.0 mm. The high mean value and SD in the osteotome group were mainly because of 1 patient, who had lost 14 mm of marginal bone. In spite of the bone loss, this implant was still stable and functioning. Taking this into consideration, the results of the remaining implants in the osteotome group were very similar to the implants of the 2 other groups.

Based on the results of this study, it may be assumed that the apical anchorage provided by augmented bone gained through a sinus lift or an osteotome technique is biomechanically similar to that found for implants in nonaugmented bone in the area of the maxillary sinus. Thus, it may be summarized that following successful bone augmentation procedures in the sinus area, implants placed under such conditions may be considered from a biomechanical point of view, and also from a prosthetic point of view, equal to implants placed under standard conditions in this patient population.

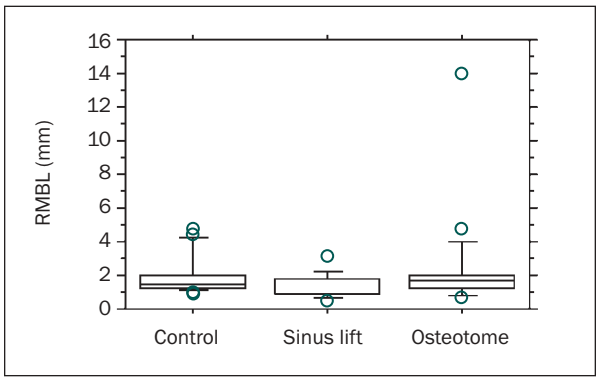

Fig 2 Radiographic marginal bone level for the 3 groups.

Several studies have longitudinally followed the changes in marginal bone levels at implants partly anchored in augmented sinuses.[31,34] However, none have included test implants with sinuses augmented by the lateral antrostomy technique or the osteotome technique using a crestal approach and compared the results with a control group of implants for which no bone augmentation was performed.

The somewhat higher degree of remodeling of marginal bone in the present study compared to data from longitudinal studies on implants in the posterior maxilla may be related to the relatively high level of plaque and associated frequency of BOP seen in this patient population. Previous studies have demonstrated that plaque and inflammation of the peri-implant tissues are associated with loss of marginal bone.[35,36]

Although no differences in the mean values regarding mucosal recession at the implants were found, the range of recession was highest in the sinus lift group. The reasons for this are presently not clear.

No association was found between the size of the implant platform and the marginal bone level in the present study. Some investigators have reported higher failure rates and more marginal bone loss with WP implants.[37,38] Although the groups were not equal in size (39 RP, 9 WP), which makes it difficult to make a sound statement, it was found that the 2 types of implants performed equally well in the present study.

CONCLUSION

The data from this study indicate that the marginal bone level and the conditions of the soft tissues at implants partly anchored in augmented sinuses or exclusively anchored in nonaugmented bone were similar after an observation period of 3 years in this patient population. Hence, the implant anchorage provided by the bone was capable of withstanding prosthetic loading, regardless of whether it was derived from nonaugmented or partially augmented bone and regardless of the clinical procedure chosen for augmentation.

The biomechanical stability and thus the conditions for prosthetic restoration could be assumed to be equal in the 3 clinical situations tested.

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