
Two-Stage Maxillary Sinus Reconstruction with Endosseous Implants: A Prospective Study

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The aim of this prospective study was to evaluate the results of 2-stage maxillary sinus reconstruction using titanium implants placed into iliac corticocancellous bone blocks previously grafted to the floor of sinuses. Fifty consecutive patients received 314 Brånemark implants of varying lengths; 202 implants were placed in the grafted bone and 112 were placed in the adjacent anterior maxillary alveolar process, which had received buccal onlay bone grafts. Follow-up time was 9 to 48 months after implant placement, which was accomplished 5 months after bone grafting. Eighty-four percent of the implants were integrated into the grafted sinuses and 75% were integrated into the anterior graft. Six patients (12%) lost implants in strategic positions, leading to secondary implant placement prior to fabrication of fixed prostheses. Thirty-eight patients (76%) received fixed prostheses. Only 5 individuals (10%) attained permanent implant-anchored overdentures. One patient lost all implants. The total implant survival rate (80.9%) and the survival rate of the fixed prostheses (100%) compare favorably with other reports.

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Key words: bone grafting, endosseous implants, maxillary sinus reconstruction, oral rehabilitation, two-stage

The rehabilitation of totally or partially edentulous jaws with endosseous implants is now a routine procedure performed all over the world. The results are quite predictable and encouraging.^{1,2} However, the severely resorbed maxilla (Class V and VI according to Cawood and Howell³) is still a major challenge and is difficult to treat. Often the maxillary sinuses and nasal cavity present anatomical limitations to implant placement, because of the insufficient volume of surrounding bone. Consequently, there has been increasing interest in reconstructing the antral

floor to optimize the bone volume of the alveolar process.

In 1980, Boyne and James⁴ presented a technique in which particulated cancellous bone, marrow, and blade implants were placed during separate procedures. One-stage reconstruction using autogeneic bone grafts exclusively, usually harvested from the iliac crest, in combination with endosseous implants, has been presented by some investigators.⁵⁻⁷ Jensen et al⁸ described a modified 2-stage technique, in which 5 patients first received iliac bone grafts in the maxillary sinuses; placement of implants in the grafted regions was performed in a second operation. A similar strategy was applied by Lundgren et al.⁹ Sutter et al¹⁰ published patient material in which both 1- and 2-stage techniques were used.

Recently, the authors presented a retrospective evaluation of 49 patients rehabilitated in 1-stage sinus reconstruction.¹¹ The results corroborated other reports⁵⁻¹³ that showed a survival rate exceeding 80% of the placed endosseous implants. The aim of the present study was to prospectively evaluate the survival of implants and prostheses that were placed using a 2-stage reconstructive procedure.

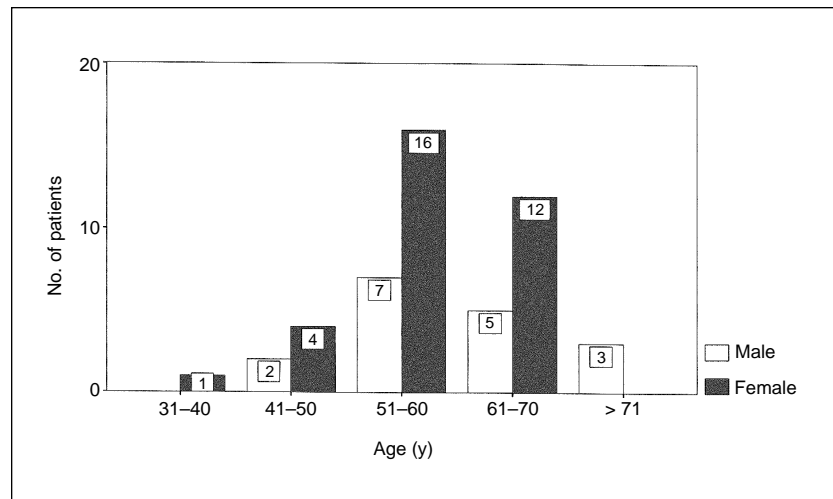
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Fig 1 Age and sex distribution of treated patients.



Materials and Methods

Patient Selection. Fifty patients, 17 males and 33 females, with a mean age of 59 years (range, 31 to 83 years) were consecutively included in the study (Fig 1). Clinical examination and preoperative radiographic investigations, which in most cases included computerized topography (CT), revealed a severe lack of bone and large pneumatization of the maxillary sinuses either unilaterally or bilaterally (Class V or VI³ in the posterior maxilla). In the area anterior to the antrums, 35 patients were classified as Class V or VI; the remaining 15 patients had 2 to 7 remaining anterior teeth. The latter patients consequently had no bone grafted to this area. All implants placed in the anterior alveolar process were located in grafted bone. All patients displayed a normal or acceptable sagittal maxillomandibular relationship.

Surgical Technique. The surgical technique used has been described earlier¹⁰ (Figs 2 and 3). Surgery was performed under general anesthesia and included a palatally pedicled mucoperiosteal flap raised to expose the lateral wall of the maxilla. A window approximately 10 × 20 mm was created to give access to the floor of the antral cavity. The antral mucosa was reflected superiorly and efforts were made to maintain mucosal integrity. Corticocancellous bone blocks, harvested from the anterior iliac crest, were fixed to the sinus floor with titanium fracture screws (length, 7 to 15 mm; diameter, 2 mm), with the cortical layer facing superiorly to secure a 2-point compact bone anchorage (Figs 2a and 3b). Great care was taken to secure initial stability of the graft. Stability of the bone block was verified by

pressing firmly with a surgical instrument. Usually, no further fixation was necessary. Cancellous bone chips were used to fill spaces between the sinus floor and the bone graft. Patients were given benzylpenicillin (3 g) and metronidazole (0.5 g) intravenously as a preventive measure.

After approximately 5 months (mean, 5.3 months; range, 4 to 12 months), the fracture screws were removed (Fig 2b) under local anesthesia, and endosseous implants were placed according to the method described by Adell et al¹⁴ (Figs 2c and 3c). Occlusal surgical guides were often used to optimize the direction and position of the implants to facilitate prosthodontic rehabilitation. The strategy was similar to that presented by Raghoobar et al.⁷

After both operations, the wound was closed with a continuous, absorbable 4-0 suture (Monocryl, Ethicon, Norderstedt, Germany). Postoperatively, the patients took antibiotic medication for 1 week.

Postoperative Management. Use of the relined original conventional dentures was allowed approximately 3 to 4 weeks after surgery. Major adjustments were often needed, as surgery often involved recontouring of the anterior alveolar crest. The abutment operation was performed 6 to 10 months (mean 6.9 months) after surgery. Healing abutments were then connected for 2 to 3 weeks. The prosthodontic treatment was carried out according to the standard procedure described by Zarb and Jansson.¹⁵

Integration of the implants was evaluated by repeated clinical and radiographic examinations according to a predetermined strategy. Clinical postoperative examinations were undertaken regularly in the interval prior to the abutment operation,

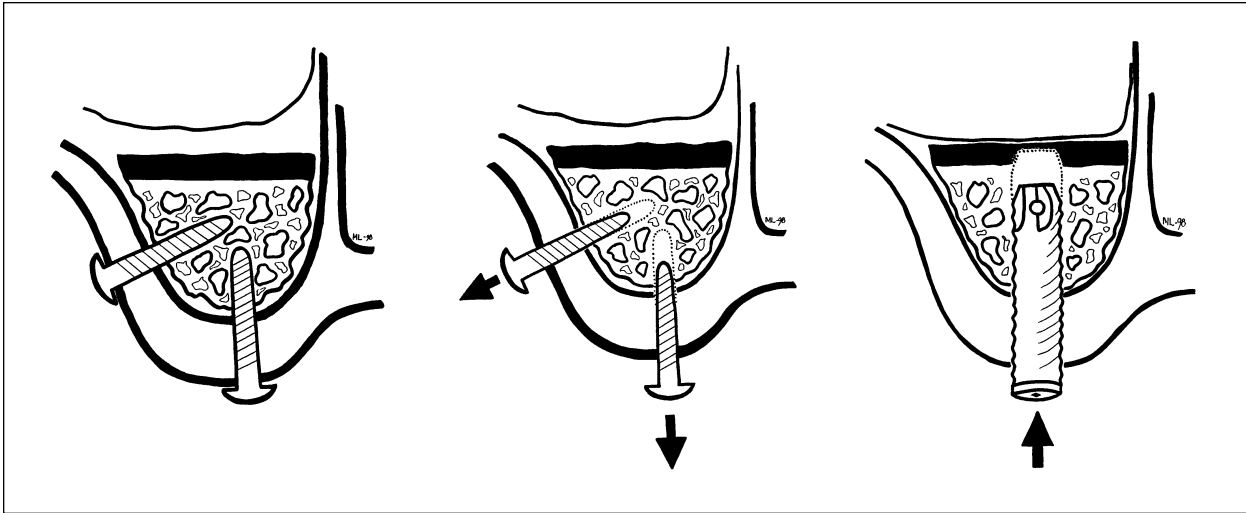
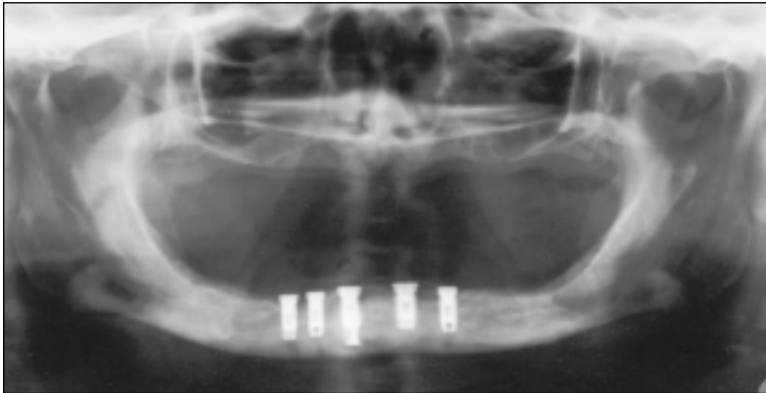


Fig 2 Drawing of the 2-stage surgical method. (Left) A bone block is placed and fixed with fracture screws. (Center) The fracture screws are removed. (Right) Implants are placed into sinus inlay bone graft.



Figs 3a to 3d Orthopantomograms illustrating the surgical strategy.

Fig 3a Preoperative.

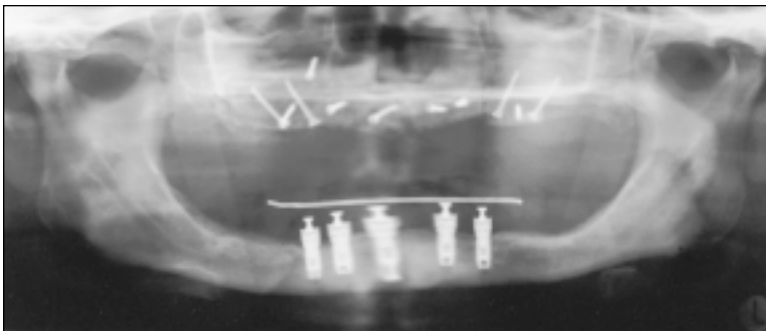


Fig 3b After bone grafting.

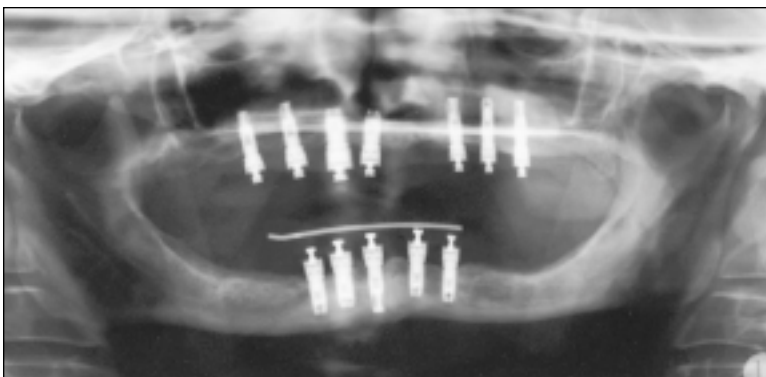
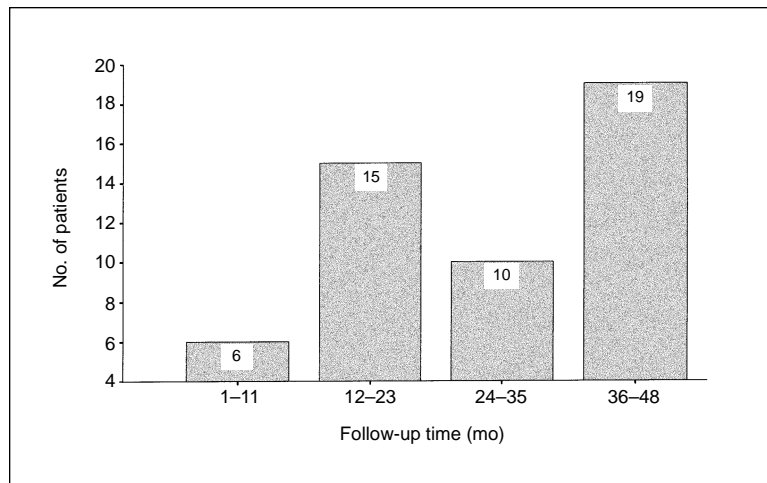


Fig 3c After implant placement.

Fig 4 Follow-up periods for the 50 patients investigated.



as well as at 2, 4, 6, and 12 months after completed prosthodontic treatment; thereafter, patients were examined annually. The duration of follow-up for all patients is reported in Fig 4. When complications such as postoperative infections or wound dehiscence occurred, additional evaluation and treatment sessions were required. All examinations included assessment of the gingival status, dental hygiene, and functional relationships. Only completely stable implants were considered successful, ie, no mobility was allowed (nonstable implants were removed). Radiographic examinations (Fig 3) were performed before implant placement, after attachment surgery, and after 6 months, 1 year, 2 years, and then every second year.

Questionnaire. All patients were asked to answer questions concerning their oral and general health, body weight and height, present or past medications taken, and actual or cured malignancies. Female participants were asked some additional questions about start and cessation of menstruation, any surgical gynecological interventions, and use of contraceptives or estrogen substitution. Smoking habits were also recorded for all patients.

Results

Most patients were healthy. Three were on medication for thyroid dysfunction and 3 were diabetic, of whom 1 used insulin injections. Two patients reported past malignancy, of whom 1 had received radiotherapy (not involving the orofacial region). Six women had undergone gynecologic surgery. Fifteen women had received estrogen substitution in the

past. Thirteen patients were nonsmokers, 18 had ceased smoking, and 19 still smoked (mean 12 cigarettes per day; mean duration 28 years). No correlation was established between an increased loss of implants and smoking habits. The patients had been edentulous in the maxilla from 0 to 45 years (mean 11 years) as a result of periodontitis (52%), caries (26%), or trauma (10%). All patients' primary goal was to obtain a fixed prosthesis. Of the 50 patients in the study, 8 reported previous unsuccessful implant placement in the maxilla without prior bone grafting. In all, 35 patients were edentulous and received bone grafts bilaterally and anteriorly, 12 patients had remaining anterior teeth and obtained only bilateral sinus grafts, and 3 individuals were grafted unilaterally in the posterior maxilla. Follow-up time varied from 9 to 48 months (mean 28 months) after implant placement.

A total of 314 Brånemark Mark II titanium implants (Nobel Biocare, Göteborg, Sweden) were placed; they varied in length from 7 to 18 mm (Table 1). Of these, 202 implants were placed in the sinus grafts and 112 in the anterior graft. Thirty-two implants (15.8%) positioned in the sinus grafts were lost, and 28 implants (25.0%) from the anteriorly grafted bone failed (Table 2). Thus, 60 of 314 implants (19.1%) failed to integrate (Tables 2 and 3).

Each implant was followed from the time of placement to the termination of this study, and the total survival time as well as the interval from placement to failure, when applicable, was recorded in months (Figs 5 and 6). Survival function, ie, survival at end, was calculated using the Cox Regression Analysis (Table 4). A statistically significant correlation

Table 1 Number and Lengths of Implants Placed

	Implants in inlay bone graft						Implants in anterior bone graft					
	7 mm	10 mm	13 mm	15 mm	18 mm	(Total)	7 mm	10 mm	13 mm	15 mm	18 mm	(Total)
Left	3	18	45	30	2	98	3	20	24	8	0	55
Right	2	18	38	46	0	104	3	22	23	9	0	57
Total	5	36	83	76	2	202	6	42	47	17	0	112

Table 2 Relationship Between Implants Lost and Placed

	Implant length (mm)					
	7	10	13	15	18	
Lost/placed implants in anterior bone graft	2/6 (33.3%)	12/42 (28.6%)	10/47 (21.3%)	4/17 (23.5%)	0/0 (0%)	28/112 (25.0%)
Lost/placed implants sinus graft	2/5 (40%)	7/36 (19.4%)	17/83 (20.5%)	5/76 (6.6%)	1/2 (50.0%)	32/202 (15.8%)
Total	4/11 (36.4%)	19/78 (24.4%)	27/130 (20.8%)	9/93 (9.7%)	1/2 (50%)	60/314 (19.1%)

Table 3 Number and Lengths of Nonintegrated Implants

	Implants in inlay bone graft						Implants in anterior bone graft					
	7 mm	10 mm	13 mm	15 mm	18 mm	(Total)	7 mm	10 mm	13 mm	15 mm	18 mm	(Total)
Left	1	3	10	2	1	17	2	6	7	2	0	17
Right	1	4	7	3	0	15	0	6	3	2	0	11
Total	2	7	17	5	1	32	2	12	10	4	0	28

between increased loss of implants and short implants, in combination with placement in the sinus inlay bone grafts, was observed (chi-square test, $P = .035$). This finding did not apply to implants placed in the anterior grafted alveolar process. It was also verified that short implants, regardless of area of placement, are exposed to a greater risk of nonintegration than longer ones (Cox Regression Analysis, $P = .0042$); this is also summarized in Table 2.

Thirty-eight patients (76%) received fixed prostheses. Six individuals (12%) obtained a temporary fixed prosthesis after the failure of 1 or more implants made permanent prosthesis fabrication impossible. The latter patients underwent additional implant placement to permit a future fixed restoration to be fabricated (Table 5). Five patients (10%) obtained a permanent overdenture since they had a

limited number of integrated implants; these patients were not willing to undergo further surgery to add to the number of implants already integrated. One patient (2%) lost all 6 implants, refused further operations, and accepted the wearing of a complete denture. All prostheses processed were assessed for survival time, and all (100%) proved to be functioning at the completion of this study (mean follow-up time, 16 months; range 0 to 34 months).

Influences on implant loss were tested for sex, age, and Body Mass Index (BMI), but no correlation was found. There were no indications that patients who lost their teeth as a result of periodontitis lost more implants than those who lost their teeth as a result of caries or trauma.

Serial pre- and postoperative intraoral and panoramic radiographs displayed no definite general-

Table 4 Implants Surviving at End of Follow-Up Period using Cox Regression Analysis

	Implant position							
	Right				Left			
	4	3	2	1	1	2	3	4
No. placed	31	43	42	42	41	44	43	22
Lost	4	5	7	9	15	8	6	6
Remaining	27	38	35	33	26	36	37	18
Survival at end (%)	87.1	88.4	83.3	78.6	63.4	81.8	86.0	75.0

310 implants were available for analysis; 4 were censored before the earliest event (6 months) in a stratum. Implant position (1 to 4) signifies the relative position of the implants, ie, 1 means the most anterior position, while 4 is the most posterior.

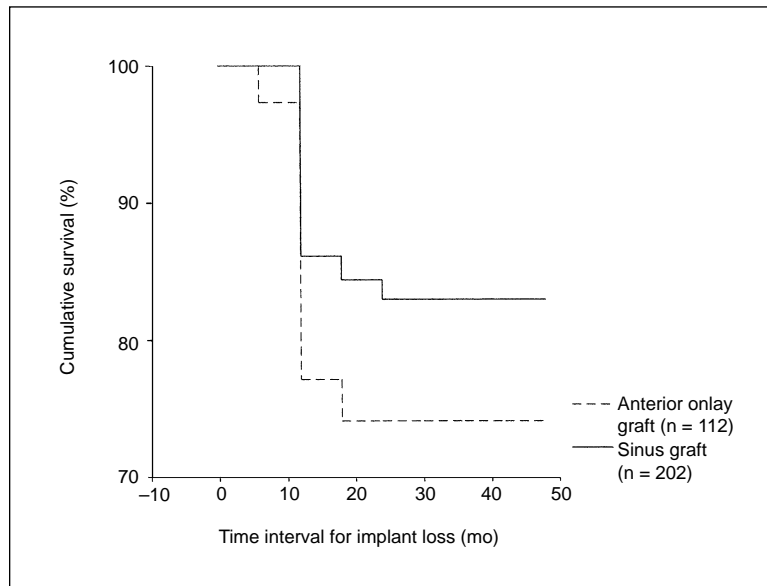
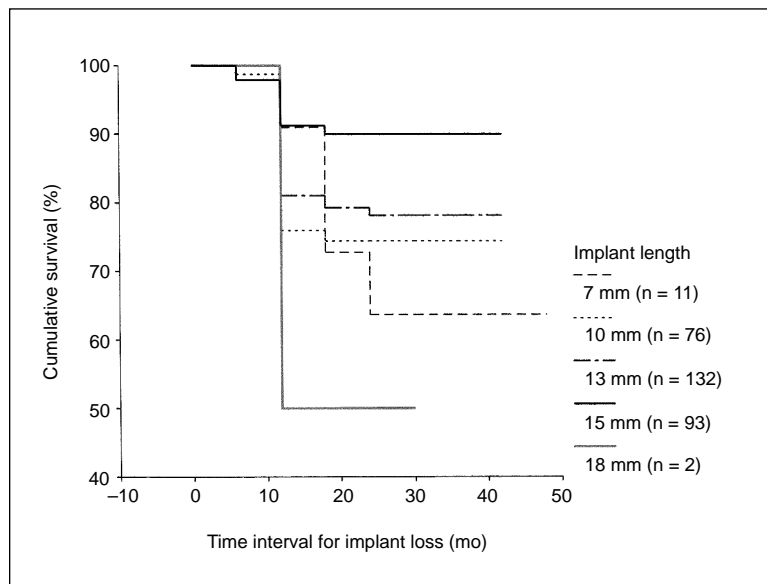
Fig 5 Plot of surviving implants in sinus bone grafts and anterior only bone grafts.**Fig 6** Plot of surviving implants correlated to implant lengths.

Table 5 Patients with Temporary Restorations and Interventions Accomplished for a Future Fixed Prosthesis

Patient no.	Implants placed		Implants lost		Relative loss (%)	Implants added
	Sinus graft	Adjacent graft	Sinus graft	Adjacent graft		
11	4	4	1	2	38	2 implants in adjacent graft
12	6	0	2	0	33	No additional implants
17	4	4	0	3	38	2 implants in adjacent graft
32	6	2	0	3	38	2 implants in adjacent graft
48	5	3	1	2	38	Not yet performed
49	2	2	0	1	25	1 implant in adjacent graft

ized loss of bone height or localized vertical or horizontal bone breakdown of the graft or the adjacent alveolar process around the implants. Because an improperly standardized technique was used and difficulties were encountered in defining identical measurement points at the superior graft margin for all time intervals, the measurement error was unacceptable and information on bone loss in relationship to uncovered implant threads was not completely reliable. Therefore, these data were omitted.

Discussion

The purpose of this report was to reflect on our experiences with sinus reconstruction performed in a 2-stage procedure. Earlier, a method was reported for placing all implants in a 1-stage procedure.⁵ Despite the additional operation and a subsequent prolonged treatment period, a 2-stage procedure was accomplished for the 50 consecutive patients reported here. The patients' anticipation of such a procedure was quite positive, and after they received specific information about the surgical strategy, all accepted the concept without hesitation.

Follow-up time ranged from 9 to 48 months following implant placement. As pointed out by several authors,^{2,12,13} most failures are believed to occur at the time of the abutment operation or earlier and during the period between the abutment connection and the time of prosthodontic treatment. Consequently, the most critical period for implant failure was covered. However, it was observed that the majority of lost implants (98.3%) were lost within a period of 18 months after implant placement. The assessment of survival time demonstrated that there is only a minor risk of losing implants after this period and before the abutment operation. There was a dramatic difference between the survival rates of the implants placed in the sinus graft (84.2%) and

those placed in the anterior grafted alveolar process (75.0%). One explanation might be that the length of the implants placed in these 2 areas differed significantly. In the sinus graft 80% (161 of 202) of the implants were 13 mm or longer, and in the anterior grafted area 60% (68 of 112) of the implants were 13 mm or longer. Naturally, the nasal cavity restricts the length of implants that can be used.

A significant correlation between increased loss of implants placed in sinus inlay bone grafts and short implant lengths was recorded. The greater number of nonintegrated short implants was not surprising. Therefore, the importance of using medium-length (10 to 15 mm) implants, when possible, at every single position in the maxilla is emphasized.

Maxillary implants in nongrafted patients are routinely loaded 6 to 8 months after placement. In this investigation, this strategy was applied to the grafted maxilla (mean, 7 months; range, 6 to 10 months). At implant placement, all bone grafts displayed absolute stability. The prepared implant sites were bleeding, indicating complete return of bone viability. This conclusion was confirmed in a histologic study.¹⁶ Additional healing time was not considered advantageous, as it needed to be balanced against the possible resorption of a nonloaded graft. The theory that implants stimulate bone preservation in the same manner that healthy teeth preserve alveolar bone should not be neglected.¹²

Thirty-eight patients received a fixed prosthesis, while 5 individuals lost so many implants (12 of 28, 43%) that it was impossible to fabricate a fixed restoration. The latter patients did not accept any further surgery for the placement of additional implants. Six patients lost 1 or 2 implants (15 of 42, 36%) in strategic positions, which made a prosthesis a questionable option. Of these, one patient accepted a temporary prosthesis and 5 accepted an additional implant placement. One individual (male, 70 years

old) lost all 6 implants and accepted the wearing of a complete denture. Thus, 38 of 50 patients wear fixed restorations and another 6 will have them fabricated following placement of additional implants. One patient lost no implants, but preferred to wear an overdenture instead of a fixed prosthesis for economic reasons. If she had accepted final treatment, 45 individuals (90%) would have had the possibility of ultimately wearing a fixed prosthesis. The survival rate of the fixed restorations (100%) compares well with other reports on patients with implants placed in nongrafted tissue.² It is important to emphasize that none of these patients would have had any possibility of reconstruction using endosseous implants without prior bone grafting.

The results from this investigation point to some very important issues. Short implants (7 mm) should be avoided in this context, as survival of longer implants is more likely. During shaping of the bone grafts, it is advisable to aim for an appropriate size of bone blocks, keeping in mind that enough bone must be grafted to accommodate both long and wide implants at the time of the second operation. Today 4.0-mm and 5.0-mm diameter implants are available. As the lack of height in the anterior maxilla is a complicating situation, these wider implants might be preferred to increase total implant surface. Again, as bone grafted in the anterior area generally increases the labiopalatal dimension more than alveolar height, wider implants could be very useful. On the other hand, clinicians should not attempt to place excessively long implants, which might penetrate the nasal cavity; this increases the risk of nasal mucosal ingrowth along the implant.

Another strategy would be to reduce the number of implants placed anteriorly and focus on placing 3 or more implants in each sinus graft. The prostheses could then be processed as fixed restorations with the anterior dental units being mostly free-standing units. This situation would be less esthetically compromising, as few abutments (which sometimes are difficult to hide) would be present anteriorly.

The authors regularly use an individual surgical guide to optimize the position and direction of implants at the time of placement. The grafted bone placed is consolidated at the site of implant placement, which implies that the 2-stage strategy has an advantage over the 1-stage procedure when it comes to placement of the implants.¹⁷ The likelihood of obtaining proper placement of the implants is far easier when graft stability is not a concern at the time of implant placement.

Conclusion

This investigation indicated that using a 2-stage strategy can make it possible for edentulous patients with severely resorbed maxillary alveolar crests to be rehabilitated with fixed prostheses. The results are predictable. In 90% of the patients a fixed restoration was possible, and the prosthesis survival rate of 100% proved to be equivalent to results reported for prosthesis survival in nongrafted maxilla.² With additional experience and knowledge, it may be possible to further improve the success of this 2-stage procedure.

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