Rehabilitation of Patients With Severely Resorbed Maxillae by Means of Implants With or Without Bone Grafts. A 1-Year Follow-up Study

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Forty-three patients with severely resorbed maxillae who had been referred for implant treatment were assigned to one of three treatment groups: bone grafting and implant placement (graft group); modified implant placement but no bone grafting (trial group); or optimized complete dentures (no-implant group). Sixteen, 20, and 7 patients, respectively, were assigned to the three groups. At the 1-year follow-up, 10% of the implants had been lost. Only a few of the failures (3/22) occurred after prosthesis placement. The cumulative success rates were 83% in the graft group and 96% in the trial group. A substantial reduction of the grafted bone, especially of the onlay grafts, occurred in many patients. During the period from prosthesis connection to the 1-year follow-up, marginal peri-implant bone loss was on average 0.5 mm. Despite the often demanding procedures involved, all but one patient in each implant group said that they would undergo the treatment again. Most patients were very satisfied with the treatment outcome and their improved masticatory ability. Those who had renounced implant treatment appeared modestly adapted to their optimized dentures, but reported retention problems and less satisfaction with mastication.
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Key words: bone resorption, bone transplant, dental implants, oral radiography, osseointegration

Treatment of edentulous patients by means of implant-supported prostheses according to the osseointegration concept has proved to be a very successful method. Success in the treatment of jaws with little to moderate resorption has led to attempts to rehabilitate jaws with more extensive bone loss. Even severely resorbed edentulous mandibles can be treated in a predictable way.[1–3] However, the results of implant treatment in the maxilla under similar conditions have not always been as satisfactory. Conventional implant procedures have thus been considered inappropriate for the treatment of severely reduced maxillary bone.[4–7]

To compensate for severe maxillary resorption, two principally different types of treatment have been proposed: *(a)* augmentation techniques, eg, bone grafting (for a review, see Tolman[8]), and *(b)* modifications of the conventional implant method, eg, a modified drilling technique or placement of implants in the maxillary tuberosity.[5,9] A variety of reconstructive procedures combining bone grafting with endosseous implants have therefore been developed.[10–12] The results available today of most of the presented methods are primarily short-term. In a recent extensive review, Tolman concluded that "detailed follow-up studies are necessary for continued advancement of bone graft techniques utilizing implants."[8p291]

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The aims of this study were to evaluate, both clinically and radiographically, the results of implant treatment in patients with severely resorbed maxillae with and without bone grafting, and to compare the use of bone grafting with other modifications of the conventional implant technique. This investigation reports the 1-year outcome with respect to implant and bone graft survival, peri-implant bone resorption, prosthodontic rehabilitation, and patient assessment of the treatment.

Materials and Methods

The patients in this study were selected from those who, during a specified time period, were referred to the Clinic of SIM-Prosthetic Dentistry, Mölndal, Sweden, for implant treatment in the maxilla. After radiographic examination, all patients who were judged to have insufficient bone for conventional implant placement were presented with three treatment options: a grafting procedure combined with implants (graft group), modified implant placement but no bone grafting (trial group), or optimized complete denture (no-implant group). Detailed information about the various treatment possibilities and risks was given to all patients, who were then invited to discuss their preferences with the specialists involved (oral surgeon and prosthodontist). The radiologist's evaluation of the maxillary bone anatomy with regard to the prerequisites for the alternatives was included in the information provided. After these discussions, 16 patients were assigned to the graft group and 20 to the trial group; the remaining 7 renounced any implant treatment and were assigned to the no-implant group. The age and gender distributions of the patients are presented in Table 1. The distribution of the patients according to the opposing dentition is given in Table 2. The majority of the patients had natural teeth in the mandible, even though the dentition often was reduced. A few had various types of prosthetic restorations (Table 2).

The study was designed according to the Declaration of Helsinki and accepted by the Ethical Committee, Medical Faculty, Göteborg University.

Radiographic Examination. A radiographic examination of all patients was performed preoperatively using intraoral, lateral, and panoramic radiographs and serial tomography with either spiral movement or with the Scanora technique.[13] The maxillary bone was examined with respect to pathologic changes and shape of the jawbone. The following measurements were performed for evaluation of the residual bone quantity: *(1)* the distance from the nasal floor to the crest of the ridge in the anterior region; *(2)* the bone height from the nasal or sinus floor to a level where the bone had a width of 4 mm in a buccopalatal direction; and *(3)* the horizontal distance from the most anterior sinus wall to the midline (if this distance was less than 13 mm, it was recorded as short).

The postoperative radiographic examination included all of these techniques except tomography, supplemented with oblique lateral views, one from each side. The postoperative exam was performed after bone grafting, after placement of the implants, after abutment connection, immediately after placement of the prosthesis, and at the 1-year follow-up. Reduction of the height and width of the bone graft was evaluated. The marginal bone level was measured in relation to the junction between the implant and the abutment. The marginal peri-implant bone loss was defined as the difference between the level at the time of prosthesis placement and at the 1-year follow-up.

Surgical Procedure. The maxillary jawbone was exposed through an incision in the buccal sulcus of the patients to have onlay grafting (Fig 1); otherwise, a crestal incision was used. In the one-stage procedure, the graft was fixed and the implants were placed simultaneously. The graft was held in place manually and with consecutively placed guide indicators (Nobel Biocare, Göteborg, Sweden). In the two-

Table 1 Age and Gender Distribution of the Patients in the Three Treatment Groups

	Treatment group						
	Graft		Trial		No implant		
Age (y)	M	F	M	F	M	F	Total
31–40	0	1	1	1	0	0	3
41–50	0	1	0	3	0	1	5
51–60	4	2	1	6	1	1	15
61–70	2	5	4	1	1	1	14
71–80	0	1	1	2	0	1	5
> 80	0	0	0	0	1	0	1
Total	6	10	7	13	3	4	43

M = male; F = female.

Table 2 Patient Distribution According to Opposing Dentition

Treatment group	Natural teeth	FISP	CD
Graft (n = 16)	15*	1	
Trial (n = 20)	13**	7	
No implant (n = 7)	6†		1

FISP = fixed full-arch implant-supported prosthesis; CD = complete denture.
*Two patients also had a removable partial denture.
**One patient also had a fixed partial implant-supported prosthesis.
†Three patients also had a removable partial denture; two patients also had a fixed partial implant-supported prosthesis.

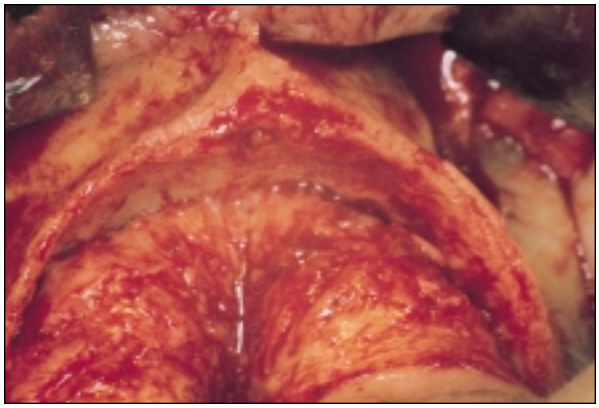

Fig 1 Thin maxilla before grafting.

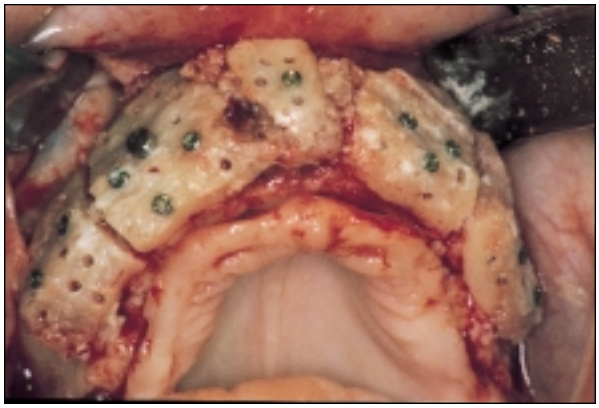

Fig 2 Buccal onlay graft placed with microscrews.

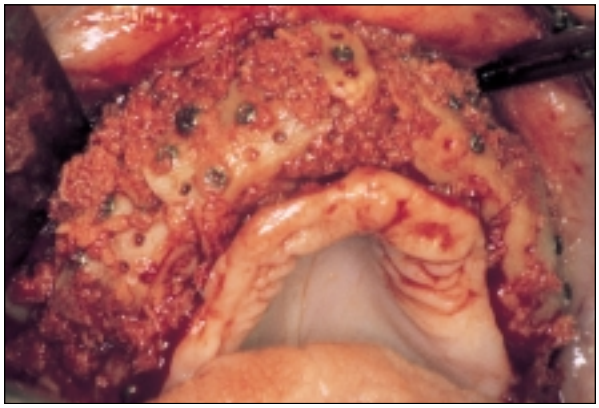

Fig 3 Buccal onlay graft packed with cancellous bone chips.

stage procedure, the graft was held in place with microscrews (Leibinger, Würzburg, Germany) in the onlay patients (Figs 2 and 3), and with a stainless steel wire in the patients having sinus or nasal inlays.

The grafting operations were performed under general anesthesia, supplemented with local anesthesia (Lidocain Adrenalin 2%, Astra, Södertälje, Sweden). Most of the patients in the trial group were under local anesthesia with sedation during surgery (Diazepam Stesolid, 0.3 mg/kg body weight). The bone harvesting from the iliac crest was performed as described by Isaksson and Alberius,[14] but involved the medial corner of the crest, including a $4 \times 1 \times 1$ cm bone portion containing both cortical and spongeous bone. The graft was placed with its compact part cranially in sinus or nasal inlay situations, and with its v shape placed caudally over the crest when the onlay technique was used. In the two-stage procedure, a healing time of 3 to 4 months was allowed prior to implant placement. A patient presentation of the two-stage procedure is shown in Figs 4a to 4f.

In the trial group, the maxillary bone was exposed, and the crest was prepared for implant placement and for unconventional approaches, such as the acceptance of free implant threads to be covered with bone chips and membranes for guided tissue regeneration; for unusual implant positions, eg, buccal to the incisive canal; and for small-diameter implants. The types and sizes of the implants placed are presented in Table 3. In 15 of the patients, the implants were placed in the second premolar, canine, and central incisor regions, while the lateral incisor region was used instead of the central incisor region in the remaining 5 patients. One patient had one implant placed in a second molar region instead of the premolar region.

One-stage grafting procedures were most common. In 11 patients, the graft and implants were placed simultaneously (10 onlay and 1 onlay + bilateral sinus inlay). A two-stage procedure was performed in 5 patients (3 unilateral sinus inlays, 1 unilateral onlay, 1 nasal inlay + bilateral sinus inlay). Of the 221 implants placed, 201 were placed at the time of bone grafting, and 20 were placed secondarily in the consolidated grafts (3 to 4 months after grafting). The distribution of bone quality and quantity is shown in Table 4.

Prosthodontic Procedure. After surgery, the patients who had undergone bone grafting were not allowed to wear their dentures for 8 weeks, after which they were provided with a new maxillary denture. Patients in the trial group were without dentures for 2 weeks prior to resumption of the use of their original dentures relined with a tissue conditioner. The soft tissues and dentures were checked regularly during the healing period, and when neces-

Figs 4a to 4f Presentation of maxillary grafting combined with implants.

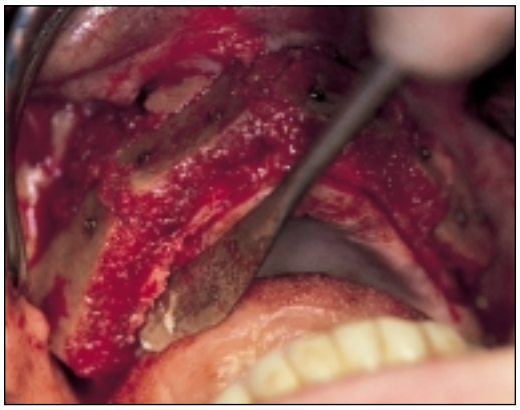

Fig 4a Buccal onlay graft fixed with microscrews.

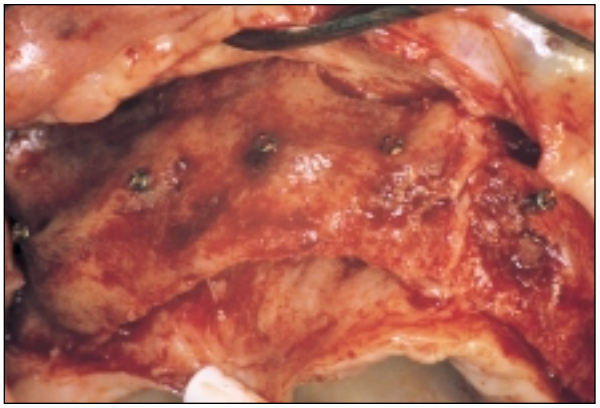

Fig 4b Remodeling of graft after 4 months.

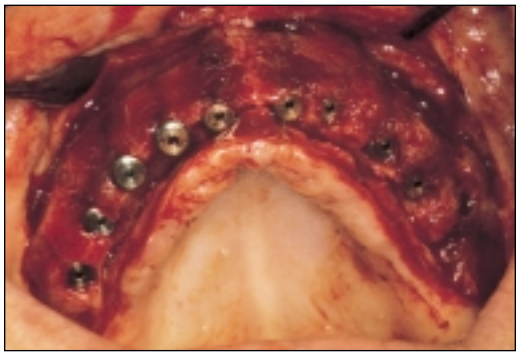

Fig 4c *(Above)* Implant placement in the graft after a 4-month healing period.

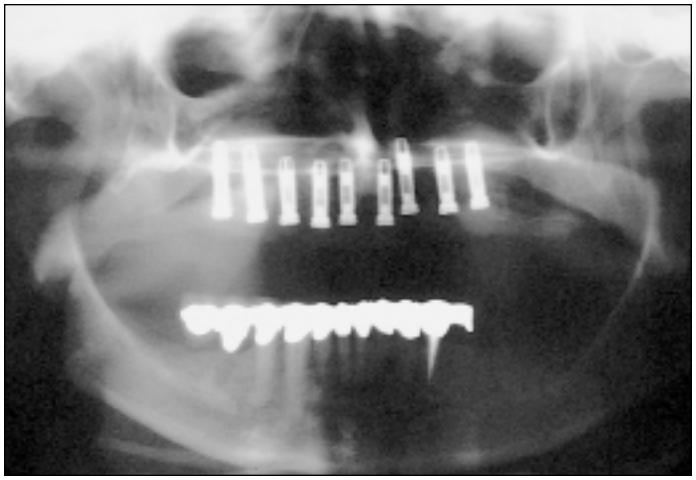

Fig 4d *(Right)* Radiographic view of the implants.

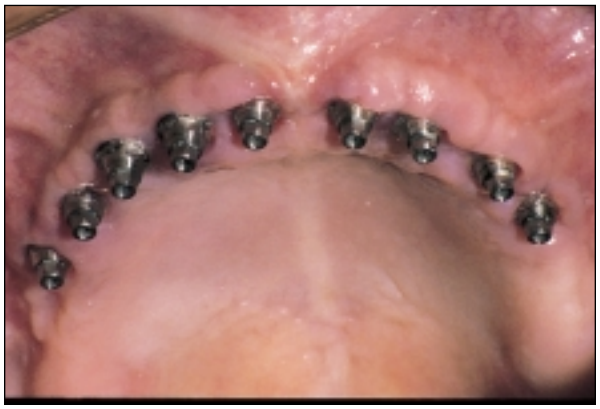

Fig 4e Status after abutment placement, 6 months after implant placement.

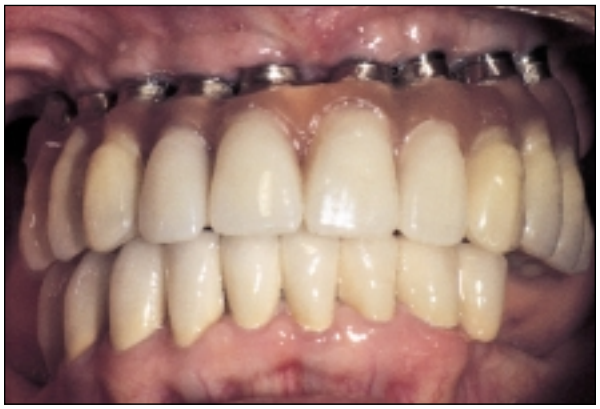

Fig 4f Prosthetic reconstruction with an implant-supported fixed partial denture in the maxilla.

Table 3 Distribution of Placed Brånemark Implants with Respect to Diameter, Type, Length, and Failure

		Graft group		Trial group	
	Length (mm)	Placed	Failed	Placed	Failed
Diameter (mm)					
3.0	10	0	0	1	0
	13	0	0	1	0
3.75	7	4	1	4	0
	8.5	3	1	11	3
	10	1	0	11	2
	13	5	0	0	0
4.00	7	0	0	2	1
	10	0	0	1	0
	15	1	0	0	0
5.00	6	0	0	1	0
	8	0	0	1	0
	10	0	0	1	0
Self-tapping	10	36	11	39	2
	13	31	4	27	1
	15	16	0	3	0
	18	2	0	0	0
Mark II	10	0	0	1	0
	13	0	0	4	0
	15	2	0	6	0
	18	0	0	6	0
Total		101	17	120	9

Table 4 Distribution in the Treatment Groups of Bone Quality and Quantity According to Lekholm and Zarb[17]

		Bone quantity				
Treatment group	Bone quality	B	C	D	E	Total
Graft	1	–	–	–	–	–
	2	–	–	1*	–	1
	3	–	1	5	–	6
	4	–	–	4**	5†	9
Total		–	1	10	5	16
Trial	1	–	–	–	–	–
	2	–	–	6‡	–	6
	3	1	1	11§	1	14
	4	–	–	–	–	–
Total		1	1	17	1	20
No implant	1	–	–	–	–	–
	2	–	–	–	–	–
	3	–	1	3	–	4
	4	–	–	–	3	3
Total		–	1	3	3	7

*6/6 implants lost.
**6/28 implants lost.
†5/35 implants lost.
‡2/38 implants lost.
§7/67 implants lost.

sary, the dentures were adjusted and/or relined. Abutment connection was performed 6 to 8 months after implant placement in all patients in both groups. The prosthetic treatment was started about 1 week later and primarily followed the standard protocol of the Brånemark system.[15] The aim was to provide the patients with a fixed implant-supported prosthesis, but when the situation was unsuitable, for example because of an insufficient number of implants and/or unfavorable implant location, an overdenture was chosen. Fixed prostheses were more common among the implant-supported reconstructions than overdentures (13:3 in the graft group and 15:5 in the trial group).

The fixed prostheses were made with a cast gold alloy frame and acrylic resin teeth and bases (Fig 4f). The overdentures were fabricated of acrylic resin and a cast cobalt-chromium framework. The retention system consisted of bars between the implants and clip attachments (Nobel Biocare) placed in the dentures. A balanced occlusion concept was the goal, as far as possible, for the overdentures, while a group contact occlusion without balancing side contacts was applied for the fixed prostheses.

Examinations. Patients in the implant groups were clinically examined according to a specified protocol at the time of connection of the prosthesis and at the follow-up each year thereafter. Clinical recordings comprised assessment of soft tissues around the implants, bleeding on probing, occlusion and wear of the artificial teeth, and any failures and/or complications related to implants and prostheses. At the 1-year follow-up, patients were asked to answer a few questions about treatment outcome. Pretreatment and current masticatory ability were assessed by means of a visual analog scale (VAS) graded 0 to 10. The follow-up examination was performed by a specialist in prosthodontics who had not participated in the treatment. Patients in the no-implant group were not clinically examined after 1 year, but interviewed by telephone using the same questionnaire given to the implant patients. When evaluating success and failure, the criteria suggested by Albrektsson et al[16] were followed.

Results

Evaluation of Bone Quality and Quantity. The radiographic evaluation showed that only 1 patient in the trial group and none in the graft group had an anterior residual ridge with a dimension large enough to accommodate a 7-mm implant. A bone height from the nasal floor to a level where the bone was 4 mm in the buccopalatal direction was extremely reduced (less than 4 mm) in 1 patient in the trial group and in 11 patients in the graft group. In 3 patients (2 in the trial and 1 in the graft group), the distance from the anterior wall of the sinus to the midline was very small (less than 13 mm). The classification of the quality and quantity of the maxillary bone according to Lekholm and Zarb[17] (Table 4) showed that the patients in the graft group, on average, exhibited more severe bone loss than those in the trial group (median values D 4 and D 3, respectively).

Implant Survival. At the 1-year follow-up, 22 (10%) of 221 placed implants had failed, 17 (17%) in the graft group and 5 (4%) in the trial group. Most of the failures were observed at the time of abutment operation, and only 3 implants were lost after connection of the prosthesis. The life table analysis showed the cumulative success rate (CSR) to be 83% in the graft group and 96% in the trial group. Failure rates of the implants placed in the one-stage and two-stage procedures in the graft group were 5% (10 of 201) and 20% (4 of 20), respectively. Failures in the graft group occurred in 4 patients. One patient in the graft group lost all 6 implants, but had a new operation in which 7 implants were placed. Two patients in the trial group have been treated with bone grafts after implant losses. Most failures involved shorter implants (Table 3). All implant losses occurred in D and E quality bone (Table 4).

Bone Graft. Marked reduction of the volume of the bone grafts occurred in all grafted patients (Figs 4a and 4b). This was first observed during the period immediately following grafting surgery. At the 1-year follow-up, more than one half the height of the graft had disappeared in 9 of the 12 patients with onlays. In 4 of these patients, no or only minor parts of the graft remained. A similarly extensive loss of bone was seen from the buccal side. The bone loss of inlay grafts was less extensive; 4 of the 5 patients with inlays had two thirds or more of the graft left at the 1-year follow-up. One patient completely lost his bilateral sinus inlays.

Marginal Bone Level and Peri-implant Bone Loss. The bone level was on average 2.9 mm apical to the implant-abutment junction at the time of prosthesis placement, without any significant difference between the graft and trial group. The range was large in both groups (0.5 to 10.0 and 0.5 to 8.0 mm, respectively). The marginal bone loss during the observation period, which did not differ between the groups, was on average 0.5 mm (range 0 to 2.0 and 0 to 3.0 mm in the graft and trial group, respectively).

Prosthesis Stability. All patients (except the patient who lost all implants) have been wearing their implant-supported prostheses continuously.

Questionnaire. The patients evaluated their masticatory ability as much improved after the treatment; similar values were recorded in the two groups

Table 5 Self-Assessed (VAS) Masticatory Ability (Mean ± SD)*

	Before treatment		After treatment	
Treatment group	Mean	SD	Mean	SD
Graft (n = 16)	3.1	2.9	8.7	1.1
Trial (n = 20)	2.9	2.4	7.9	2.0
No implant (n = 7)	–	–	5.8	1.6

*Questions asked: "How was your chewing function before treatment?" and "How is your chewing function now?"

(Table 5). The mean values for all patients according to the VAS assessment was 3.0 before and 8.3 at the 1-year follow-up. Sixty percent in the graft group and 29% in the trial group reported residual phonetic problems at the 1-year examination. Answers to questions pertaining to the esthetic results of treatment and whether oral hygiene procedures were difficult to perform did not differ significantly between the groups.

All but one patient in each group expressed willingness to undergo the treatment again even when knowing the difficulties and problems involved.

Clinical Examinations. Gingival bleeding around implants was recorded at a few sites in nine patients. There was no gingival bleeding observed in 63% of the patients in the graft group and in 82% of those in the trial group. The dental wear was more marked in the trial group than in the graft group, in which the great majority (88%) had no or minimal wear. One quarter of the patients in both groups had a prenormal jaw relationship. One patient in the graft group had a postnormal (Angle Class II) jaw relationship, while the remaining patients had normal jaw relationships.

Donor Site. The occurrence of hip donor site morbidity was low, and only one patient had a prolonged period (greater than 2 weeks) of postoperative pain. This patient also had a disturbance of the lateral cutaneous nerve of the thigh. The paresthesia resolved completely within 2 months.

Complications. Two of the four patients in the graft group who lost implants also lost the entire grafted bone block. Most probably, the one who had an onlay graft lost the bone block because of traumatic occlusion from the opposite jaw combined with an infection of the graft through a dehiscence of the mucosa. The graft sequestrated and was lost. The other loss was in a heavy smoker who lost bilateral sinus inlays and still had an oroantral fistula on one side.

Primarily minor prosthodontic problems were encountered and managed by means of routine clinical and laboratory procedures.

No-Implant Group. The patients who renounced implant treatment assessed their mean masticatory ability as 5.8 (SD 1.6) according to the VAS at the 1-year follow-up. Six of seven reported retention problems with their complete dentures. Nevertheless, two said their mastication functioned well, three said it functioned fairly well, and only one said it was problematic. One did not wish to answer these questions.

These patients' reasons for refraining from implant treatment varied, but fear and hesitation for the complicated, time-consuming, and expensive treatment necessary were most often mentioned. Five of these patients said they would still renounce implant treatment today, one was uncertain, and one would now like to have implants.

Discussion

All patients in this study had lost so much maxillary bone that conventional implant treatment was judged to be impossible. The treatment options available at the clinic at that time were presented to the patients, who took part in the decision and had an influence on the chosen method. However, besides patient preferences, the clinical and radiographic evaluation also influenced the decision. A retrospective comparison of the bone quality and quantity between the groups suggests that the graft group exhibited more severe residual ridge resorption than the trial group (Table 4). It is probable that the amount of ridge resorption, as manifested in the radiographic examinations, to some extent affected the placement of the patients in the different groups. Thus, this is not a randomized study, and the results must be evaluated with caution. At the start of this study, the knowledge of alternative treatment for severely resorbed maxillae was insufficient for proper decision-making. A fully randomized study was therefore difficult to design and motivate patients for. Nevertheless, it was considered valuable to evaluate the outcome of the various treatments by carefully registering clinical and radiographic observations as well as patient views at regular follow-ups. The necessity for more research in this field was one of the conclusions of an extensive review of grafting techniques in implant treatment of severely resorbed jaws.[8]

The implant survival in this study compares well with that reported in studies using similar procedures.[2,11,12,18–20] The implant survival rate is higher than that presented by Nyström et al[20] for the development group in their study. Their patients, however, all belonged to classes V and VI according to the classification system proposed by Cawood and Howell,[21] and were probably more severely affected in general

than patients in the present study, some of whom had less severe bone resorption according to the Lekholm and Zarb classification system[17] (Table 4).

Varying success rates have been reported in comparisons of one- and two-stage procedures.[8] This study suggested that the results were better with the one-stage than with the two-stage procedure. However, the number of patients and implants in the latter group was too small for the results to be conclusive. In a recent study with a larger number of patients, it was concluded that the results were more predictable when the implants were placed in a secondary stage 6 to 9 months after the time of bone grafting rather than simultaneously.[10] The two-stage procedure is said to allow the bone time to heal before implant placement. If a postoperative infection develops, it is easier to manage when only the bone graft is involved. In a one-stage procedure, healing can be complicated by the implants placed in the grafted bone. Even if a loss of bone volume because of infection occurs in the two-stage procedure, enough bone often remains to allow placement of implants. As a consequence of such considerations, it is a tendency today, at least in Sweden, to prefer a two-stage procedure.

Rapid graft resorption has been reported in several studies of bone grafting techniques.[1,19] In a study using computed tomography to measure the fate of the bone graft, a 2.0-mm reduction in height and a 3.6-mm reduction in width were found at a 2-year postoperative follow-up.[22] Most of this reduction took place during the first few months. In a recent study by Widmark et al[23] using localized bone grafts from the mandible in the anterior maxilla for single-tooth implants, 25% had been resorbed after 4 months and 60% after 10 months. These findings, that in many patients grafts are substantially reduced and that this occurs primarily in the initial postoperative period, are corroborated by the present study. It can be speculated that this rapid initial resorption may be a consequence of excessive augmentation beyond the limits of normal anatomy in the grafted region. It should be emphasized, however, that in spite of the severe reduction of the bone graft, the grafting procedure provided enough bone to enable implant placement with total bony coverage.

The mean marginal peri-implant bone loss of 0.5 mm up to the 1-year follow-up is remarkably small with respect to the amount of remodeling that the graft undergoes. One interpretation is that the bone adjacent to the implants is maintained as a result of proper stimulation, while the more peripheral portions are resorbed because of inadequate stimulation.

Despite the complexity of the treatment in the graft group, including harvesting of the graft from the iliac bone with often reported short-term complications, overall the patients were very satisfied with the treatment and its outcome. In fact, donor site morbidity in these patients was rare, which verifies findings in a recent study also using bone harvesting from the anterior iliac crest.[24] Patient satisfaction was also demonstrated by the fact that practically all said that they would undergo the treatment again.

On average, those who had refrained from implants reported lower self-assessed masticatory ability than those with implant-supported prostheses. Nevertheless, they exhibited a modest level of adaptation to their optimized complete dentures, albeit with a sigh of resignation. It was probably appropriate from a psychologic aspect that these patients were given the opportunity to be examined and informed and to participate in the evaluation of possibilities, limitations, and risk of implant treatment. Most of them renounced implant treatment because they thought it would be too tiring, time-consuming, and/or expensive with an uncertain outcome.

Conclusion

Implant treatment in patients with severely resorbed maxillae is a demanding procedure, but it can be successful, in the short-term perspective, with both bone grafting procedures and modified placement of implants without bone grafts. However, the success rate and implant survival are lower, and the complication rate is higher than for implants placed in maxillae with better bone quality and quantity. The choice of appropriate treatment in borderline cases—bone grafting, modified conventional implant treatment, or optimized complete dentures—is difficult and influenced by many factors. It is clearly advantageous to include the patients, after careful presentation of information, in the choice of treatment options. This was especially obvious for the group that declined implant treatment, but reached a level of modest adaptation to their optimized complete dentures.

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References

1. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and performed autologous bone grafts in combination with osseointegrated implants. Scand J Plast Reconstr Surg 1980;14:23–48.
2. Adell R, Lekholm U, Gröndahl K, Brånemark P-I, Lindström J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. Int J Oral Maxillofac Implants 1990;5:233–246.
3. Zarb GA, Schmitt A. The edentulous predicament II: The longitudinal effectiveness of implant-supported overdentures. J Am Dent Assoc 1996;127:66–72.
4. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone. A 5-year analysis. J Periodontol 1991;62:2–4.
5. Bahat O. Osseointegrated implants in the maxillary tuberosity: Report on 45 consecutive patients. Int J Oral Maxillofac Implants 1992;7:459–467.
6. Jemt T, Book K, Lindén B, Urde G. Failures and complications in 92 consecutively inserted overdentures supported by Brånemark implants in severely resorbed edentulous maxillae: A study from prosthetic treatment to first annual check up. Int J Oral Maxillofac Implants 1992;7:162–167.
7. Gunne J, Nyström E, Kahnberg K-E. Bone grafts and implants in the treatment of the severely resorbed maxillae: A 3-year follow-up of the prosthetic restoration. Int J Prosthodont 1995;8:38–45.
8. Tolman DE. Reconstructive procedures with endosseous implants in grafted bone: A review of the literature. Int J Oral Maxillofac Implants 1995;10:275–294.
9. Balshi TJ, Lee HY, Hernandez RE. The use of pterygomaxillary implants in the partially edentulous patient: A preliminary report. Int J Oral Maxillofac Implants 1995;10:89–98.
10. Nyström E. Onlay bone grafts and implants in the reconstruction of severely resorbed maxillae. A 1-stage procedure [thesis]. Umeå, Sweden, Umeå Univ, 1995.
11. Köndell PÅ, Nordenram Å, Moberg LE, Eliasson S, Nyberg B. Reconstruction of the resorbed edentulous maxilla using autogenous rib grafts and osseointegrated implants. Clin Oral Implants Res 1996;7:286–290.
12. Triplett RG, Schow SR. Autologous bone grafts and endosseous implants: Complementary techniques. J Oral Maxillofac Surg 1996;54:486–494.
13. Gröndahl K, Ekestubbe A, Gröndahl H-G. Radiography in Oral Endosseous Prosthetics. Göteborg: Nobel Biocare AB, 1996.
14. Isaksson S, Alberius P. Maxillary alveolar ridge augmentation with onlay bone-grafts and immediate endosseous implants. J Craniomaxillofac Surg 1992;20:2–7.
15. Zarb GA, Jansson T. Prosthodontic procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:241–282.
16. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
17. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
18. Nord PG, Åstrand P. Implantatbehandling vid kraftigt resorberade käkar. Metodbeskrivning och preliminärt resultat. Tandläkartidningen 1992;84:4–10.
19. Isaksson S. Evaluation of three bone grafting techniques for severely resorbed maxillae in conjunction with immediate endosseous implants. Int J Oral Maxillofac Implants 1994;9:679–688.
20. Nyström E, Kahnberg K-E, Gunne J. Bone grafts and Brånemark implants in the treatment of the severely resorbed maxilla: A 2-year longitudinal study. Int J Oral Maxillofac Implants 1993;8:45–53.
21. Cawood JI, Howell RA. A classification of the edentulous jaw. Int J Oral Maxillofac Surg 1988;17:232–236.
22. Nyström E, Legrell PE, Forssell Å, Kahnberg K-E. Combined use of bone grafts and implants in the severely resorbed maxilla. Postoperative evaluation by computed tomography. Int J Oral Maxillofac Surg 1995;24:20–25.
23. Widmark G, Andersson B, Ivanoff CJ. Mandibular bone graft in the anterior maxilla for single-tooth implants. Presentation of a surgical method. Int J Oral Maxillofac Surg 1997;26:106–109.
24. Beirne JC, Barry NJ, Brady FA, Morris VB. Donor site morbidity of the anterior iliac crest following cancellous bone harvest. Int J Oral Maxillofac Surg 1996;25:268–271.