Implant Reconstruction of the Bone-Grafted Maxilla: Review of the Literature and Presentation of 8 Cases

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Purpose: This study prospectively investigates the long-term success of iliac crest bone grafting and the secondary placement of osseointegrated implants in reconstructing maxillae with severely reduced bone mass.

Materials and Methods: Eight consecutive patients (7 women, 1 man), aged 18 to 69 (mean, 49.6), were treated by augmentation of their maxillae with corticocancellous autogenous iliac bone blocks. Forty-one Branemark implants of 7 to 15 mm in length and 3.75 mm in diameter were placed after a minimum delay of 6 months. Bone healing, maintenance of bone height, and implant stability were measured by clinical examination and radiographic control.

Results: One patient was lost to follow-up at 24 months after delivery of the prosthesis and one was lost at 75 months. The average duration of follow-up after loading of the implants was 90.5 months, and the longest was 154 months. Thirty-four of 41 (83%) of the implants survived to the end of the observation period. Four of 6 implants that failed were 7 mm in length and the other 2 were 10 mm in length. One 10-mm implant was "slept" because of poor positioning. All prostheses survived. There was one significant gingival infection that resulted in loss of 1.5 mm of bone after which the implant remained stable. None of the other implants were associated with crestal bone loss of more than 0.5 mm for the duration of this study.

Conclusions: Delayed placement of osseointegrated implants in maxillae augmented by iliac bone grafts is predictable and successful in the long term.

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The rehabilitation of the edentulous, atrophic maxilla remains a formidable problem. As the edentulous maxilla undergoes resorption, the denture-bearing area of the alveolar ridge becomes narrower and shorter as its anterior surface migrates dorsally and superiorly thereby creating a "knife-edge" form for the ridge. Resorption of the edentulous maxilla results in progressive loss of alveolar bone height occurring over decades of observation.[1] Loss of bone substance reduces the volume of bone available to accept the placement of implants, and diminished quality of bone increases the chance of implant failure in those maxillae for which a marginally adequate bone volume might still exist. As this occurs, vertically directed resorption increases the interarch space. As the projection of the maxilla diminishes in the sagittal plane, the intermaxillary relationships change thereby creating a pseudoprognathism. The combination of loss of projection of the maxilla and diminished vertical bone height results in collapse of the soft tissues of the midface and an aged appearance while simultaneously creating an oral environment unsuitable for denture retention. Alteration in muscle attachments results in circumoral hypotonia and collapse that combine to impair function and augment the appearance of facial aging. In its consensus statement on

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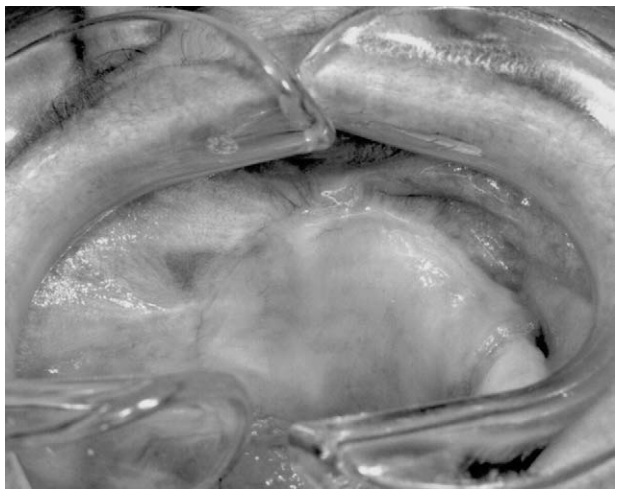

FIGURE 1. Maxillary edentulous ridge after resection of entire alveolus.

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preprosthetic surgery, the International Research Group on reconstructive Preprosthetic Surgery reported that bone loss in edentulous jaws is related to a variety of local and systemic factors, the latter of which include adverse loading by a prosthesis, inflammation of the overlying mucosa, vascular changes, and surgical procedures that require elevation of a mucoperiosteal flap. Although bone loss is quite consistent, there are wide variations in the rate of loss and in the final form of the residual alveolar ridge.[2]

The goals of reconstructive preprosthetic surgery are to provide an environment for a prosthesis that will restore function, be stable and retentive, preserve the associated structures, and satisfy esthetics. In other words, restoration of facial dimension, support for the soft tissues, increase of bone volume, and restoring maxillomandibular relationships are all essential goals of reconstruction.

Reviewing the evidence-based data from refereed journals indicates that these objectives can be achieved by placement of endosteal implants, surgical correction of the maxillomandibular relationships, restoration of hard tissue ridge form, and enhancement of the soft tissue by bone and soft tissue grafting procedures. Studies have shown that augmentation procedures using interpositional free bone grafts in combination with endosteal implants inserted at a secondary stage are satisfactory. Onlay and interpositional bone grafts carried out in conjunction with immediate implant insertion behave less predictably but in selected cases are a viable alternative.[3-6]

The 2 accepted methods for reconstructing the severely atrophic maxilla (Cawood class VI) are by simultaneous Le Fort I osteotomy with interpositional bone grafting[4-6] or by iliac crest onlay bone grafting. In regard to the interpositional LeFort I technique, bone graft integration is predictable, the denture bearing ridge is covered with keratinized mucosa, maxillomandibular ridge relationships can be corrected, and implants may be placed initially or at a second stage. Keller, using the interpositional LeFort I technique, reported 76% implant success with secondary placement of implants.[4] In regard to iliac onlay grafting, either 3 blocks of bone or a horseshoe-shaped piece of iliac crest is placed over the atrophic maxilla. The perialar regions may be simultaneously augmented and advancement of the alveolus occurs from forward placement of the graft material. The predictability of having keratinized mucosa over the potential implant sites is not reliable and bone resorption may be rapid unless implants are placed. Therefore relapse of onlay grafts is based on graft resorption whereas relapse of the LeFort I advancement is a function of maxillary posterior drift postoperatively. Both procedures produce clinically acceptable results. This article presents the survival results of implant placement in atrophic maxillae that were augmented with onlay iliac bone grafts followed by secondary implant placement using the Branemark system.

Materials and Methods

There were 8 patients; 7 women and 1 man ranging in age from 18 to 69 years with an average of 49.6 years. All but 1 patient was edentulous because of dental disease and one patient became edentulous after resection of the entire maxillary alveolus (Figs 1, 2). All of the patients were selected on the basis of having a maximum vertical height of less than 4 mm

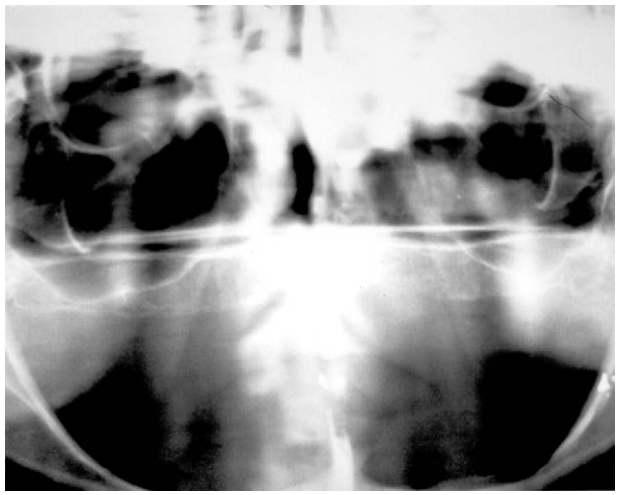

FIGURE 2. Orthopantomogram of typical edentulous maxilla requiring augmentation bone grafting.

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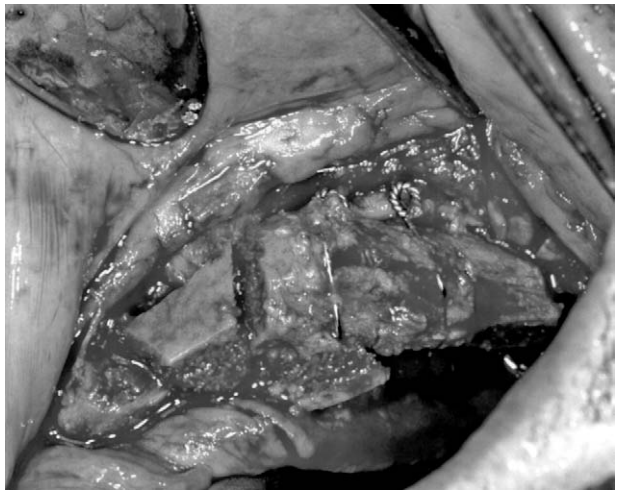

FIGURE 3. Corticocancellous blocks secured with per alveolar wires. Marrow packed into interstices of graft and between graft and residual ridge.

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as measured on an orthopantomogram. These patients were treated consecutively in a community hospital-based practice of oral and maxillofacial surgery integrated with a resident training program at Sinai Hospital of Detroit. A single surgeon placed all grafts and implants. Maxillae were augmented with corticocancellous blocks harvested as a monocortical block or as a horseshoe- or "U"-shaped bicortical block from the medial table of the ilium. Marrow was used to fill in the interstices as necessary. All implants were placed at a second operation after allowing at least 6 months of bone consolidation to occur after grafting. The Branemark system was used and all implants were of standard 3.75 mm diameter. The longest possible implant was chosen for each site. All implants, bone graft harvests, and maxillary reconstructions were carried out by a single surgical team.

All operations were carried out in the operating theater on in-patients who were admitted to the hospital on the morning of surgery and remained hospitalized for 3 days on average. While 1 team of oral and maxillofacial surgeons prepared the recipient site, a second team of oral and maxillofacial surgeons harvested the autogenous iliac crest donor bone. Sterility was easily maintained at the donor site and all operations were completed in less than 3 hours from intubation to closure. For bone harvesting, an incision of 6 cm was made parallel to but lateral to the iliac crest so that, with retraction, the anterior superior iliac spine and at least 9 cm of bone dorsal to it could be exposed. A midcrestal incision was then made through periosteum avoiding the muscle attachments as much as possible and the superior crest and medial cortex were exposed subperiosteally. Vertical and horizontal osteotomies were made using an air-powered sagittal saw with straight and angled blades. Irrigation with saline accompanied the osteotomies. The bone was delivered by gently malleting curved and straight osteotomes through the bone incisions as necessary. Most of the time the inferior horizontal bone incision was limited to a depth of 3.5 cm below the crest to reduce the likelihood of penetrating through the lateral cortex in the region where the medial and lateral cortex fuse.

As much bone marrow as possible was then removed with bone gouges and curettes. Hemostasis was obtained with electrocautery, hemostatic bovine collagen material, or fibrillar collagen. Occasionally Gelfoam soaked in thrombin was used to control persistent venous oozing. The use of bone wax was avoided whenever possible. A closed suction drain was used for most cases. The marrow was placed in a 30-ml medicine cup partly filled with room temperature saline and the block graft was wrapped in a cool saline-soaked sponge. Contouring of the block either into 3 rectangular pieces (Fig 3) or a single "U"-shaped graft (Figs 4, 5), depending on the thickness of the block, began immediately after removal from the ilium using a high-speed drill and burs with high-flow saline irrigation. The contact surface of the grafts with the underlying maxilla was also modified to assure a stable fit. No attempt was made to "decorticate" the blocks or the recipient maxilla except as necessary to alter their contour to provide the best fit at the recipient site. As each block was contoured, the others remained in a basin of room temperature saline waiting their turn for contouring and transfer to the maxilla. The time from bone harvest to insertion at the recipient site was generally less than 30 minutes.

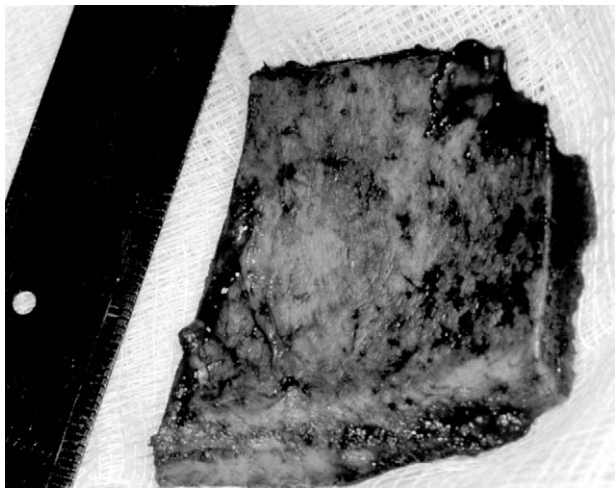

FIGURE 4. Donor bone from ilium to be prepared as "horseshoe" to onlay on maxilla.

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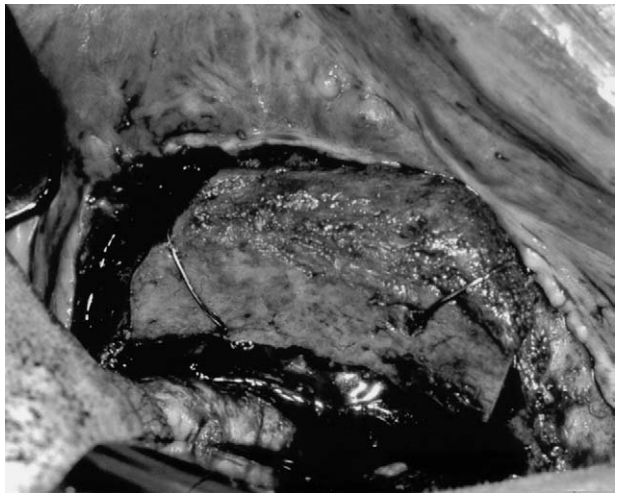

FIGURE 5. "Horseshoe" graft in place with additional strut of iliac bone placed on labial surface of maxilla.

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The recipient site was prepared by raising mucoperiosteal flaps using a midcrestal or slightly labially placed incision made through the attached gingiva. The maxilla was exposed bilaterally from the tuberosity to the anterior nasal spine and superiorly to the infraorbital foramina and piriform rims.

After contouring, the bone blocks were secured to the maxilla with 26 gauge stainless steel per-alveolar wires looped around them. When augmentation of the piriform region was required, corticocancellous struts were adapted to fit the underlying contour of the bone and each was secured with a single 2-mm titanium bone screw.

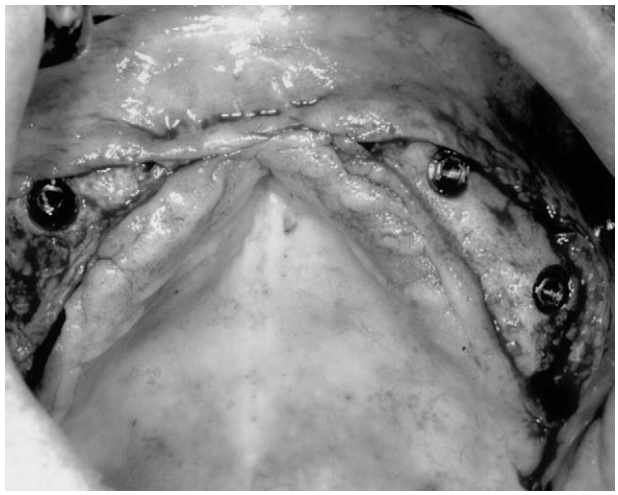

FIGURE 6. Stage I implant placement into engrafted bone.

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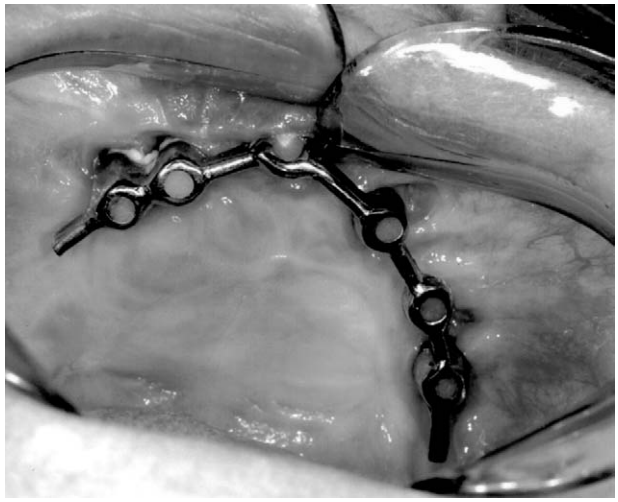

FIGURE 7. Connecting bar to support removable prosthesis.

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Using fine skin hooks, the labiobuccal mucoperiosteal flap was draped over the grafts to assess tension at the site of closure. If necessary, the periosteum was incised ("window-shaded") with a series of parallel cuts made through the periosteum with a scalpel blade to "relax" the flap. The incision was closed with vertical mattress sutures of 3-0 poly-l-glycolic acid (Vicryl) reinforced by a second continuous suture layer of the same material.

After bone healing was complete, orthopantomograms and occlusal radiographs were used along with clinical examination to document bone volume before implant placement. Computed tomography was not used.

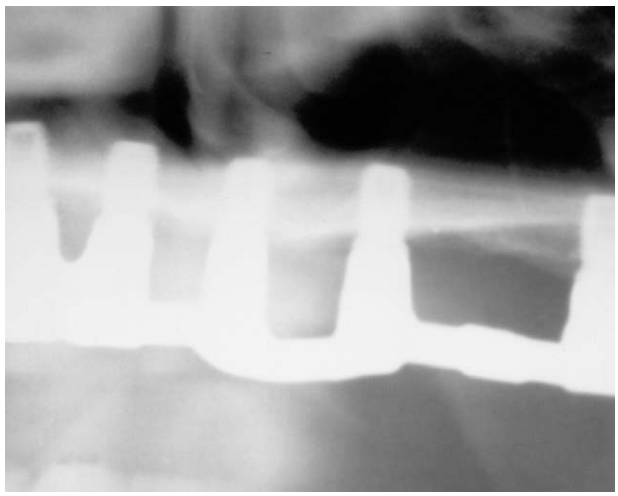

FIGURE 8. Orthopantomogram at 129 months after placement of 7 mm implants for patient demonstrated in Figures 1 and 3. No resorption of bone is present around implants.

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Table 1. IMPLANT STUDY MATERIAL

Implant size (mm)	7	10	13	15
Number of implants	10	21	7	3
Number lost by Stage II	3	0	0	0
Number lost after delivery of prosthesis	1	2	0	0
"Slept"	0	1	0	0

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The per-alveolar retention wires were removed at stage I surgery for implant placement. If necessary, vestibular extension procedures combined with split thickness skin grafting were carried out at 5 months followed in 6 to 8 weeks by stage I implant surgery. Stage I surgery followed the strict Branemark protocol and self-tapping fixtures without countersinking were used (Fig 6). Stage II fixture placement occurred at an interval of 3 to 7.5 months after stage I surgery.

Patients were followed for a minimum of 24 months after delivery of the prosthesis with the longest being 154 months. Orthopantomographs were obtained yearly to monitor the bone graft-implant interface. A representative case of a woman (Fig 1) restored with 5 Branemark implants of 7 mm length restored with a connecting bar (Fig 7) and overdenture with radiographic control at 129 months is demonstrated in Figure 8.

Results

There were 8 patients in this series who received 41 Branemark implants, all placed on a delayed basis after bone grafting. Thirty-four of 41 (82.9%) implants survived until the end of the study period. The characteristics of the implants are displayed in Table 1.

The median time intervals between grafting and last follow-up examination are presented in Table 2.

COMPLICATIONS

There were no intraoperative complications. One patient (patient 6) lost significant volume of her bone graft after the mucosa broke down during the first month after surgery. A second patient (patient 8) lost 2 small bone chips of 2 to 3 mm at 13 months after surgery that did not interfere with implant placement. She also had a postoperative hematoma of the palate that was aspirated in the clinic. One of her anterior 10-mm implants was "slept" because it was too labial in its placement.

IMPLANT FAILURE

Four of the 7-mm implants were lost. Three occurred in 1 patient (patient 6), one spontaneously exfoliating at 3 months, 1 loosening at 5 months after having seemingly survived a gingival infection at 2 months, and 1 at 15 months after delivery of the prosthesis. Her prosthesis became loose, and all but one implant was removed with the prosthesis at 23 months. The remaining implant remains in place and in function surrounded by healthy gingiva at 99 months after placement. A conventional denture, retained by large amounts of denture adhesive, has been worn by the patient for the past 67 months. Patient 5 lost a single 7-mm implant by spontaneous exfoliation 3 months after placement.

Two of the 10-mm implants failed after stage II surgery. One implant was lost after abutment placement during loading (patient 1) and another 10-mm implant failed 5 months after loading (patient 2). Patient 2 developed a soft tissue infection around an incisor implant site located at the junction of attached and mobile mucosa, which did not result in implant loss. However, at 2.5 years there was crestal bone loss of 1.5 mm. The implant remained firm afterward.

There were 3 other soft tissue infections. In 1 case soft tissue edema, erythema, and pain without pus formation developed around an anterior 7-mm implant 2 months after stage 1 surgery. This resolved with antibiotic therapy, and the implant has remained sound for 37 months after implant placement. Significant bone loss around surviving implants occurred only in the 1 implant around which 1.5 mm of crestal bone was lost. None of the other implants had bone loss in excess of 0.5 mm.

The morbidity associated with iliac grafting was limited to donor site pain and limp. Pain required parenteral narcotic analgesics in most patients for 2 or

Table 2. TIME SCALE FOR POSTOPERATIVE EVALUATIONS IN MONTHS

Patient	T_1	T_2	T_3	T_4
1	8	7.5	8.5	78
2	15	7	5	41
3	6	6	6	24
4	12	7	12	126
5	11	3	4	107
6	12	4	1	103
7	12	5	3	75
8	7	6	6	154

T_1, time to stage I implant placement; T_2, time to stage II abutment placement; T_3, time to prosthesis delivery; T_4, time to last evaluation after loading of prosthesis. Patients 2 and 7 lost to follow-up at 24 and 75 months respectively. Mean T_4 for all patients, 76 months; range, 24–154 months; median, 90.5 months.

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3 days. Placement of a catheter within the wound attached to a slow release pump administering bupivacaine became available near the end of the study period. Their use for 2 days after surgery greatly reduced the narcotic requirement. After discharge on the third day, oral analgesics were adequate to control pain. All patients were discharged with a "walker" that was later replaced by a cane. Generally patients less than 60 years old were ambulating normally in 2 weeks but some older patients required use of a mechanical aid for up to 5 weeks. For the 8 iliac grafts reported there was 1 patient who spontaneously fractured her anterior iliac spine 4 weeks after surgery. She required a cane to assist in walking for 4 months.

Discussion

Historically it was hoped that the insertion of endosseous implants into severely resorbed jaws would permit denture wearing in these patients. However, consistently durable results were not achieved. Implant-based overdenture reconstructions had a 5-year cumulative implant failure rate of 28.8% whereas implant anchored fixed bridges placed into jaws having better volume and quantity of bone failed only 7.9% of the time. Consequently, improvement of bone quality before implant placement by iliac crest augmentation bone grafting of the severely resorbed maxilla has been accepted as rational therapy.[7]

However, it is also well documented that iliac bone grafts as onlays to augment the maxilla tend to resorb quite rapidly just as is the case for the mandible with estimates of loss of ridge height ranging from 20% to 31% at 1 year to 44% to 92% at 3 years.[8-10]

Endosseous implants placed into the edentulous maxilla have been associated with mean marginal bone loss of 0.8 mm 5 years after loading using an overdenture[2,3] and 0.2 mm after loading with a fixed prosthesis.[7] In the latter case, even despite 3-dimensional distortion of 275 μm measured around cylinder posts the mean bone loss still did not exceed 0.5 mm although the maximum bone loss noted was 2.9 mm.[11]

Unconnected maxillary fixtures observed for 5 years were associated with a mean yearly marginal bone loss of 0.1 mm. In this study it was noted that 75% of the failures during the 5-year observation period occurred during the first year before loading implying that bone-implant interface factors were more important determinants of success than were implant-loading factors. In these patients restored with overdentures, the 5-year survival figure for the implants was 72.4%, and the survival figure for the prostheses was 77.9%.[3] These results, compared to 94.5% implant survival and 100% prosthetic success in the mandible were attributed to case selection. It was also noted that 90% of the treated maxillae functioned against a lower arch containing some natural teeth and a removable partial denture. The treated mandibles functioned against complete upper dentures. Although the maxillary failure rate exceeded that for the mandible, no statistically significant relationship was found between failed overdentures and bone quality, bone resorption, gender, and the surgical center where the patient was treated. It has also been noted that there was no difference in implant or prosthesis survival in the same jaw when removable dentures were compared to fixed bridges.[7]

Lekholm et al[12] designed a study to evaluate stress at the marginal bone interface by placing Branemark implants with exposed threads. They did not experience soft tissue problems or progressive marginal bone loss. For the worst group of 51 patients with 107 test implants developing marginal bone loss beyond the second thread at the first annual review examination there were only 9 episodes of soft tissue problems. These were limited to 5 cases of simple inflammation, 3 cases of hyperplasia, and 1 fistula. Three of 107 implants were lost by the end of the first year. Mean marginal bone loss of 0.2 to 0.6 mm for the remaining implants occurred from year 1 to year 5.

Because clinical experience with the placement of endosseous and transosseous implants has demonstrated clearly that the rate of bone resorption diminishes in the regions where implants have been placed in the mandible and maxilla,[2,3,7,11,13-16] interest developed to discover whether this same retardation of bone loss around implant sites would also occur in jaws augmented with autogenous bone grafts.[7,11,13] In fact, Jemt et al[3] reported a rate of peri-implant bone resorption of 0.4 mm/year in maxillae augmented with ilium and observed over a 5-year period. However, the most recent review of resorption occurring around maxillary implant sites augmented with ilium was not as positive. Nystrom et al[17] reported on a series of 30 patients with severe maxillary resorption who were treated by iliac augmentation using a horseshoe-shaped 1 piece bicortical corticocancellous graft that was secured to the residual maxillary alveolar ridge into which 6 conical implants were placed. This 3-year study demonstrated that there was a mean bone loss of 4.9 mm around the implants. In another study,[15] after localized augmentation, implants were placed after a healing period of 3 months using self-tapping Branemark implants or ITI hollow cylinder implants. Marginal bone loss was reported as occurring within the first year in 3 patients and did not exceed 80% of the implant length. No more specific details were rendered in the article except for the statement that after year 1, "no bone loss around the implant was observed." Although details in this study are lacking, support is given to the concept that

minimal bone loss is expected around the implants. Clayman[14] reported a rate of bone loss around the transosteal posts of mandibular staple bone plates placed into bone-grafted regions of the mandibular symphysis of 0 to 0.7 mm/year over a 16-month observation period. In an 8-year follow-up not reported in the literature, the total additional bone loss was 0.8 mm.

Concurrently with an assessment of bone resorption one wishes to also know the long-term survival rate of the implants. Tolman[18] reviewed the literature reporting survival statistics of Branemark implants placed into maxillae augmented with corticocancellous blocks of ilium. Of 1,240 implants reviewed, a "long-term" survival rate of 87% was reported. Others[3,7,19] have noted that in non-grafted maxillae, 7-mm Branemark implants placed by necessity in areas of diminished bone volume and density were subject to high loss rates.

For the 8 iliac grafts reported there was 1 patient who spontaneously fractured her anterior iliac spine 4 weeks after surgery. She required a cane to assist in walking for 4 months. This complication is usually associated with bicortical grafts rather than monocortical grafts. At our institution there have been 3 cases of spontaneous fracture of the anterior superior iliac spine from 1 to 4 weeks after bone harvesting occurring among 137 similar iliac grafts harvested during a 6-year period for various reconstructive procedures. Tolman,[18] in his review of the literature reporting on iliac bone grafting in the maxilla, noted that 3 of 79 (4%) patients had long-term pain and dysfunction at the donor site. There were 2 fractures. Williamson,[20] in his series of 18 medial iliac crest donor sites, reported no complications. All patients left the hospital 2 or 3 days after surgery and were able to resume walking with mild discomfort within 2 to 3 weeks. There were no late gait or sensory disturbances. The donor sites were not drained at surgery and there were no postoperative infections.

Forty-one Branemark implants were placed on a delayed basis. It was noted that 1 or more screw heads sometimes became exposed after 2 to 3 months as the mucosa became quite thin with the passage of time especially if some of the covering mucosa was not heavily keratinized. The total number of those events was not recorded. Exposure of the cover screws during the waiting period until stage II surgery was not related to implant complications. In fact this event made stage II easier because it was easier to locate the implant and use a dermatologic punch to excise the surrounding mucosa.

There were no immediate postoperative infections. One patient lost the distal one half of a corticocancellous block when the suture line mucosa dehisced during the second postoperative week. The mucosa healed rapidly thereafter and the remaining bone became properly integrated to the underlying maxillary ridge.

Tolman,[18] in his 1995 literature review of 591 patients, reported on a subgroup of iliac augmentation grafts to the maxilla. In 79 patients who received 436 Branemark implants (394 immediate and 42 delayed), there were 16 cases of wound dehiscence that directly contributed to the loss of 13 of 436 implants (3%).

Mucosal inflammation or infection around the implants, either gingival or mucosal, was recorded in 6 of 41 implants in this series. Two of these 6 cases were the result of non-integration of the implants during the initial healing phase. For the 4 implants that survived, in all but 1 case this was managed by enhanced local oral hygiene measures consisting of the use of thickened dental floss or wool yarn to wrap around the posts to clean them while compressing the gingiva, direct mucosal compression with a rubber tip, and chlorhexidine. In 1 case these measures were ineffective and a split thickness skin graft was placed to replace mobile mucosa with keratinized attached tissue. This solved the problem. Despite gingival inflammation there has been excessive bone loss of more than 1.5 mm in only 1 case, a 10-mm implant around which a gingival abscess had occurred after stage I surgery. After resolution of the abscess there has been no additional significant bone loss.

Four implants in 4 different patients in this study developed peri-implant soft tissue infections that required treatment with oral antibiotics. Two of these implants were lost. Both of the implants that were lost were 7 mm long and both survivors were 10 mm long. Probably because these 7-mm implants engaged only 2 to 3 mm of basal maxillary bone and only a small amount of additional grafted bone, the soft tissue infection was sufficient to cause enough lysis of bone ("saucerization") around these short implants for them to lose their precarious attachment to the bone and become exfoliated. These implants were lost before stage II and loading.

Gingival complications have been infrequent and have not been associated with excessive bone loss around implants in native jaw bones. Even reports on the long-term outcomes of the mandibular staple bone plate did not find a correlation between localized gingival complications and bone loss.[14,23] The transosteal posts in the mandibular staple consist of a threaded post to which is attached a fastener. The threads, usually 2 in number, are present between the cortical surface of the bone and the smooth inferior edge of the fastener. This presents an unfavorable surface to the gingival sulcus and consequently an early gingival complication rate of 36.5% was reported in a series of 104 staples.[23] Most importantly,

despite this high rate of early gingival complications, excessive bone loss of more than 3 mm was only observed in 8 of 104 (7.7%) of the staples. Therefore, it is reassuring to note that in our series of bone-grafted maxillae the few early gingival problems and the one late gingival problem in the patient requiring skin grafting were also not associated with significant bone loss or exfoliation of the implants.

Lekholm et al[12] studying Branemark implants with exposed threads at the bony margin found no higher frequency of mucosal problems compared to control implants placed without exposed threads. The implant failure rate was the same for the test (exposed threads) and control (no exposed threads) groups.

Referring to Table 2 one notes that all except 1 patient had stage I surgery within 1 year of the time of bone grafting (range, 6 to 15 months). Although others have reported successful implantation within 3 to 4 months, the accepted principle has been to wait at least 6 months until stage I surgery. Stage II surgery was deferred until at least 3 months after stage I surgery (range, 3 to 7.5 months) as recommended by the Branemark protocol.[21,22] Several patients received somewhat delayed treatment because of intercurrent illnesses or socioeconomic factors none of which had a detrimental effect on outcomes. After stage II, the prostheses were delivered expeditiously. No attempts were made to gradually load any of the prostheses and, as expected, there were no prosthetic failures.

It is noted in this study that 10 (24%) of the implants placed were 7 mm long. Seventy percent survived until the end of the study period. In all of these cases resorptive remodeling of the bone graft had already reduced bone volume sufficiently to limit implant length to 7 mm. A trend toward a higher failure rate attributed to the shorter (7 mm) implants was suspected as has been noted by Albrektsson et al.[13] This suggests that stage I implant surgery should be attempted whenever clinical signs of graft consolidation are present, perhaps as early as 4 months.

The most extensive analysis of the literature is provided by Tolman's 1995 review[18] in which he reported on 546 bone grafts placed to augment the maxilla. A total of 359 were blocks and 187 were particulate. A total of 1,240 endosteal implants of different manufacturers were placed into the 359 blocks. The overall success rate was 87%. Abstracting the subgroup analogous to the current study one notes that there were 42 Branemark implants placed into corticocancellous iliac blocks on a delayed basis. There were 38 regular and 4 self-tapping implants. Nine of these 42 (21.4%) implants failed. Of 38 regular implants, 7 (18.4%) failed, and of the 4 self-tapping, 2 (50%) failed. Failure according to implant length was not recorded. In this study,[18] 33 of 42 (78.6%) of the Branemark implants placed on a delayed basis survived. For the entire study, 314 of 394 or 79.7% of the implants placed on an immediate basis survived. There was no difference between groups for delayed versus immediate placement. For both groups the period of follow-up was 0 to 120 months. For all types of maxillary bone grafting including sinus lifts, nasal inlays, and combinations including onlay grafts to the occlusal table and interpositional block grafts combined with LeFort I osteotomies there were 1,738 implants placed into 546 bone grafts of 12 different types with 196 implant losses for a success rate of 89%. Williamson[20] reported a series of 2-stage implants placed into maxillae augmented by various types of bone. In most cases a sinus lift accompanied by augmentation of the "premaxilla" was accomplished. Implants were placed on a delayed basis and the success rate of the implants was reported as being 85.5% with a prosthesis being placed in function from 3 months to 8 years (average 2.2 years) after stage II surgery.

More recently a retrospective study evaluating 7 patients with loaded implants restored with a fixed prothesis noted a mean marginal bone loss of 0.2 mm after 5 years. A similar group of 7 patients evaluated on a prospective basis averaged 0.5 mm of marginal bone loss after loading. Both groups showed a maximum range of 2.9 mm of bone loss but for both groups the mean bone loss did not exceed 0.5 mm after 5 years.[11,12] Another study from the same researchers noted that unconnected mandibular implants lost only 0.1 mm of marginal bone height during year 1 after placement, but after loading the marginal bone loss increased to 0.5 mm after 5 years. In the maxilla it reached 0.8 mm.[3] In the current study marginal bone loss was not directly measured for all implants but empiric observation was in compliance with the notion that during the first 2 years of function there was minor marginal bone loss that then remained static. Aside from the implants that were lost, only the 1 implant associated with an abscess had noticeable marginal bone loss (1.5 mm). Although this observation is consistent with reports from the literature, no attempt has been made to quantify it because the purpose of this study was to assess implant survival rather than quantitatively measure marginal bone loss.

For a small selected group of patients having Branemark implants inserted into iliac crest bone grafts placed at the time of a sinus lift operation, Raghoebar et al[16] reported that 88 of 93 (94.6%) of the implants survived from 6 to 36 months with an average of 16 months follow-up. Long-term survival statistics were not reported. Of 25 patients, 16 were restored with implant supported overdentures and 9 had bone-anchored bridges. Of the 41 implants surviving to stage

II, 39 (95.1%) have been in function for an average of 34.9 months (24 to 64 months) without complications.

Maxillary implant failures were all associated with poor quality crestal bone after grafting or soft tissue infection surrounding 7 mm implants during the early phase of healing after stage II surgery. Prosthetic reconstruction consisting of fixed, implant-borne prostheses was completed, on average, 5 months after stage II. None of the prostheses were loose or failed during the time of this study.

The Branemark implant system is quite satisfactory for use after iliac crest bone graft augmentation of the maxilla. The implants should be placed (stage I surgery) about 6 months after grafting and self-tapping implants should be placed without countersinking. For those implants achieving osseointegration the survival rate of 2 years after stage II was 92%. For all implants of 7, 10, 13, and 15 mm length taken as a group overall, survival rate was 83% (34 of 41). For 7-mm implants the overall rate was 70% (7 of 10) and for the twenty-one 10-mm implants it was 85.7% (18 of 21). The initial success rate for the 10-mm implant group was 100%, there being no surgical stage losses. There was a trend toward a significant difference in survival related to the implant length. At 2 years after placement the 7-mm group had a survival rate of 84.6% (13 of 15) and this did not change. There were 2 late losses for implants of 10 mm (90.5% success). There were not surgical or prosthetic losses for the 10 implants that were 13 or 15 mm in length.

Two 10-mm implants failed after stage II. These failures were attributed to functional loading in excess of the ability of the osseointegrated interface to withstand that load. No specific pattern of loss was identified.

In conclusion, 7-mm implants are at increased risk for failure at 40% versus 9.5% compared to implants 10 mm or longer. This is more likely secondary to bone factors than any intrinsic deficit in the shorter implants.

References

1. Atwood DA: Bone loss of edentulous alveolar ridges. J Periodontol 50:11, 1979
2. International Research Group on Reconstructive Preprosthetic Surgery. Consensus Report. Int J Oral Maxillofac Surg 29:159, 2000
3. Jemt T, Chai J, Harnett J, et al: A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 11: 291, 1996
4. Keller EE, Van Rockel NB, Desjardins RP, et al: Prosthetic reconstruction of the severely resorbed maxilla with iliac grafting and tissue-integrated prostheses. Int J Oral Maxillofac Implants 2:155, 1987
5. Sailer HF: A new method of inserting endosseous implants in totally atrophic maxillae. J Craniomaxillofac Surg 17:299, 1989
6. Stoelinga PJW, Slagter AP, Brouns JJA. Rehabilitation of patients with severe (Class VI) maxillary resorption using Le Fort I osteotomy, interpositional bone grafts and endosteal implants: 1-8 years follow-up on a two-stage procedure. Int J Oral Maxillofac Surg 29:188, 2000
7. Jemt T, Lekholm U: Implant treatment in edentulous maxillae: A 6-year follow-up report on patients with different degrees of jaw resorption. Int J of Oral Maxillofac Implants 10: 303, 1995
8. Baker RD, Connole PW, Davis WH, et al: Long-term results of alveolar ridge augmentation. J Oral Surg 37:486, 1979
9. Baker RD, Connole PW: Preprosthetic augmentation grafting-autogenous bone. J Oral Surg 35:541, 1977
10. Fazili M, van Overvest-Eerdman SGR, Vernooy AM, et al. Follow-up investigation of reconstruction of the alveolar process in the atrophic mandible. Int J Oral Surg 7:400, 1978
11. Jemt T, Book K: Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants 11:620, 1996
12. Lekholm V, Sennerby L, Roos J, et al: Soft tissue and marginal bone conditions at osseointegrated implants have exposed threads: A 5-year retrospective study. Int J Oral Maxillofac Implants 11:599, 1996
13. Albrektsson T, Dahl E, Enbom L, et al: Osseointegrated oral implants. A Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. J Periodontol 59:287, 1988
14. Clayman L: Mandibular ridge preservation with the mandibular staple bone plate *in* Giardin C (ed), Maxillofacial Surgery. Bologna, Italy, Monduzzi Editore, 1982, p 925
15. Raghoebar GM, Batenburg RHK, Vissink A, et al: Augmentation of localized defects of the maxillary ridge with autogenous bone before insertion of implants. J Oral Maxillofac Surg 54: 1180, 1996
16. Raghoebar GM, Brouwer TJ, Reintsema H, et al: Augmentation of the maxillary sinus floor with autogenous bone for the placement of endosseous implants: A preliminary report. J Oral Maxillofac Surg 51:198, 1993
17. Nystrom NE, Halqvist J, Kahnberg KE, et al: Autogenous onlay bone graft fixed with screw implants for the treatment of severely resorbed maxilla. Radiographic dimensions, postoperative bone loss, and changes in soft tissue profile. Int J Oral Maxillofac Surg 25:351, 1996
18. Tolman DE: Reconstructive procedures with endosseous implants in grafted bone. A review of the literature. Int J Oral Maxillofac Implants 10:275, 1995
19. Friberg B, Jemt T, Lekholm U: Early failures in 4641 consecutively placed Branemark dental implants: A study from Stage I surgery to the connection of completed prostheses. Int J Oral Maxillofac Implant 6:142, 1991
20. Williamson AW: Rehabilitation of the resorbed maxilla and mandible using autogenous bone grafts and osseointegrated implants. Int J Oral Maxillofac Implants 11:476, 1996
21. Branemark PI: Osseointegration and its experimental background. J Prosthet Dent 50:399, 1983
22. Branemark PI, Hansson BO, Adell R, et al: Osseointegrated implants in the treatment of the edentulous jaw. Experiences of a 10-year period. Scand J Plastic Reconstr Surg 11:1, 1977
23. Helfrick JF, Topf JS, Kaufman M: Mandibular staple bone plate: Long-term evaluation of 250 cases. J Am Dent Assoc 204:318, 1982