Maxillary Antral-Nasal Inlay Autogenous Bone Graft Reconstruction of Compromised Maxilla: A 12-Year Retrospective Study

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During a 12-year period (1984–1996), 118 maxillary inlay autogenous bone grafts and 248 commercially pure titanium threaded root-form endosseous implants were placed in 54 consecutively treated patients with compromised maxillary bone. In this retrospective clinical study, 3 groups of patients were reviewed, group selection being based on anatomic location and surgical access to the recipient site. Group 1 included patients with bone grafts placed in the antrum floor via an intraoral antrostomy exposure, group 2 included patients with bone grafts placed in the nasal floor via an anterior intraoral nasotomy exposure, and group 3 included patients with bone grafts placed in the antral and nasal floor via an intraoral Le Fort I osteotomy downfracture exposure. Each patient received an implant-supported dental prosthesis. For the combined 3 groups, survival rates were 87% for endosseous implants and 100% for autogenous bone grafts. The success rate for the dental prostheses in the 3 groups was 95%. Sixty-nine dental prostheses functioned a mean of 57.1 months, whereas 3 prostheses required remaking because of implant loss. Of the medical and mechanical risk factors tabulated in this study, current use of nicotine, history of sinusitis, molar site implant placement, and shorter implant lengths had the most influence on implant failure.
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Key words: atrophic maxilla, autogenous bone graft, endosseous implants

In 1994, a preliminary 6-year retrospective report[1] described a maxillary 1-stage inlay composite bone graft procedure involving 30 recipient sites (20 patients and 83 implants) in the floor of the antral and nasal cavities via an intraoral antrostomy or anterior nasotomy exposure. All iliac corticocancellous block bone grafts healed without evidence of oral, antral, or nasal sepsis (100% success). Of the 83 implants placed simultaneously in the bone grafts, 5 were removed because of failure to achieve or maintain osseointegration (6% implant failure). Fixed or fixed-removable prostheses were utilized in all 20 patients. During the study period, all patients had continuous prosthesis function. That initial report provided a pertinent literature review to 1994 and detailed surgical techniques involving the donor and recipient sites. The surgical and prosthetic treatment protocol has not changed since that 1994 report. The present study involves additional patients in whom inlay bone grafts were placed into the same anatomic recipient sites via a modified approach; that is, maxillary Le Fort I osteotomy downfracture exposure in addition to the oral antrostomy or anterior nasotomy exposure. The surgical technique for the Le Fort I downfracture approach has previously been described.[2–4] The surgical technique for obtaining autogenous iliac bone utilized in 49 of 54 patients has been described by Keller and Triplett[5] and others [6,7] and is associated with a favorable prognosis, having minimal surgical morbidity when done from the anteromedial approach.

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Methods and Materials

Medical, surgical, and prosthetic records were reviewed in 54 patients with advanced maxillary bone resorption in whom autogenous inlay bone grafts were placed in the maxillary antrum or nasal floor. Three distinct treatment groups were identified on the basis of the surgical approach utilized to gain access for placement of the antral or nasal inlay bone grafts. The inlay bone graft studied in this report, in contrast to the onlay bone graft reported previously for a similar group of maxillary compromised patients,[8,9] is placed superior to the resorbed edentulous alveolar ridge in the antral or nasal floor, rather than inferior to the alveolar ridge, when onlay grafting techniques are utilized. The endosseous implant in the inlay graft traverses through the residual alveolar bone before it engages and penetrates the nasal or antral bone graft. All titanium endosseous implants used were Brånemark System (Nobel Biocare USA, Westmont, IL).

Three patient groups were studied: group 1 comprised 37 patients with 58 recipient sites and 40 dental prostheses, in whom the antral floor bone graft was placed via an intraoral antrostomy exposure; group 2 comprised 15 patients with 32 recipient sites and 15 dental prostheses, in whom the nasal floor bone graft was placed via an intraoral anterior nasotomy exposure; and group 3 comprised 10 patients with 28 recipient sites and 14 dental prostheses, in whom the nasal or antral bone graft was placed via an intraoral Le Fort I osteotomy downfracture exposure. Eight patients were included in 2 groups (group 1 and group 2 because they had both an intraoral nasotomy and antrostomy as separate procedures).

Review of the Mayo Clinic medical records identified patient age and gender, as well as significant medical diagnoses that could place the patient at increased risk of compromised bone graft healing or failure to achieve and maintain endosseous implant osseointegration. These potential factors are: *(1)* nicotine use; *(2)* altered bone metabolism associated with menopause, excessive exogenous steroids, or endocrine or metabolic disease; *(3)* previous physical tissue insults that compromised blood supply or decreased cellular viability, such as irradiation, chemotherapy, trauma, or sepsis (sinusitis); and *(4)* significant cardiovascular disease affecting peripheral vasculature.

Review of the surgical records documented dates of surgical procedures for implant placement, uncovering or removal of endosseous implants, and management of postsurgical oral, antral, or nasal complications. The surgical approach (antrostomy, nasotomy, or Le Fort I osteotomy) and procedure type (1- or 2-stage) were identified for each patient. Details of the bone graft and endosseous implant reconstruction obtained from surgical dictation notes included bone graft data—type (cortical, corticocancellous, or cancellous); form (block or particulate); and donor site (ilium, mandible, maxillary tuberosity, or alveolus)—and implant data—number placed and removed; type (regular, self-tapping, wide, Mark II self-tapping); and length (7 to 20 mm). Implant location (corresponding to tooth numbers 1 to 16) was obtained from the surgical dictation or from pretreatment or follow-up radiographic imaging. Intraoperative complications or difficulties associated with the implants, bone graft, or nasal/antral cavities were recorded. Generally, details of antral membrane integrity were not recorded by the surgeon, because this bone grafting method (corticocancellous block in the antral floor) is not significantly affected by the membrane integrity. In addition, repair of a ruptured antral membrane was not attempted when it occurred in a healthy, well-ventilated antrum. Pretreatment and current surgical follow-up notes and radiographs were analyzed for all patients.

Review of the prosthetic records documented the prosthesis placement date (and subsequent months of prosthetic loading); prosthesis type (fixed, fixed-removable, overdenture); and opposing mandibular arch occlusion (natural teeth, implant-supported prosthesis, or fixed-removable partial or complete denture). The most recent prosthesis evaluation and follow-up dental records were reviewed. To be included in this study, the patients had to have 6 months of continuous prosthesis function. Delays in prosthesis fabrication as well as the need to remake or modify the prosthesis secondary to implant loss were recorded.

The status of peri-implant soft tissue, implant marginal bone level, and antral-nasal cavity health were not quantified. However, all patients were evaluated clinically and radiographically by prosthodontists, restorative dentists, or oral and maxillofacial surgeons when symptoms or physical findings indicated. Likewise, treatment related to abnormalities in these areas was noted and recorded.

After collection of medical, surgical, and prosthetic data, implant loss associated with medical or mechanical risk factors was recorded. The identified medical risk factors were postmenopause (with or without estrogen replacement), nicotine use (past and current), previous history of sinusitis requiring medical or surgical treatment, previous head and neck irradiation for malignancy, diabetes

Table 1 General, Bone Graft, and Implant Data*

	Group 1	Group 2	Group 3	Total
No. of patients (male/female)	37 (24/13)	15 (12/3)	10 (6/4)	62 (42/20)
Mean age (y) (range)	56 (18 to 73)	59 (30 to 73)	28 (15 to 65)	48 (15 to 73)
No. of recipient sites	58	32	28 (16 antral/12 nasal)	118 (74 antral/44 nasal)
Surgical type	55 one-stage, 3 two-stage	30 one-stage, 2 two-stage	2 one-stage, 26 two-stage	87 one-stage, 31 two-stage
Bone graft type	1 cortical, 57 cortico-cancellous	2 cortical, 6 cortico-cancellous, 24 cancellous	28 cortico-cancellous	3 cortical, 91 cortico-cancellous, 24 cancellous
Bone graft form	58 block	6 block, 26 particulate	28 block	92 block, 26 particulate
Bone graft donor site	57 ilium, 1 mandible	24 ilium, 6 maxillary tuberosity, 2 alveolar	28 ilium	109 ilium, 1 mandible, 6 maxillary tuberosity, 2 alveolar
No. of implants placed	139	56	53	248
No. of implants removed (nonfunctioning)	20 (2)	4 (1)	9 (0)	33 (3)
Percent of implants removed	14.4	7.0	17.0	13.3

*Eight patients were counted twice because they had both an intraoral nasotomy and antrostomy as separate procedures.

mellitus, significant cardiovascular disease, and prolonged exogenous steroid exposure. Mechanical risk factors included months of implant function; implant location (molar, premolar, or anterior sites); and opposing mandibular occlusion (natural teeth, implant-supported prosthesis, or fixed-removable partial or complete denture).

Results

This 12-year retrospective clinical review represents consecutively operated patients, with no patients lost to follow-up. One patient died of malignant disease during the study (5 years after bone graft and implant placement).

Group 1 (Antral Placement via Oral Antrostomy). *General Data.* Thirty-seven patients (24 females and 13 males) with a mean age of 56 years (range, 18 to 73) underwent 58 antral bone graft placements via oral antrostomy (Table 1, Figs 1 to 4); 55 antral grafts were accomplished in 1 stage and 3 were done in 2 stages. In the three 2-stage reconstructions, 2 antra received delayed implant placement (2 implants in each antrum) because of previous loss of implants. The third antrum was anatomically too narrow to allow simultaneous implant and block bone graft placement (implant placement was delayed 5 months, and the antral block bone graft was stabilized with wire osteosynthesis).

Bone Graft Data. All 37 patients (58 antral recipient sites) received block bone grafts (Table 1). Corticocancellous bone from the anterior iliac crest was placed in 57 antra, and a cortical graft from the anterior mandible was placed in 1 antrum. All bone grafts healed uneventfully.

Endosseous Implant Data. One hundred thirty-nine implants were placed in 58 antra (2.4 implants per antrum); 20 (14.4%) were removed from 12 antra in 10 patients, and 2 osseointegrated implants remained nonfunctional (sleeping) (Tables 1 and 2). Fourteen of the 20 removed implants in 7 patients were not osseointegrated at the time of uncovering surgery. The remaining 6 removed implants in 4 patients had functioned 8 months (1 implant supporting a fixed prosthesis), 10 months (1 implant supporting a fixed prosthesis), 30 months (2 implants supporting fixed prostheses), and 31 months (2 implants supporting an overdenture).

Implant Type. Of the implants placed, 119 were 3.75-mm routine self-tapping, 9 were 4.00-mm-wide, 8 were 3.75-mm Mark II self-tapping, and 3 were 3.75-mm regular (Table 2). Only 3 implants (3.75-mm regular) required pretapping before placement. Implant removal was 11.8% for regular self-tapping implants (14 of 119 removed), whereas implant removal was more common (but not statistically significant because of the small number placed) for the routine 3.75-mm implants (1 of 3 removed), wide 4.00-mm implants (3 of 9 removed), and Mark II 3.75-mm self-tapping implants (2 of 8 removed).

Implant Length. Of the implants placed, 8 were 10 or 13 mm long (2 or 25% removed) and 131 were 15, 18, or 20 mm long (18 or 13.7% removed).

Prosthetic Data. Thirty-seven patients received 40 dental prostheses (30 fixed, 5 fixed-removable, and 5 overdentures); 26 prostheses were opposed by natural teeth and 14 opposed a fixed implant prosthesis (Table 3). Of the 4 patients in whom implants were removed after prosthetic loading, 3 had natural teeth opposing the implants; also, 3 of the 4 patients who lost implants had implants supporting a fixed prosthesis (the fourth had an overdenture prosthesis). Of the 4 patients who lost implants after prosthesis function, 2 patients required minor prosthodontic modifications (1 patient visit), 1 patient required a prosthesis remake when 2 implants were lost after 30

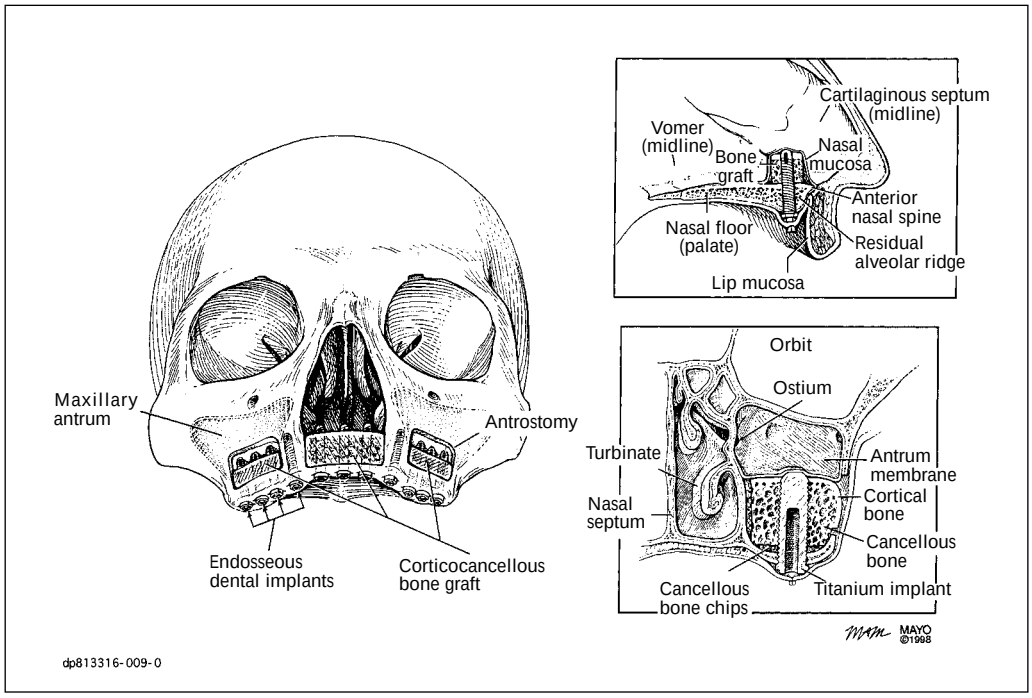


Fig 1 Drawing of 1-stage antral and nasal composite inlay bone graft procedure via an oral antrostomy or oral nasotomy surgical exposure. Note bicortical implant stabilization (residual ridge cortex and iliac bone graft cortex facing antral or nasal cavity) and preservation of antral or nasal mucosa. The endosseous dental implants serve to skeletally fix the autogenous bone graft and later function as skeletal anchorage of the dental prosthesis.

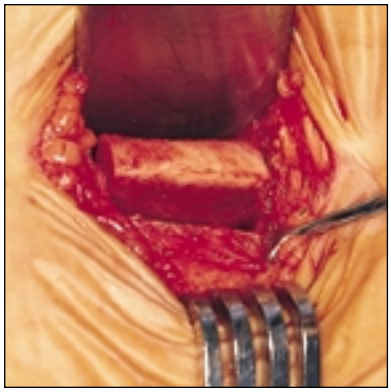
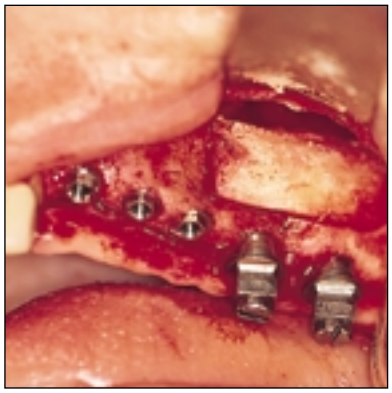
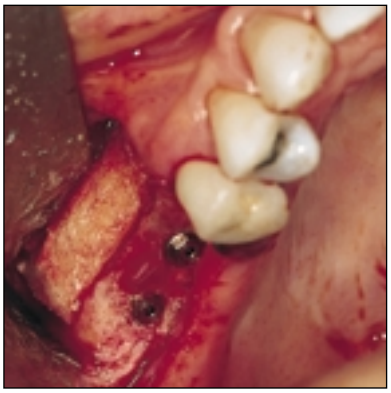


Fig 2 Surgical photo of iliac donor site for autogenous corticocancellous block bone graft; note preservation of lateral cortex of anterior iliac crest. This bone graft contains both cortical and dense cancellous bone.





Figs 3a and 3b Surgical photos of antral recipient sites in totally (*left*) and partially (*right*) edentulous patients. The cortex of the bone graft is facing laterally (antrostomy) and superiorly (antral membrane), and the cancellous portion faces the antral floor and medial wall (lateral nasal wall), where it ultimately receives its blood supply. Endosseous implants traverse through the residual ridge cortex and then through the corticocancellous block bone graft.

months of function, and the fourth patient required a prosthesis remake when 1 implant on a 2-implant reconstruction was lost after 8 months of function (a new implant was placed). One 8-month prosthesis delay occurred when 6 of 8 implants were initially nonintegrated in a bilateral antral reconstruction; 4 additional implants were placed in the healed bone graft and a complete-arch fixed-removable prosthesis was eventually fabricated.

Group 2 (Nasal Placement via Oral Nasotomy). *General Data.* Fifteen patients (12 females and 3 males) with a mean age of 59 years (range, 30 to 73) underwent 32 nasal bone graft placements

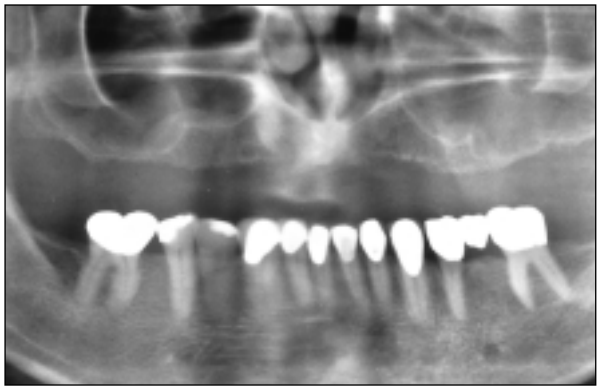


Fig 4a Pretreatment radiograph of maxillary edentulous patient (group 1) in whom a 1-stage bilateral antral-inlay bone graft was utilized. Note large pneumatized antrum.

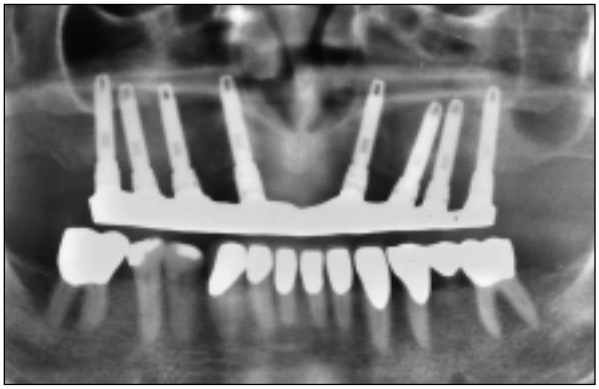


Fig 4b Posttreatment radiograph. Note new antral floor. Three endosseous implants were used for each side, and an endosseous implant was placed into each piriform rim cortex.

Table 2 Implant Data

	Group 1		Group 2		Group 3		Total	
Implant type/ length (mm)	No. placed	No. removed (mo. in function)	No. placed	No. removed (mo. in function)	No. placed	No. removed (mo. in function)	No. placed	No. removed (%)
Regular (3.75 mm)								
7	0	0	0	0	3	2 (0)	3	2
10	0	0	7	0	5	1 (0)	12	1
13	0	0	1	0	7	3 (1-0, 2-5)	8	3
15	0	0	1	0	2	0	3	0
18	0	0	0	0	6	0	6	0
20	3	1 (0)	0	0	4	0	7	1
Subtotal	3	1	9	0	27	6	39	7 (18.0)
Routine self-tapping (3.75 mm)								
10	2	0	1	0	1	0	4	0
13	6	2 (30)	2	0	3	1 (0)	11	3
15	51	3 (0)	18	0	5	1 (0)	74	4
18	60	9 (6-0, 1-10, 2-31)	15	0	15	0	90	9
Subtotal	119	14	36	0	24	2	179	16 (8.9)
Wide (4.00 mm)								
10	0	0	1	0	1	1 (10)	2	1
13	0	0	1	0	0	0	1	0
15	1	0	3	1 (10)	0	0	4	1
18	8	3 (0)	0	0	1	0	9	3
Subtotal	9	3	5	1	2	1	16	5 (31.2)
Mark II self-tapping (3.75 mm)								
13	0	0	2	2 (0)	0	0	2	2
15	8	2 (1-0, 1-8)	3	1 (0)	0	0	11	3
18	0	0	1	0	0	0	1	0
Subtotal	8	2	6	3	0	0	14	5 (35.7)
Total	139	20	56	4	53	9	248	33 (13.3)

Table 3 Prosthetic Data

	Group 1	Group 2	Group 3	Total
Prosthesis type				
Fixed	30	7	8	45
Fixed-removable	5	4	1	10
Overdenture	5	4	5	14
Complications				
Delayed treatment	1 (fixed)	1 (fixed-removable)	—	2
Modified treatment	2 (overdenture)	—	—	2
Remake	2 (both fixed)	—	1 (overdenture)	3
Opposing occlusion				
Natural teeth	26	7	9	42
Implant-fixed	14	7	5	26
Implant-overdenture	—	1	—	1
Mean mo. in function (range)	41 (6 to 98)	54.4 (9 to 123)	76.0 (6 to 139)	57.1 (6 to 139)

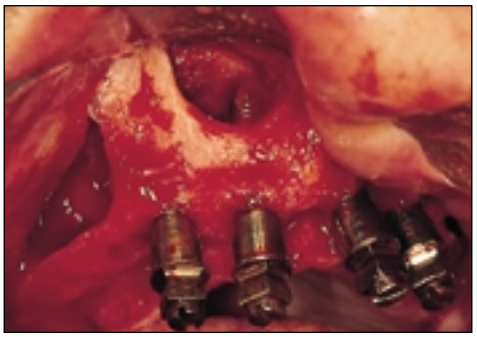


Fig 5 Surgical photo of nasal recipient site in totally edentulous patient. Note that the iliac cortical block graft forms the roof of the nasal floor reconstruction, and cancellous particulate iliac bone is packed around the endosseous implant, which is stabilized by the residual alveolar ridge (nasal floor cortex).

via an oral nasotomy exposure; 30 were accomplished in 1 stage, and 2 anatomic sites received 3 endosseous implants in the previously placed bone graft (Table 1, Figs 1, 5, and 6).

Bone Graft Data. Twenty-six recipient sites in 15 patients received particulate bone and 6 received block bone; 24 received cancellous bone, 6 received corticocancellous bone, and 2 received cortical grafts. Twenty-four of the 32 recipient sites received bone from the anterior-medial ilium (11 of 15 patients). The alternate donor site was the maxillary tuberosity (particulate bone) in 6 sites (3 patients) and the maxillary alveolus (particulate bone) in 2 sites (1 patient). All bone grafts in the 32 recipient sites healed uneventfully.

Endosseous Implant Data. Fifty-six implants were placed in 32 recipient sites, 1 was nonfunctional, and 4 implants (7%) were removed at uncovering surgery in 1 patient (Tables 1 and 2). Three implants were subsequently placed successfully as a secondary procedure (prosthesis delay).

Implant Type. Of the implants placed, 36 were 3.75-mm self-tapping, 9 were regular (required pretapping), 5 were 4.00-mm-wide, and 6 were 3.75-mm Mark II self-tapping (Table 2). Implant survival was 100% for the regular and routine self-tapping implants (45 placed). The implant survival rate was lower (but not statistically significant) for the 4.00-mm-wide implants (1 of 5 removed) and 3.75-mm Mark II self-tapping implants (3 of 6 removed).

Implant Length. Of the implants placed, 41 were 15 or 18 mm long (2 implants or 5% removed) and 14 implants were 10 or 13 mm long (2 or 14.3% removed) (Table 2). Of the 4 implants removed at implant uncovering, 3 were 3.75-mm Mark II self-tapping and 1 was 4.00-mm-wide.

Prosthetic Data. Fifteen patients received 15 prostheses (7 fixed, 4 fixed-removable, and 4 overdentures) (Table 3). Opposing occlusion was natural teeth in 7 patients, fixed implant prosthesis in 7 patients, and overdenture prosthesis in 1 patient, respectively. The 1 patient who lost 4 implants functioned against natural mandibular teeth, and an 18-month prosthesis delay occurred (the interim prosthesis was partially implant-supported).

Group 3 (Nasal-Antral via Le Fort Downfracture). *General Data.* Ten patients (6 females and 4 males) with a mean age of 28 years (range, 15 to 65) underwent a nasal (12 sites) or antral (16 sites) bone graft reconstruction via a Le Fort I osteotomy exposure (Table 1, Figs 7 to 10). In contrast to patients in groups 1 and 2, all but 1 patient (2 recipient sites) received a 2-stage procedure (implants were placed 6 months after osteotomy). Eight patients had skeletal malocclusion (vertical and horizontal maxillary deficiency) that was secondary to trauma (4 patients) or

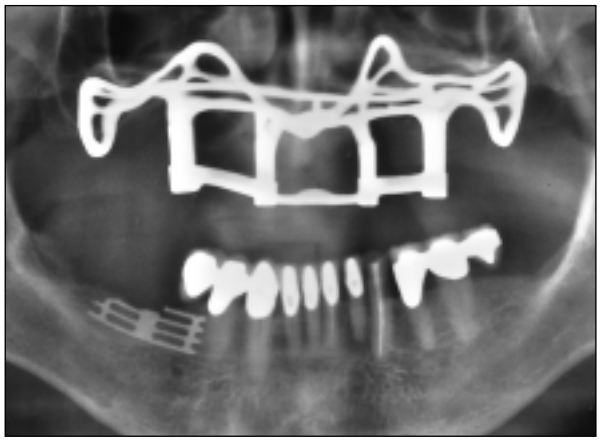


Fig 6a Pretreatment panoramic radiograph of maxillary edentulous patient (group 2) in whom a 2-stage bilateral nasal inlay bone graft was utilized. This patient originally presented with bilateral antral sepsis and oral-antral fistula secondary to a nonintegrated subperiosteal implant. Antral debridement, nasal antrostomy, and closure of oral-antral fistula were performed 3 months prior to the bone graft procedure. Note total lack of antral floor on the left.

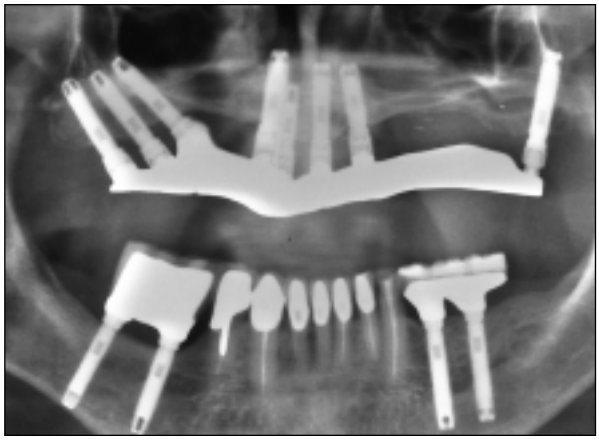


Fig 6b Posttreatment panoramic radiograph. A left pterygoid implant was placed and satisfied the prosthesis bone anchorage required due to the lack of antral floor. The right posterior implants were placed in an antral inlay bone graft, and the anterior implants were placed in a nasal (bilateral) inlay bone graft.

genetic (4 patients). One patient had advanced bone loss secondary to long-term removable denture use. All 10 patients had bone compromise in edentulous sites that required endosseous implant reconstruction.

Bone Graft Data. All 10 patients (28 recipient sites) received corticocancellous block bone grafts from the anterior-medial ilium (Table 1). All bone grafts healed without complication; however, the first 4 operated patients received osteotomy and bone graft transosseous wire synthesis rather than rigid internal miniplate osseosynthesis stabilization, which resulted in a reduction in bone graft volume during bone graft healing (ultimately, fewer and shorter endosseous implants were placed in these patients). Healing of bone graft and osteotomy sites was significantly improved in the last 6 operated patients, where osteotomy and bone graft internal rigid miniplate osteosynthesis were utilized.

Endosseous Implant Data. Fifty-three implants were placed in 28 recipient sites, and 9 were removed (17% implant failure) from 6 patients (Tables 1 and 2). In 6 patients with miniplate rigid stabilization, implant removal was 3.6% (1 of 28 removed); in contrast, implant removal was 32% (8 of 25 removed) in the remaining 4 patients with wire osteosynthesis stabilization. Seven implants (5 patients) were removed at uncovering surgery and 2 implants were removed after 5 months of function. Implant removal was similar in the nasal (4 implants) and the antral (5 implants) recipient sites. Two patients lost 6 of the 9 lost impants (3 each); both of these patients received transosseous wire osteotomy and bone graft stabilization. Opposing occlusion of removed implants was natural teeth for 8 patients and fixed implant prosthesis for 1 patient. The 2 implants lost during prosthetic function opposed mandibular natural teeth.

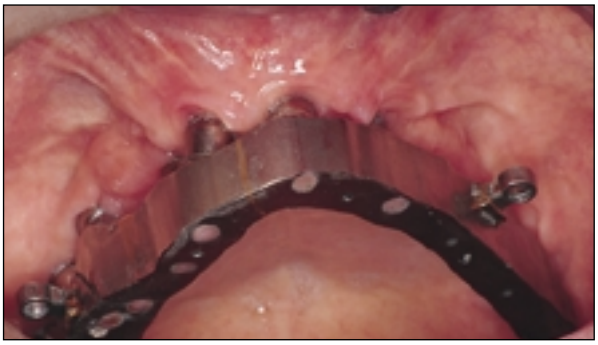


Fig 6c Clinical photo of implant-connecting milled bar.

Implant Type. Of the implants placed, 24 were 3.75-mm self-tapping, 27 were regular 3.75-mm (required pretapping), and 2 were 4.00-mm-wide (Table 2). Implant removal was 8.3% for routine self-tapping implants and 22.0% for regular implants. Twenty-seven implants (51%) required pretapping, in contrast to groups 1 and 2, where only 6% of implants required pretapping.

Implant Length. Of the implants placed, 20 were 10 or 13 mm long (40% were removed) and 33 were 15, 18, or 20 mm long (3% were removed)

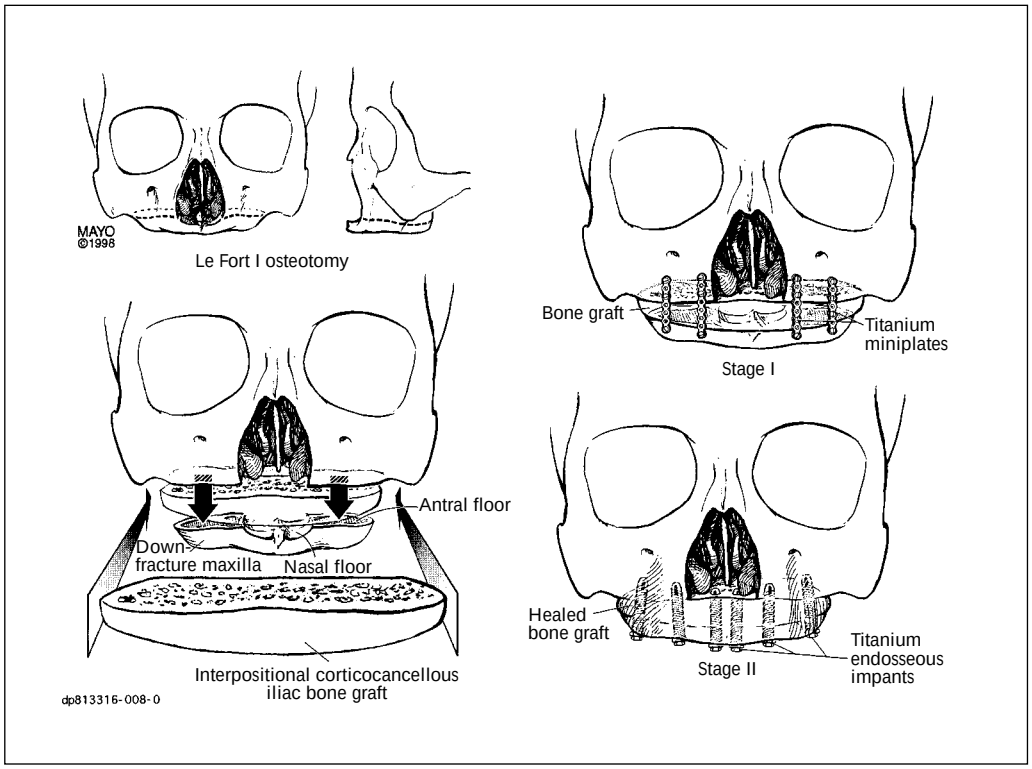
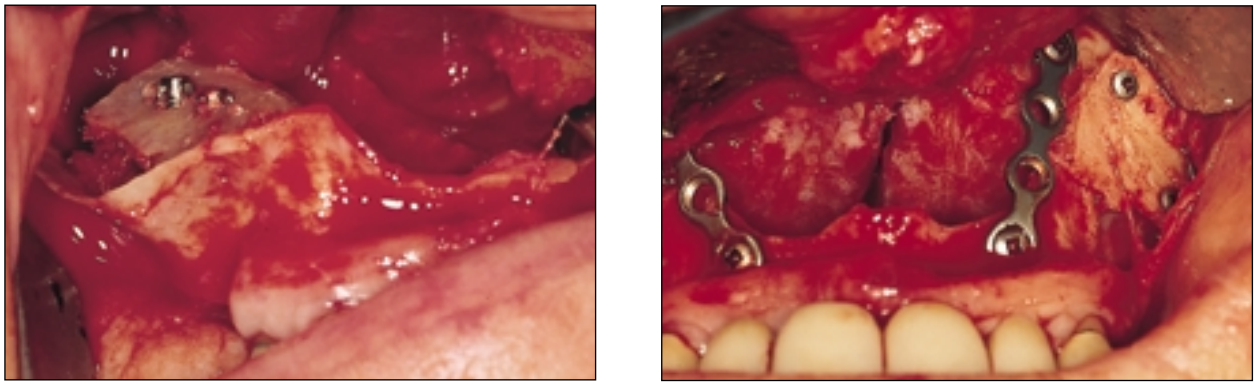


Fig 7 Drawing of 2-stage antral/nasal composite interpositional iliac bone graft procedure via a Le Fort I osteotomy downfracture surgical exposure. Note internal rigid stabilization of corticocancellous block graft and mobilized maxilla via titanium miniplates and secondary placement of endosseous dental implants for dental prosthesis skeletal anchorage.



Figs 8a and 8b Surgical photos of downfractured maxilla in a 1-stage procedure. Note the antral bone graft with 2 penetrating endosseous implants (*left*) and the titanium miniplate stabilizing the downfractured maxilla (*right*). The 1-stage (versus 2-stage) Le Fort I osteotomy procedure is infrequently utilized.

(Table 2). Only two 4.00-mm-wide implants were placed in this group (1 was removed).

Prosthetic Data. Ten patients received 14 dental prostheses (8 fixed, 1 fixed-removable, and 5 overdentures) (Table 3). Nine prostheses occluded with natural mandibular teeth and 5 prostheses occluded with a fixed mandibular implant prosthesis. The 2 implants that were lost after prosthesis function were free-standing implants under a magnet-retained overdenture prosthesis that opposed natural teeth; this patient eventually received 4 additional implants and a fixed-removable dental prosthesis (the third patient in this series required a prosthesis remake related to implant removal).

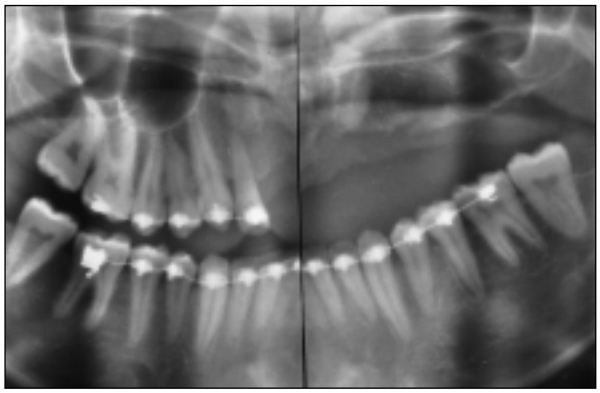


Fig 9a Pretreatment panoramic radiograph of maxillary partially edentulous patient with asymmetric skeletal Class III malocclusion secondary to genetic disorder (odonto-dysplasia).

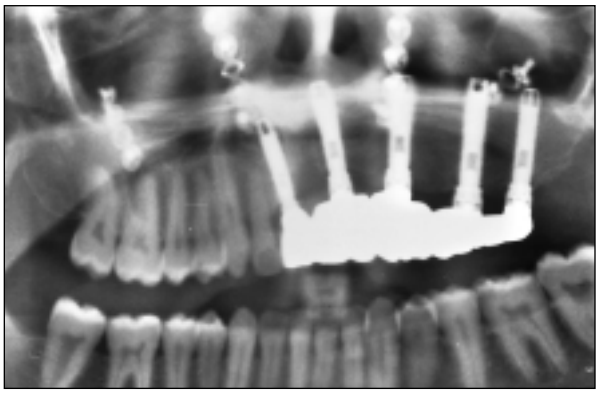


Fig 9b Posttreatment panoramic radiograph. The patient received a 2-stage Le Fort I osteotomy for maxillary repositioning and simultaneous placement of the left antral floor iliac bone graft. Endosseous implants were placed 6 months later.

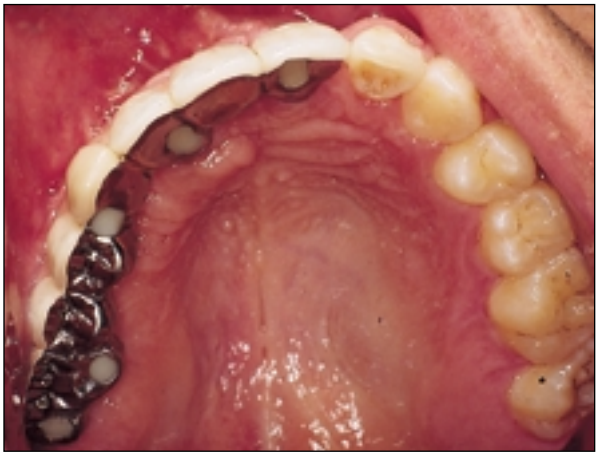


Fig 9c Posttreatment fixed continuous dental prosthesis.

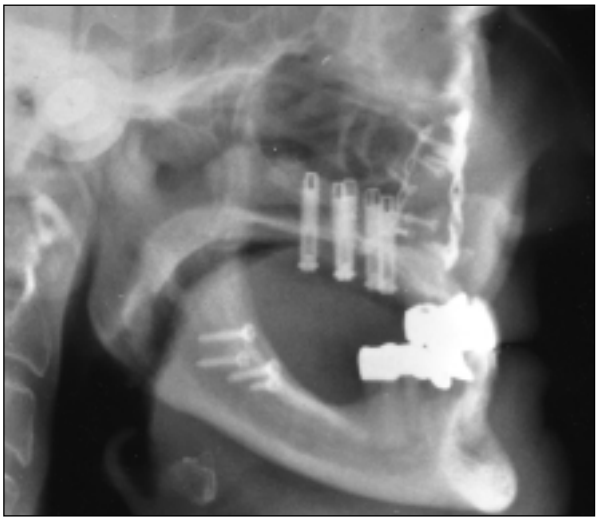


Fig 10 Posttreatment lateral cephalometric radiograph of patient who received a 1-stage Le Fort I osteotomy downfracture exposure for placement of antral-inlay block bone grafts and simultaneous placement of endosseous dental implants. This patient also required a vertical (10 mm) and horizontal (5 mm) maxillary advancement for correction of maxillary deficiency and Class III skeletal malocclusion. Note titanium miniplates for osteotomy stabilization and endosseous implants for bone graft stabilization and eventual skeletal anchorage for a bilateral fixed dental prosthesis.

Medical Risk Factors Data. *Menopause Status.* Twenty-nine of 54 patients were postmenopausal, and 13 of these patients were receiving estrogen replacement at the time of implant surgery (Table 4). Implant removal was 11.1% for all 29 patients (117 implants placed, 13 removed); 9.2% for the 16 patients (76 implants placed, 7 removed) who did not receive estrogen replacement; and 14.6% for the 13 patients (41 implants placed, 6 removed) who received estrogen replacement.

Nicotine Use. Twenty patients had previously used nicotine (smoking) and 8 of these patients were using nicotine (smoking) at the time of implant surgery (Table 4). Implant removal was 10.5% (105 placed, 11 removed) for all 28 patients; 21.9% (32 placed, 7 removed) in the 8 currently smoking patients; and 5.5% (73 placed, 4 removed) in the 20 patients who had smoked in the past.

Sinusitis. Eight patients had histories of sinusitis that had required previous medical or surgical treatment; implant removal was 24.3% (37 placed, 9 removed) (Table 4). In group 3 (4 patients) implant loss was 32.0% (25 placed, 8 removed). In group 1 (4 patients) implant loss was 8.3% (12 placed, 1 removed).

Table 4 Medical Risk Factors and Implant Data

	Group 1		Group 2		Group 3		Total	
Medical risk factors	No. placed	No. removed (%)	No. placed	No. removed (%)	No. placed	No. removed (%)	No. placed	No. removed (%)
Postmenopause								
Estrogen replacement	23	5 (21.7)	12	0	6	1 (16.6)	41	6 (14.6)
No estrogen replacement	43	4 (9.3)	19	0	14	3 (21.4)	76	7 (9.2)
Nicotine used								
Past	45	3 (6.6)	17	0	11	1 (9.1)	73	4 (5.5)
Current	17	4 (23.5)	6	0	9	3 (33.3)	32	7 (21.9)
Sinusitis*	12	1 (8.3)	0	0	25	8 (32.0)	37	9 (24.3)
Irradiated†	7	0	4	0	0	0	11	0 (0)
Diabetes mellitus	6	0	0	0	5	0	11	0 (0)
Total	139	20 (14.4)	56	4 (7.0)	53	9 (17.0)	248	33 (13.3)

*Patients with past histories of antral disease requiring medical or surgical treatment.
†Patients with past histories of preimplant tumoricidal irradiation therapy for head and neck malignancy (patients with 55 cGy and 61 cGy, respectively).

Following are details of the 8 patients with histories of sinusitis. In group 1, 2 patients had received treatment for antral disease and were free of infection at the time of antral grafting and implant placement, and 2 patients required antral surgery (removal of subperiosteal implant, infected tooth, and oral-antral fistula closure) 3 months before bone grafting and implant placement. In these 4 patients, only 1 implant was removed. In group 3, 4 patients had a history of chronic sinusitis; 3 patients had chronic sinusitis secondary to previous midface trauma and the fourth patient received wire osteosynthesis/bone graft stabilization. Thus, these group 3 patients had additional significant risk factors that increased their chances for implant failure (32.0%).

Irradiation. Two patients received external beam irradiation to the head and neck for malignant disease (1 patient received 55 cGy, the other received 61 cGy). The 11 implants placed in maxillary irradiated bone remained functional throughout the study.

Diabetes Mellitus. Two patients had long-standing, diet-controlled diabetes mellitus. The 11 implants in these 2 patients remained functional throughout the study.

Other Medical Risk Factors. None of the patients had significant peripheral cardiovascular disease, excessive exposure to exogenous steroids, or insulin-dependent diabetes mellitus.

Mechanical Risk Factors. *Months of Implant Function.* Twenty-five of 33 removed implants were removed at implant uncovering surgery; 4 additional implants were removed less than 12 months after prosthesis loading, and 4 implants were removed after 30 months (2 patients) and 31 months (2 patients) of prosthesis loading (Table 5).

Failed Implant Location. Eighty-five implants were in molar locations, and 13 (15.3%) were removed. A majority of the molar implants placed (76) and 12 of the 13 removed molar implants were in group 1. Ten of the 13 removed implants were removed at uncovering surgery, and the 3 remaining implants functioned for 8, 30, and 31 months, respectively.

Eighty-eight implants were in premolar locations, with 12 (13.5%) removed. A majority of the premolar implants placed (61) were in group 1 and the remaining 27 were in group 2; implant removal percentage was equal in each group (group 1, 13.1%, and group 2, 14.8%). Seven of the 12 removed implants were removed at implant uncovering, and the remaining 5 functioned for 5, 5, 10, 30, and 31 months, respectively.

Seventy-five implants were placed in anterior locations and 8 (10.6%) were removed. A majority of the 56 anterior implants placed were in group 2 (8 were lost for a 7.1% loss rate). In contrast, anterior implant loss was 23.5% in group 3 (4 of 17 removed at uncovering surgery).

Opposing Occlusion. One hundred fifty-seven implants were opposed by mandibular natural teeth (29, or 18.5%, were lost) and 91 implants opposed a mandibular implant-supported prosthesis (4, or 4.4%, were lost).

Discussion

All 74 antral recipient sites received block bone grafts regardless of the surgical exposure approach (oral antrostomy or Le Fort I osteotomy). Of the 32 nasal bone grafts that were performed via the oral nasotomy exposure, 26 received particulate

Table 5 Mechanical Risk Factors and Implant Data

Mechanical risk factors	Group 1		Group 2		Group 3		Total	
	No. placed	No. removed (%)	No. placed	No. removed (%)	No. placed	No. removed (%)	No. placed	No. removed (%)
Location*								
Molar	76	12 (15.8)	0	0	9	1 (11.0)	85	13 (15.3)
Premolar	61	8 (13.1)	0	0	27	4 (14.8)	88	12 (13.5)
Anterior	2	0	56	4 (7.0)	17	4 (23.5)	75	8 (10.6)
Opposing occlusion								
Natural teeth†	93	17 (18.3)	25	4 (16.0)	39	8 (20.5)	157	29 (18.5)
Current implant prosthesis‡	46	3 (6.5)	31	0 (0)	14	1 (7.1)	91	4 (4.4)
Total	139	20 (14.4)	56	4 (7.0)	53	9 (17.0)	248	33 (13.3)

*Molar = teeth 1 to 3 and 14 to 16; premolar = teeth 4, 5, 12, and 13; anterior = teeth 6 to 11.
†Natural teeth includes patients with fixed or removable partial denture.
‡Current implant prosthesis includes both mandibular fixed and overdenture implant prosthesis. There were no complete removable dentures opposing the maxillary implant reconstruction.

bone and 6 block grafts. Three clinical/surgical factors were involved in the selection of block versus particulate bone grafts for the floor of the antral or nasal cavities.

The first is that the antral mucosa can be easily torn and almost impossible to repair, whereas the nasal mucosa is less easily torn and relatively easy to repair. When particulate bone grafts are placed, they need to be anatomically confined by either the nasal or the antral mucosa. Therefore, the surgeon can choose to use block or particulate bone in the nasal sites (where the membrane is consistently intact) rather than in the antral sites (where the membrane is frequently not intact). When the membrane is not intact, the surgeon must use the block bone grafts, which can be stabilized in the floor with endosseous implants, wires, or miniplates, unless an allogeneic or homologous membrane is used to confine or stabilize the particulate bone graft. The corticocancellous blocks utilized in this series had the dense cortex facing the open antrum and the porous cancellous portion facing the antral floor and lateral nasal wall, where the bone graft ultimately receives its blood supply (Fig 1). It is hypothesized that limiting (or eliminating) allogeneic or homogenous materials in the frequently exposed antral cavity has merit, and the use of such materials was not part of the initial (and current) surgical protocol in this patient population.

The second factor is that all of the patients in this study had major bone deficits resulting in a very thin, low-density antral floor (residual alveolus) of 1 to 3 mm in height. However, the nasal floor is frequently thicker (3 to 5 mm) and has higher-density bone than does the antral floor. In the thinner and less dense antral floor bone, very little endosseous implant stabilization can be expected, whereas in the nasal floor, the residual bone consistently provides adequate initial implant stabilization. Accordingly, the surgeon who wishes to provide a 1-stage reconstruction (which is highly desirable for practical and biologic reasons) can select a cortical or cancellous particulate graft in the nasal sites, but must use a cortical or corticocancellous block bone graft in the antral sites to achieve rigid bicortical stabilization of the endosseous implant. If the surgeon places very small antral grafts in 1- or 2-tooth size recipient sites, a 2-stage particulate bone graft technique may be used because the residual bone is usually of better quality and larger quantity in the partially edentulous patient and antral membrane elevation is usually limited. A longer treatment time (12 rather than 6 months) is also more acceptable in the partially edentulous patient than in the totally edentulous patient. The only 2-stage antral reconstructions in the present study involved 2 patients in whom secondary implants replaced previously removed implants and another patient in whom the anterior extension of the antrum was too narrow for simultaneous implant placement.

The third factor is desirability of providing 1-stage rather than 2-stage endosseous implant reconstruction in the totally edentulous patient. The cortical or corticocancellous block allows the possibility of a 1-stage procedure by providing bicortical implant stabilization, especially in the antral recipient sites, as noted previously. A 1-stage procedure is desirous, as a short healing period of 4 to 6 months (rather than 10 to 12 months) is required prior to bone graft loading via a prosthesis. The longer healing period (10 to 12

months) allows bone graft resorption to occur in an anatomic site (antral floor) where there is very little if any functional loading. Loading the bone graft/endosseous implant (composite bone graft) reconstruction at 6 months after placement will provide early functional stimulation to the remodeling bone graft (provided uncomplicated healing has occurred before this time). The totally edentulous patient may use an interim complete denture, which risks early loading of the implants (as in any maxillary reconstruction in which the head of the implant exits the residual ridge bone). A 12-month interim prosthesis loading period is less desirable than a 6-month period, not only from a biologic standpoint (as noted previously) but also from functional and esthetic standpoints. In 2 patients, prosthesis placement was delayed because of implant loss at stage 2 surgery, requiring placement of additional implants. In both patients, the remaining osseointegrated implants were utilized to stabilize the interim prosthesis during the additional healing time, as well as to provide functional load to the previously placed remodeling autogenous bone grafts.

Bone grafting of the nasal and antral floors via the Le Fort I downfracture exposure for eventual endosseous implant placement was first described by Keller et al[3] in 1987. Endosseous implants were placed as a secondary procedure (2-stage procedure) after osteotomy and bone graft healing. Three of the 4 patients presented with posttraumatic maxillary retrognathia, and the fourth patient exhibited vertical maxillary deficiency secondary to long-term bone loss secondary to nonphysiologic mucoperiosteal loading of a removable denture. The Le Fort I downfracture exposure technique was used to graft deficient bone in endosseous implant sites and to correct simultaneously the coexisting maxillary skeletal malocclusion. Two of the 4 patients described in the 1987 report and the 6 additional patients included in this report were partially edentulous, which documents the indication for this procedure; that is, partially edentulous patients with skeletal malocclusion and compromised bone in the alveolar bone sites require endosseous implants for skeletal support of a dental prosthesis. Totally edentulous patients are better treated with the complete-arch, 1-stage onlay block bone graft[9] or the nasal/antral 1-stage inlay block bone graft[1] procedure. In 1989 Sailer[4] reported bone grafting of the nasal and antral floor via the Le Fort I downfracture exposure with simultaneous endosseous implant placement (1-stage procedure) in 5 totally edentulous patients. In 3 of the 5 patients, all 21 implants were described as "perfectly healed" when the implants were uncovered. The 1-stage procedure described by Sailer[4] is an improvement for the totally edentulous patient. However, as noted previously, this procedure is rarely used by the authors for the totally edentulous patient.

Implant loss in this current study was greatest in the Le Fort I osteotomy downfracture exposure group; however, in the last 6 treated patients, when rigid internal fixation was utilized for osteotomy and bone graft stabilization, only 1 implant was removed. The endosseous implants in group 3 were placed 6 months after bone graft placement in 9 of 10 patients; implant placement in the downfractured maxilla is technically difficult, and additional incisions may be needed for the Le Fort I osteotomy (sulcus) and endosseous implant placement (ridge crest). In this series, group 3 patients were often partially rather than totally edentulous. Utilizing this surgical approach for posttraumatic or congenitally retrognathic patients with partial edentulism requires precise implant placement for prosthodontic reconstruction. Also, the downfractured maxilla is associated with a period of significant ischemia, which may compromise the biologic process of osseointegration of implants. In addition, the interpositional bone graft in these patients is used for stabilization of the horizontally and vertically advanced maxilla, and as such, is under definite but minimal functional load during the healing period. The graft should theoretically retain its position and bulk (in contrast to the nonstimulated inlay nasal or antral bone graft) for later secondary implant placement. Bone graft healing in the first 4 patients of group 3 was compromised because stabilization was accomplished with nonrigid wire osteosynthesis, and this compromise was reflected in the generally shorter implant length, with a higher failure rate in these 4 patients. This group also included 3 patients with posttraumatic retrognathia in whom chronic antral sepsis existed before treatment, and sepsis was encountered during the Le Fort I osteotomy in all 3 patients. Antral debridement along with establishment of dependent antral drainage is provided during the osteotomy procedure when an infected or poorly ventilated (or both) antrum is encountered. These adjunctive antral procedures should allow for uncomplicated osteotomy and interpositional bone graft healing.[10]

Implant loss was greater in the antrum than in the nasal recipient sites, because the endosseous implants in the nasal region received a significant percentage of their stabilization (100% when particulate bone grafts are used) from the residual

bone, in contrast to the endosseous implants in the antral recipient sites, in which the implants received most of their support from the block bone graft. Implant loss in this compromised group of patients would be expected to be much higher if implant reconstruction was attempted without simultaneous bone grafts. An initial attempt to avoid bone grafting in 8 significantly compromised patients resulted in a high rate of implant failure (35 of 42 implants removed[11]). When it occurs in the compromised maxilla, implant loss tends to involve multiple implants in the same patient, as in this series; 25 of the 33 removed implants were in 8 patients. Additional implants are generally placed in compromised maxillary patients in anticipation of increased implant loss. This practice accounted for the low incidence of prosthetic construction delay (3.4%) or need to remake prostheses (4.9%) in spite of a 13.3% implant removal during the 12-year study.

Because particular patients tend to lose multiple implants, implant loss should be evaluated relative to potential medical and biomechanical risk factors. Twenty-nine patients were postmenopausal, and the implant removal rate in this group was lower than for all patients. However, the 13 postmenopausal patients who received estrogen replacement had a higher implant removal percentage than did the 16 postmenopausal patients who did not receive replacement therapy. Two publications[12,13] reviewed the literature relative to the advisability of placing endosseous implants into bone of reduced density (reduced mineralization or osteoporotic), which is present in a significant percentage of postmenopausal women. Neither review found scientific evidence that would contraindicate endosseous implants for osteoporotic women[12] or for women of postmenopausal age.[13] However, a recent study[14] documented a reduced relative bone mass density (89.2%) in a group of 11 patients who had advanced maxillary bone compromise reconstructed with a 1-stage bone graft and who experienced implant loss of 43% as compared to a matched group, who experienced implant loss of only 6% where bone mass density was significantly higher (98.6%). Another recent study[15] documented increased implant loss in female patients who received bone grafts than in male patients who received bone grafts, which was considered to be related to the difference in the quality of bone grafts (reduced bone density in female patients). Martin et al[16] studied estrogen-deficient, ovariectomized beagle dogs, and Mori et al[17] studied ovariectomized, low-calcium-diet beagle dogs, and both groups demonstrated delayed bone formation[17] and reduced push-out strength[16] of endosseous implants. However, osseointegration of the implants occurred consistently.

Most clinicians who place endosseous implants concur that patients with advanced maxillary bone loss will (regardless of age) typically demonstrate residual bone of reduced mineralization, particularly in the posterior regions. In contrast, the same group of patients who have advanced bone loss of the mandible will characteristically demonstrate residual bone of increased mineralization. Generally, endosseous implant loss will be much higher in the compromised non–bone-grafted maxilla[18] than in the compromised non–bone-grafted mandible.[19] This difference in bone mass maintenance or implant survival in the same patients with advanced maxillary or mandibular bone loss suggests a functional cause rather than an age, gender, or metabolic status etiology. This functional status factor was dramatically demonstrated in a recent series[19] of 52 non–bone-grafted patients, in whom an implant survival rate of 93% and an increase in mandibular body bone height of 31% (average height went from 6.5 mm to 8.5 mm) was found; the patients had advanced mandibular bone loss that was reconstructed solely with endosseous implants. This increased bone formation after increased functional loading (patients went from complete dentures to complete-arch fixed implant prostheses) has not been observed in the maxilla, possibly because of its fixed anatomic position in the midface and its functional status relative to muscle attachments. Advanced alveolar and basal bone loss in edentulous maxillae and mandibles is frequently related to nonphysiologic mucoperiosteal loading from a removable denture.

Age, gender, nicotine exposure, and hormonal status are theoretical factors that likely have a modulating role.[13,14,20,21] In a recent study[19] of advanced mandibular bone loss (52 non–bone graft and 9 bone graft), 60 of the 61 patients were female, and 48 of the 61 were over age 50 (mean age of 57) when they presented for implant reconstruction. Because bone mass increased in the 52 female non–bone graft patients after increased endosseous prosthesis functional loading (implant-supported vs mucoperiosteal-supported prosthesis), the positive functional aspects of this model apparently have a greater role than do age, gender, or hormone-related aspects in maintenance of mandibular bone mass.

The use of nicotine in the implant population is common and is associated with reduced bone mass density and increased implant loss.[14,20,21] Many clinicians refuse to place implants unless nicotine use is

discontinued. Results from this patient series seem to corroborate this assessment, inasmuch as the 8 patients who were current smokers had an implant removal rate of 21.9%. The 20 patients who had histories of nicotine exposure and had ceased smoking had a low implant removal rate (5.5%).

A history of chronic sinusitis was noted in 8 antral bone graft patients (17.0%). In four group 1 patients, antral sepsis was treated successfully before bone grafting, and implant placement and implant percentage removal was less than that of the overall series. However, four group 3 patients had untreated sinusitis from previous midface trauma (3 of 4 patients) and other risk factors (wire osteosynthesis), which resulted in a much higher rate of implant loss. Improved presurgical diagnosis in this group would have been beneficial.

Two patients who had received external beam irradiation to the head and neck for malignant disease experienced uncomplicated bone graft and implant healing, which corresponds with previous experience in the irradiated mandible.[22,23] Implant and bone graft healing was also uncomplicated in 2 adult-onset diabetic patients.

Biomechanical risk factors included the time of prosthesis function, location of the implants, and presence of opposing occlusion. Because 25 of 33 lost implants were removed at stage 2 surgery, achieving osseointegration seems to be more significant than does maintaining osseointegration during function. This finding is further substantiated because only 3 of 54 patients required prosthesis remake subsequent to implant removal, and only 2 patients required significant prosthesis modification associated with implant removal. In addition, only 2 of 54 patients lost enough implants to require placement of additional implants to satisfy prosthetic loading requirements.

The location of endosseous implants relative to implant loss indicated that the percentage of lost implants was highest in the molar region and lowest in the anterior region. One noticeable exception to this trend existed in the group 3 patients, in whom there was a 23.5% rate of implant removal in the anterior region; however, this difference was related to other risk factors (nonrigid osteotomy and bone graft stabilization) in this group.

Implant removal related to the opposing occlusion revealed a much higher failure rate when implants opposed natural teeth rather than opposing implant-supported prostheses. Four of 5 patients who lost implants after functional loading had implant prostheses functioning against natural teeth. Because loss of implants in this patient material occurred primarily before prosthesis loading at stage 2 surgery, the occlusion or interim prosthesis type becomes an important consideration. Fortunately, an interim functioning prosthesis was frequently not present in those patients who had simultaneous complete-arch mandibular implant reconstruction.

Most of the implants placed were self-tapping (179 of 248 placed), and the rate of loss was the lowest (8.9%) with this implant type. The high rate of implant loss found for the 4.00-mm-wide and 3.75-mm Mark II self-tapping implants was not statistically significant because of the low numbers of implants placed; however, the large difference from the routine 3.75-mm self-tapping implants is of concern. Because of early unfavorable experience with the Mark II 3.75-mm self-tapping implant in a 1-stage antral/nasal bone grafting procedure, its use is not recommended for this clinical situation. Since bicortical implant stabilization is critical in the sinus inlay graft, the modified tip of this implant may not provide the needed cortical thread engagement of the cortex portion of the corticocancellous block graft that the routine self-tapping implant provides.

Implant length was investigated as a risk factor. Comparison of implant percentage loss in the shorter implant (26%) versus the longer implants (8% loss) revealed a striking difference. This increased loss of shorter implants has been previously described in compromised maxillary bone treated without adjunctive bone grafting.[11,18] The Type IV bone typically found in these patients is described as a "thin layer of cortical bone surrounding a core of low-density trabecular bone."[24p202] This Type IV bone was typically encountered in the posterior maxillae of patients in groups 1 and 3. Analysis of data regarding loss of implants after prosthetic loading in relation to implant length or type did not provide meaningful data because of the few implants lost after prosthesis loading.

Conclusions

Patients in this population who had compromised maxillary bone reconstructed with autogenous bone grafts, endosseous implants, and dental prostheses demonstrated:

1. Bone graft healing was highly successful (100%) and endosseous implant survival was acceptable (86.7%). Dental implant prosthetic rehabilitation was also highly predictable, as only 3 of 69 prostheses required retreatment secondary to implant loss.

2. A higher rate of implant loss was seen in the Le Fort I downfracture group, particularly in patients treated with wire versus miniplate osteosynthesis.
3. Medical risk factors seem to contribute to implant loss in patients who smoke, in postmenopausal patients receiving estrogen replacement, and in patients with a history of antral sepsis.
4. The effect of mechanical risk factors was inconclusive, as a majority of the lost implants were not functionally loaded; however, implant loss was much higher when the patient had opposing natural teeth rather than an opposing implant-supported prosthesis.
5. Implant loss was related more frequently to failure to achieve initial osseointegration than to failure to maintain osseointegration during function.
6. Endosseous implant type and length affected implant survival.

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