Histomorphometric Evaluation and Clinical Assessment of Endosseous Implants in Iliac Bone Grafts with Shortened Healing Periods

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Purpose: *In the present study solid monocortical hipbone onlay grafts of the maxilla were analyzed histologically after a healing period of 3 months. The clinical success of the implants placed in the grafted bone was evaluated.* ***Materials and Methods:*** *Nineteen patients underwent augmentation with avascular iliac bone. A 2-stage procedure was performed with a 3-month healing period between graft and implant placement. At implant placement bone biopsy samples were taken at the proposed implant sites.* ***Results:*** *Of the 117 implants placed, 1 was not osseointegrated at the time of abutment connection. No implants were lost after loading during an observation period of up to 3 years. Clinical appearance of the augmented bone after 3 months showed a dense cortical layer with good blood perfusion. Histologic specimens were analyzed quantitatively and showed an average of 43.2% newly formed bone.* ***Discussion:*** *Histomorphometry showed that the amount of newly formed bone after 3 months was comparable to that found after a healing period of 4.5 months. The clinical success of the implants placed after the shortened healing period was comparable to that found in nonaugmented bone.* ***Conclusion:*** *This study showed that after avascular iliac bone grafting, 3 months of revascularization was sufficient to ensure the secure placement of dental implants in second-stage surgery for this patient population.* INT J ORAL MAXILLOFAC IMPLANTS 2006;21:392–398

Key words: *dental implants, iliac bone grafting, onlay bone grafting*

Severe atrophy of the maxilla can be successfully treated with augmentation procedures in combination with dental implants. Success in grafting avascular iliac bone in extremely resorbed maxillae has been well documented. Long-term survival rates range from 67% to 96% using various surgical procedures (a horseshoe onlay graft, inlay grafts, and LeFort I osteotomy with interpositional bone graft) and implant systems.[1–3]

The timing of implant placement in conjunction with major bone augmentation is still a matter of discussion. It has been hypothesized that secondary implant placement may be preferable in the long term, since revascularization of the graft will result in better primary stability and osseointegration.[1] In patients with severe atrophy (residual bone volume < 5 mm) it is advantageous to place the implants in a secondary procedure, since primary stability of the implants cannot be ensured. Moreover, ideal placement of implants is easier in a secondary procedure, resulting in a more esthetic result.

Time lapses to secondary implant placement reported in the literature have ranged from 4 to 6 months,[1,4–6] but to date no data are available to support this waiting period. As bone grafts readily resorb without implants,[7] it seems advisable to place them as early as possible. Histomorphometric analysis has shown that ongoing major bone remodeling can already be seen after 4.5 months.[4,8]

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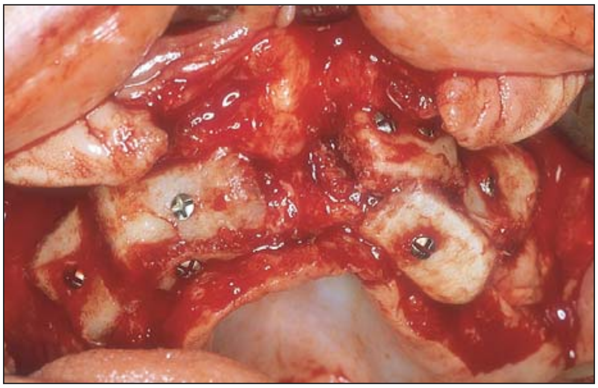

Fig 1a Occlusal view of the iliac bone blocks fixed to the maxillary residual ridge.

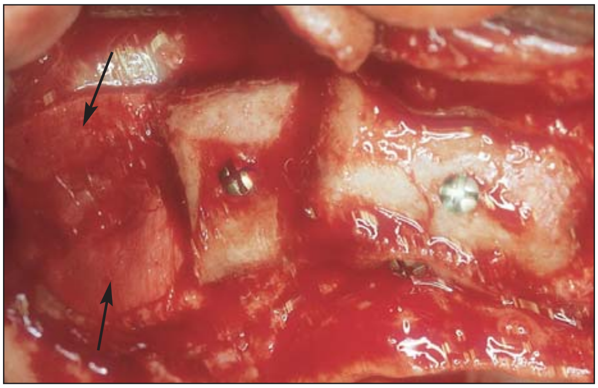

Fig 1b The access to the maxillary sinus in the lateral wall was covered with a resorbable membrane *(arrows)* after augmentation of the sinus with cancellous hipbone.

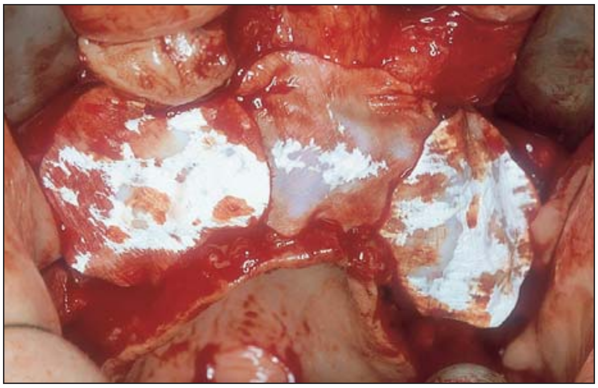

Fig 1c The bone blocks were covered with a resorbable membrane to avoid ingrowth of the periosteum into the gaps.

Since all seek to shorten treatment time while ensuring a predictable result and a high success rate, the quality of grafted iliac bone after 3 months and the clinical success of implants with a shortened healing period of 3 months were investigated.

MATERIALS AND METHODS

Patients and Surgical Procedures

From 2001 to 2004, 19 patients (14 women and 5 men; mean age, 50 years; range, 17 to 67 years) underwent augmentation procedures with autologous bone.

In all patients, a 2-stage procedure was performed, with a 3-month healing period between bone grafting and implant placement. At the time of implant placement bone biopsy specimens were taken at the sites of the implants. Control specimens were taken from the iliac crests of 2 patients. The implants were allowed to osseointegrate for 3 months before healing abutments were placed.

The surgeries for bone augmentation and implant placement were performed under general anesthesia. The corticocancellous iliac bone graft was harvested from the anterior iliac crest. The augmentation procedures used were either *(1)* a combination of an onlay graft in the anterior region from canine to canine and conventional sinus augmentation in the posterior region, as described by Neyt and associates,[9] or *(2)* an onlay graft only. In all cases computerized tomography (CT) examination was performed prior to the grafting procedure.

The size and contour of the onlay grafts were limited to the size needed for an appropriate implant length (11 to 16 mm). A midcrestal incision was made along the alveolar crest, along with 2 vertical releasing incisions to the left and right of the third molar region. In cases where a combination of onlay and sinus grafting was used, a mucoperiosteal flap was raised, exposing the lateral wall of the sinuses and the complete alveolar crest. A standard sinus floor elevation, as described by Boyne and James,[10] was performed with cancellous hipbone. In the anterior region 4 to 6 corticocancellous bone blocks were fixed on the labial and occlusal aspects of the alveolar ridge. Each one was secured with 1 or 2 microscrews 12 to 14 mm in length (Modus 1.5; Medartis, Basel, Switzerland) (Fig 1a). The windows in the lateral wall of the sinus (Fig 1b) and the augmented bone blocks were covered with resorbable membranes (Bio-Gide; Geistlich Biomaterials, Wolhusen, Switzerland) (Fig 1c). The passively mobilized mucosa was closed with a running suture and secured with 4 or 5 interrupted sutures (5-0 Monocryl; Johnson & Johnson/Ethicon, Somerville, NJ). The patients were given an intravenous antibiotic (clindamycin 600 mg) during the operation and an oral antibiotic postoperatively (clindamycin 300 mg) for 7 days.

Table 1 Distribution of Implants in Augmented Bone

	Onlay + sinus	Onlay only
Steri-Oss		
8 mm	–	–
10 mm	4	3
12 mm	4	1
14 mm	1	–
16 mm	1	–
Total	10	4
Camlog		
9 mm	17	2
11 mm	31	20
13 mm	25	8
16 mm	–	–
Total	73	30

Ten patients were treated on an outpatient basis and left the hospital the same day; they were seen 1 and 3 days postoperatively. Nine patients remained hospitalized for 3 to 5 days. The sutures were removed after 10 days.

The patients were seen every 4 weeks after the surgical procedures and every 12 weeks in the first year after abutment connection. Panoramic radiographic examination was performed immediately before and after the next surgical procedure.

Implant Placement

After a healing period of 3 months, the same incision line that was used in the grafting procedure was used for the preparation of a mucoperiosteal flap to remove the miniscrews, retrieve the bone biopsy specimens, and place the implants. The implants, either Camlog Rootline (Altatech Biotechnologies, Wimsheim, Germany), Camlog Screwline (Altatech), or titanium plasma-sprayed Steri-Oss (Nobel Biocare, Gothenburg, Sweden) were placed using a surgical guide.

Three months after implant placement, reopening surgery was performed under local anesthesia. Osseointegration was tested clinically by applying a controlled rotational force of 35 Ncm. If the implant showed no signs of rotation and the patient felt no pain, the healing abutment was connected and the implant was considered clinically successful. The flap was closed with interrupted sutures (5-0 Monocryl).

Provisional Prosthetic Treatment

Of the 19 patients, 12 were edentulous. These patients received their relined dentures 1 to 3 days after bone grafting and implant placement or at the time of suture removal. The patients were only allowed to use their dentures for esthetic purposes in the first 4 weeks after the bone augmentation procedure. Thereafter, they were not limited in their use of dentures.

Histologic Evaluation

Bone biopsy specimens (5 to 9 mm in length, 2 mm in diameter) were obtained from the onlay grafted areas using a trephine drill (width, 2 mm) (Straumann, Basel, Switzerland). The bone specimens were fixed in 4% formalin for 2 days and then decalcified in 17% nitric acid. After processing (ThermoShandon; Thermo Electron, Waltham, MA), the tissues were embedded in paraffin. Serial sections 5 μm thick were prepared and stained with hematoxylin-eosin (H&E) and Masson's trichrome. A mean of 2 sections were obtained from each specimen. For qualitative assessment of the remodeling process, the stained preparations were examined under a light microscope (BH 50; Olympus, Tokyo, Japan) at a magnification of up to 100×. The amount of bone, trabeculae, and fibrous and fatty tissue was calculated using a millimeter eyepiece in a binocular microscope at 40× magnification by a single observer who was unaware of the clinical data. The percentage of each type of tissue (new bone, necrotic bone, and connective tissue) in each section was calculated by taking the cross-sectional area of each type of tissue and dividing it by the cross-sectional area of the whole section.

Criteria for Clinical Success

Based on clinical and radiologic findings, each implant was classified either as successful or nonsuccessful using the criteria established by Buser and coworkers[11]:

- Absence of persistent subjective complaints such as pain, foreign body sensation, and/or dysesthesia
- Absence of peri-implant infection with suppuration
- Absence of mobility
- Absence of continuous radiolucency around the implant

RESULTS

One hundred seventeen implants (97 Camlog Rootline, 6 Camlog Screwline, and 14 Steri-Oss) (Nobel Biocare) were placed in 19 patients (Table 1). For all patients the time of implant placement was 3 months after grafting. All 19 grafts were successful based on the fact that implants were placed in all patients without the need for regrafting. The grafting procedure comprised either a combination of sinus augmentation and onlay grafting or onlay grafting alone. Fourteen patients were in the "onlay/sinus" group, and 5 patients received only an onlay graft.

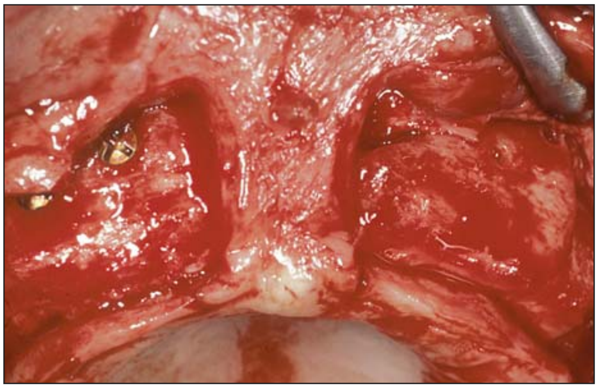

Fig 2 The graft after a healing period of 3 months, at the time of microscrew removal and implant placement.

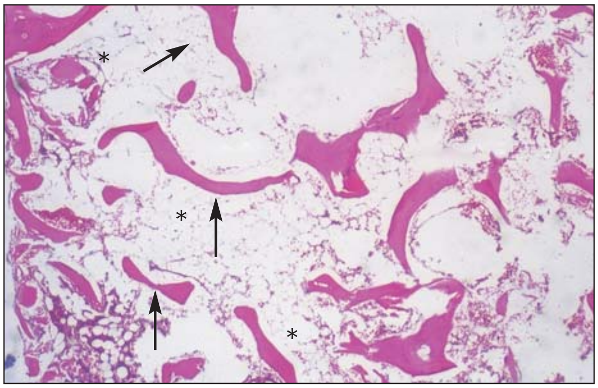

Fig 3 Control specimen from the iliac crest showing loose cancellous bone *(arrow)* and large trabecular spaces *(asterisk)* (H&E; original magnification ×10).

Eighty-three implants were placed in the patients who had received a combination of onlay graft and sinus augmentation. In patients who received onlay grafts alone, 34 implants were placed.

Of the 117 implants, 1 implant was not osseointegrated at the time of abutment connection; this implant was replaced in the same implant site and, to date, has remained successfully osseointegrated. The only complications observed were minor dehiscences (2 × 6 mm and 5 × 10 mm) in 2 patients with onlay grafts. Both of these patients had had previous surgical interventions, including bone augmentation and multiple attempts to place implants, which had resulted in scar tissue.

No implants were lost after loading. All implants were successful, resulting in a success rate of 100% after abutment connection.

The average observation period after loading was 12 months (range, 2 months to 2.5 years); the average observation period after implant placement was 18 months (range, 4 months to 3 years).

After 3 months, observation of the augmented bone revealed a dense cortical layer with good blood perfusion/supply. Gaps between the bone chips were not visible; the alveolar crest displayed a smooth surface (Fig 2).

Control bone specimens from the iliac crest showed loose cancellous bone structure with large trabecular spaces (Fig 3), lipoid tissue, and hematopoietic bone marrow. Within the trabecular spaces, vital cellular elements in various stages of maturation were seen, and osteoblasts, osteoclasts, and immature precursors were found. At the time of implant placement, 3 months after grafting, the trabeculae of the grafted bone had a denser structure than the control specimen. Zones of newly formed bone with osteoid depositions were found, indicating ongoing remodeling (Fig 4). The trabecular spaces showed fatty degeneration, with a decrease in vital cells. Osteoids with osteoclasts and osteoblasts could be seen. Twenty-seven sites in 10 patients were quantitatively analyzed. Figure 5 shows the average amounts of new bone, necrotic bone, and connective tissue found in the biopsy samples obtained from the onlay-grafted areas expressed as percentages. The specimens contained an average of 43.2% newly formed bone. The average amount of necrotic bone was 15.2%, and an average of 41.6% connective tissue could be seen. No foreign body reaction, granuloma formation, or eosinophilia were observed.

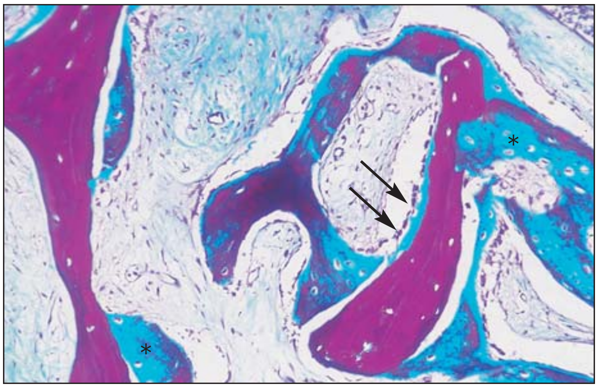

Fig 4 Histologic appearance of grafted bone after 3 months showing new bone formation *(asterisk)* with osteoid deposition, indicating ongoing remodeling *(arrow)* (Masson's trichrome; original magnification ×40).

The size and contour of the onlay graft was limited to the implant length (11 to 16 mm). This resulted in tensionless soft tissue closure and allowed optimal alveolar ridge contouring.

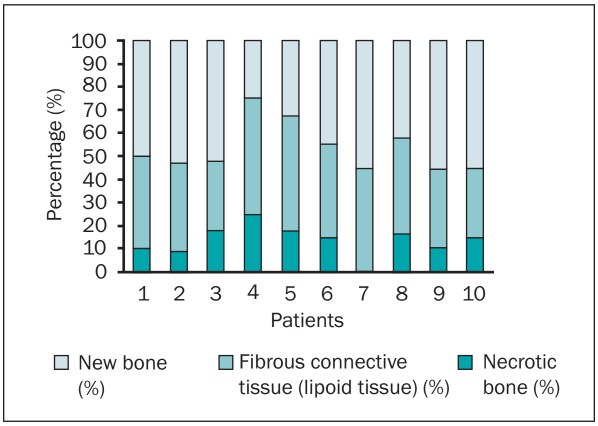

Fig 5 Results of histomorphometric analysis of 27 specimens obtained from onlay-grafted bone from 10 patients. The mean values are expressed in percentages and range from 25% to 55% for new bone and 9% to 25% for necrotic bone.

DISCUSSION

In the present study it was possible to demonstrate that, with a shortened healing period (3 months) both postgrafting and after implant placement, successful treatment could be performed. To date, with an observation period of up to 3 years after implant placement, all of the implants that were loaded remain successfully integrated. The 2-stage approach to the placement of implants in extremely atrophied jaws reconstructed with autologous grafts is known to be a reliable technique.[5,12] Many studies have shown that implants placed in augmented areas using various grafting techniques can have long-term success.[1,13] Studies addressing the optimal time-point for implant placement in augmented areas have suggested a period of 4 to 6 months after grafting.[4,6,8,14,15] Raghoebar and associates demonstrated comparable success rates with the placement of implants after a 3-month healing period after grafting.[16]

During healing and remodeling, the degree of bone-implant contact increases as maturation of the bone progresses. Tissue perfusion and mass transport in the vicinity of implant surfaces prior to integration may play a crucial role in modulatory cellular activities associated with bone remodeling. This calls for the placement of implants at an early stage in the remodeling process.[17–20] Mechanical loading is known to activate several cellular processes in osteocytes, promoting bone formation. Elucidation of the mechanochemical transduction mechanisms in bone may provide a basis for the application of biomimetic principles for the determination of optimal loading forces and schedules.[21] The optimal timing of secondary implant placement in grafted areas has previously been assumed to lie between 4.5 and 5 months.[4,8,22] In the present study, histologic evaluation confirmed adequate bony structure for secure implant placement after a healing period of 3 months.

The values found for new bone formation ranged from 25% to 55%; this is comparable to the results of studies with a healing period of 4 to 5 months.[4,8] Moreover, by shortening the healing period before implant placement, it was possible to prevent the onset of resorption. The process of osseointegration leads to increased bone density as a result of the stimulation of the remodeling process in the bone. This has been described as the *regional acceleratory phenomenon*.[23]

It is known that woven bone needs mechanical loads to be replaced on basic molecular unit-based remodeling by lamellar bone.[24] These mechanisms are also applicable in fracture repair of long bones. Four events are required to initiate fracture healing: recruitment of osteoprogenitor cells, induction of osteoblastic activity of local cells, modulation and activation of the process, and finally, osteoconduction. Each step is essential to finally achieve a 3-dimensional lattice of bone. It is known that biophysical stimulation in the form of ultrasound or a pulsed electromagnetic field can enhance the process of bone formation; the dose effect and timing are still matters of discussion.[25] It is also known that rigid fixation over a long period of time may delay or minimize the exudation of morphogenetic substances and growth factors necessary for bone formation; however, excess motion during fracture healing can result in nonunion.[26] In cases of nonunion of long bone fractures, bone-marrow grafting is applied. Iliac bone shows a high osteoinductive potential because of the large amount of osteoprogenitor cells in the marrow. Partial weight-bearing of these patients is started after a healing period of 4 weeks, and full weight-bearing is allowed after 8 weeks of healing.[27] The same principles at work in long-bone fracture healing apply to graft consolidation and remodeling of the grafted bone.

The healing process following tooth removal is comparable to the process of fracture healing of long bones. Pronounced remodeling and resorption of tissues are observed within a period of 4 to 8 weeks. These processes seem to be more pronounced during the initial phase of healing. In the first weeks of healing, surface resorption is seen in extraction sites.[28,29] Bone resorption of 45 μm/day is comparable to that of fracture sites in long bones of dogs.[28] Two weeks after tooth removal the bundle bone has been replaced by woven bone. After 4 to 8 weeks, pronounced alteration of the tissue within extraction sites is seen, a cortical ridge seals the entrance of the extraction socket, and woven bone has been replaced by lamellar bone and marrow. The reason for resorption, especially of the buccal plate, is presently not understood, but one possible reason is a diminished blood supply of the cortical osteocytes after elevation of the mucoperiosteal flap, although resorption has been known to take place even after extractions without elevation of a flap. Other factors that seem to be important for bone resorption and remodeling include adaptation to diminished bone loading and genetically predetermined demands regarding the ridge geometry of edentulous ridges.[30]

In experimental and in vivo studies it has been demonstrated that rough-surface implants have high primary retentive properties that make them suitable for early loading even in poor-quality bone.[8,31,32] It is well known that sandblasted acid-etched implants can be used successfully in cases of shortened healing periods in nongrafted bone.[32,33] The exact mechanisms that cause osteoblasts to produce more bone in the presence of a microrough surface are not yet fully understood. In this study, it has been possible to show that early loading (3 months) using rough-surface implants can also be successfully applied to grafted iliac bone. Furthermore, by adapting bone grafts to the size of the implant, it is possible to minimize grafting failures related to dehiscences and to promote attached gingiva around the implants.

CONCLUSION

This study demonstrated that after bone grafting, a period of 3 months was sufficient to revascularize and ensure the secure placement of dental implants at second-stage surgery. Furthermore, it was possible to demonstrate that rough-surface implants placed in grafted bone can be successfully loaded after a shortened healing period of 3 months; this had already been achieved in nongrafted bone. The observation period after prosthetic rehabilitation is still limited, but prospective follow-up will allow long-term evaluation of this procedure.

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