Histologic Evaluation of Autogenous Calvarial Bone in Maxillary Onlay Bone Grafts: A Report of 2 Cases

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Bone augmentation for implant dentistry has become a necessary procedure for a number of edentulous patients. Calvarial bone grafting constitutes an important tool in achieving maxillary augmentation and sinus elevation. Much effort has been directed toward improving graft survival and volumetric maintenance. The purpose of the present study was to evaluate the histologic results of the calvarial onlay graft for maxillary reconstruction before implant placement. Two patients underwent maxillary augmentation using autogenous calvarial onlay grafts. After a 4-month healing period, biopsies of the augmented regions were performed and implants were placed. The implants were loaded after 5 months and then clinically examined after 15 months of function. Biopsies showed that calvarial onlay grafts were well incorporated into the pre-existing bone after a 4-month period. Histologic and histomorphometric findings demonstrated a living bone that showed features characteristic of mature and compact osseous tissue. The restored implants were stable and osseointegrated after a 15-month period of follow-up. The use of calvarial onlay grafts can be a predictable and successful method to achieve maxillary augmentation, allowing appropriate placement of implants and stable prosthetic restorations. (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:594–598)

Key words: *alveolar ridge augmentation, bone grafting, calvarial bone, dental implants, histology, histomorphometry*

Insufficient bone height in the resorbed maxilla, resulting from expansion of the maxillary sinus and/or atrophic reduction of the alveolar process of the maxilla, represents a contraindication for the placement of dental implants. This anatomic problem can, in many cases, be solved by onlay bone grafting.[1] In conventional reconstruction of the facial skeleton, bone grafts are usually harvested from distant sites such as the ilium or ribs. Because of the morbidity associated with the use of these sites, the calvarium was studied as an alternative donor site.[2] Calvarial bone grafts were used for the first time for the reconstruction of the orbital walls.[3,4] Since then, they have been utilized mainly for reconstructive procedures, including alveolar cleft grafts, Le Fort I osteotomies, midface onlay grafts, grafting of mandibular continuity defects,[2] correction of the deformities caused by Apert's and Crouzon's syndromes,[5] correction of traumatic or postoperative defects of the orbitocranial skeleton,[6] correction of sphenoid wing defects of the posterior orbit and frontal and middle cranial fossae,[7] dorsonasal reconstruction,[8] and sinus lift techniques for preprosthetic purposes.[9,10] Calvarial bone has been reported to be superior to iliac bone for onlay grafting because of decreased resorption.[11,12] It is a membranous bone formed by cortical and cancellous bone that shows rapid vascularization at the transplant site, which is a prerequisite to successful

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osteogenesis. The aim of this report was to demonstrate the histologic features of calvarial bone onlays used for bone augmentation in the upper maxillary region prior to implant placement.

MATERIALS AND METHODS

Two patients, a 56-year-old woman and a 65-year-old man, presented with Class IV alveolar bone resorption according to the Cawood and Howell classification.[13] Before treatment, the patients provided written, informed consent, and all the procedures were approved by the Bioethical Committee of the Istituto Stomatologico Italiano, Milan, Italy. Both patients underwent a maxillary onlay graft using autogenous calvarial bone, one in the premolar region and the other in the paramedian maxillary region.

Surgical Procedures

The grafting operations were performed under general anesthesia. Flap reflection was performed at the recipient site prior to graft harvest. Calvarial harvest was carried out from the parietal area and, if possible, maintained posterior to the coronal suture and avoiding the superior sagittal sinus and the temporalis muscle. According to the technique developed by Tessier in 1995,[14] a groove was drilled around the cortex of the harvest area, and osteotomes were then used through the diploic space to split the outer cortical table. Once the graft was obtained, additional bone chips were taken from the uncovered diploic bone. The maxillary onlay graft was carried out; the cortico-onlay graft was fixed with lag screws and the residual gaps were filled with bone chips and bone dust left over from the drilling procedure.

Four months of osseous healing were allowed, and 15 implants (6 in the female patient and 9 in the male patient) were placed (Osseotite implants, 3.75 mm in diameter; 3i/Implant Innovations, West Palm Beach, FL). After 5 months, the implants were loaded with provisional restorations. Definitive prostheses were put in place 3 months later. A clinical examination was performed after approximately 15 months of functional loading.

Histologic Procedures and Histomorphometric Analysis

In both patients, a biopsy of the maxillary augmented region was carried out with a trephine 4 months after surgery (Fig 1a). The calvarial graft constituted the vestibular part of the biopsies, whereas the pre-existing basal bone represented the palatal region (Fig 1b). Biopsies were immediately immersed in a fixative solution consisting of 2.5% glutaraldehyde and 2.5% paraformaldehyde in 0.1 mol/L sodium phosphate (PBS), pH 7.2. After washing in 0.1 mol/L PBS, the specimens were dehydrated in graded alcohols and processed for embedding in LR White resin (London Resin, Berkshire, United Kingdom). Semi-thin sections were cut using the Precise System 1 (Assing, Rome, Italy) and stained with acid fuchsin and toluidine blue for light microscopic examination.

Histomorphometry was performed by measuring the extent of the areas of bony trabeculae and comparing it with the global area of bone and marrow spaces, both in the grafted area and in the pre-existing bone. The analysis was carried out using a light microscope (Laborlux S; Leitz, Wetzlar, Germany) connected to a high-resolution video camera (3CCD, JVC KY-F55B, Segrate [MI], Italy) and interfaced to a monitor and personal computer. This optical system was associated with a digitizing pad (Matrix Vision, Oppenweiler, Germany) and a histometry software package with image-capturing capabilities (Image Pro Plus 4.5; MediaCybernetics, Immagini & Computer, Milano, Italy).

RESULTS

Clinical Findings

After surgery, no dural laceration, no bleeding, and no infection occurred at the donor site, and no neurologic injuries or prolonged postoperative pain were observed in the patients. No graft failures were present in either patient. After a period of 4 months, the radiographic evaluations showed complete integration of the onlay graft at the site of the maxillary reconstruction. Clinically, a very small reduction in the volume of the bone grafts occurred, but the width of the newly formed bone appeared to be suitable for implant placement. The implants were placed and then successfully restored. At the most recent examination, after a loading period of approximately 15 months, all implants were clinically stable and osseointegrated, and no pain, clinical signs of infection, signs of bone loss, dehiscences, or radiolucencies were present around the implants.

Light Microscopic Observations and Histomorphometric Results

At the time of retrieval of the biopsies, the calvarial grafts were stable and fully incorporated into the maxillary recipient sites (Fig 1c). The grafted bone was compact and well vascularized; it appeared to be

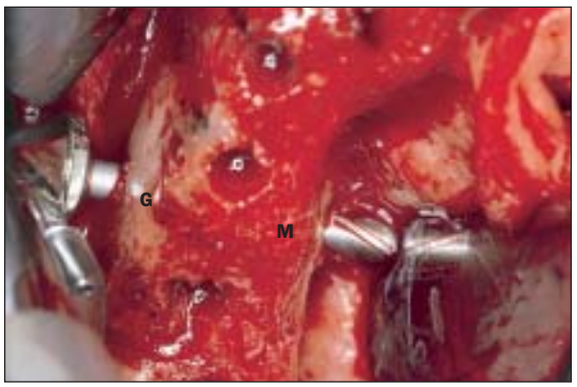

Fig 1a A biopsy was obtained 4 months after placement of an onlay calvarial graft (G) in the premolar area. The trephine bur retrieved the vestibular onlay graft and the pre-existing palatal bone (M).

Fig 1b Macroscopic view of the bioptical sample. G = graft; M = preexisting bone.

Fig 1c Microscopic view of the bioptical sample. On the left is the calvarial onlay (G); on the right is the pre-existing bone (M) (magnification ×4).

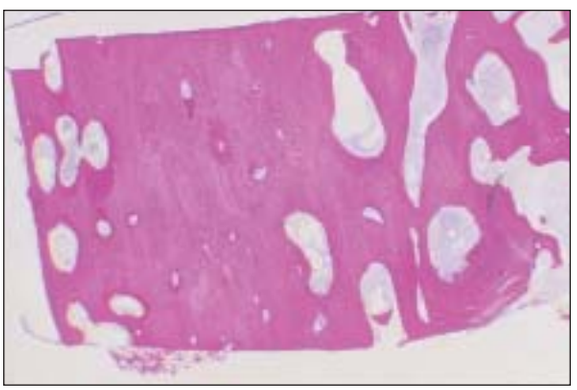

Fig 2 Histologically, the calvarial onlay graft appears well integrated and shows mainly compact bone (magnification ×10).

covered by new lamellar bone, which was intensely stained with acid fuchsin (Fig 2). There were also zones of active remodeling, organized in lamellar structures. Especially at the interface between pre-existing and new bone, there was newly formed osseous tissue, which presented more marrow spaces than the core of the graft (Fig 3). In general, the calvarial graft presented structural features similar to those seen in the pre-existing bone. However, a denser trabecular design and a more compact lamellar aspect were observed in the graft in comparison to the pre-existing maxillary bone, which was rich in marrow spaces (Fig 4). The onlay graft exhibited numerous osteocytic lacunae, well defined Haversian canals, and osteon formation (Figs 5a and 5b). There were no signs of inflammation and multinucleated cells, and monocytes were not detected. The histomorphometric data showed high bone density in the samples harvested after 4 months. The overall mean histomorphometric density of bone trabeculae for the calvarial onlay graft was 54.88%. The pre-existing bone had a mean histomorphometric value of bony trabeculae scoring 46.42%.

DISCUSSION

The treatment of severe resorption of the maxillary residual ridge usually involves various grafting materials, such as autogenous bone or bone substitutes. Autogenous bone still represents the best grafting material, but resorption must be taken into consideration. Rapid graft resorption has been reported in several studies of bone grafting techniques.[15–21] Most of this reduction takes place during the first few months after grafting. Since the advent of the modern era of craniofacial surgery, craniomaxillofacial surgery has advanced in many ways, for example, through the use of autogenous

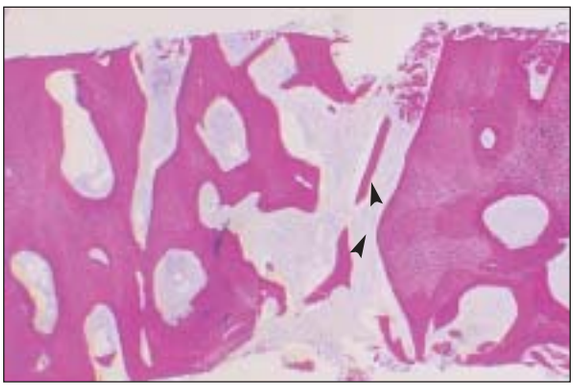

Fig 3 The bone between the onlay graft and the pre-existing bone presents active remodeling, demonstrated by the intensely stained areas of newly formed bone *(arrowheads)* (magnification ×10).

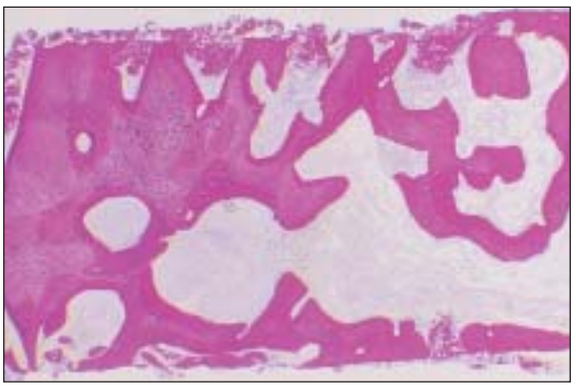

Fig 4 Micrograph showing the palatal pre-existing bone, which presents large marrow spaces (magnification ×10).

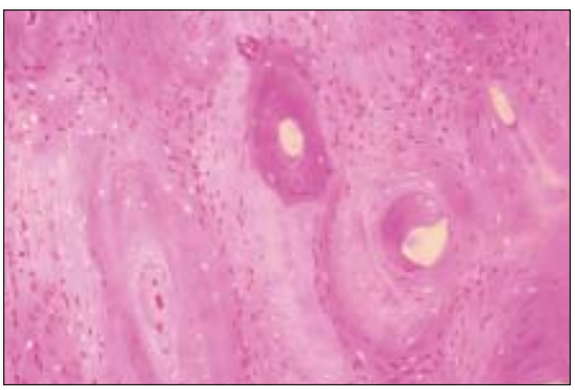

Fig 5a Characteristic well-organized and compact structure of the integrated calvarial graft (magnification ×20).

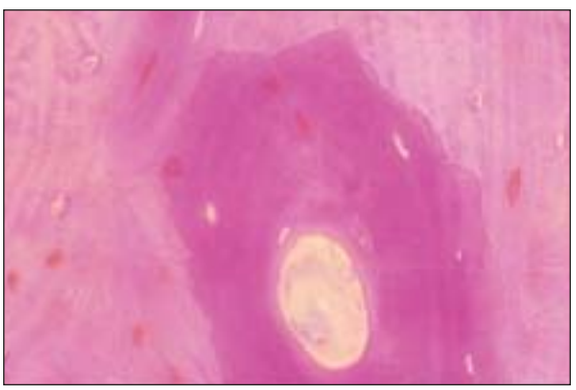

Fig 5b The onlay graft presents osteon formation, showing the ongoing bone remodeling process (magnification ×40).

cranial bone grafts for onlay or interpositional application.[5] Membranous bone used as onlay grafts for augmentation of craniofacial skeletal contour has been shown to be superior to endochondral grafts in maintaining volume. Several authors[22–24] reported that the higher tendency to resorption of iliac onlay grafts compared to calvarial grafts was because of their different embryonic origin (endochondral versus membranous). The membranous bone undergoes less resorption and revascularizes faster than endochondral bone. The scientific rationale for this seeming embryologic advantage, however, has never been proven.

Recent hypotheses contend that the pattern of onlay bone graft resorption is primarily determined by a graft's micro-architecture relative to the cortical/cancellous composition.[25–27] Calvarial bone has excellent mechanical strength and has little tendency to resorption because of its large cortical component. Although the harvesting and shaping cranial bone require special expertise, and there is potential morbidity,[28] harvest from the calvarial donor site causes less discomfort to the patient compared with harvest from the rib or iliac crest, and the scar is well hidden. Thus, calvarium is becoming a popular donor site for bone grafts used in craniofacial skeletal procedures.

Both the clinical and histologic results of the present study corroborate the findings that calvarial onlay grafts can be well integrated and result in the formation of mature and compact osseous tissue. At the interface between the grafted onlay and the pre-existing bone, the osseous tissue appeared to have large marrow spaces and was undergoing active remodeling.

CONCLUSION

Histologic and histomorphometric evaluation showed that the use of calvarial onlay grafts in 2 patients led to newly formed trabecular and compact

bone of a very good quality after 4 months. The calvarial bone grafts provided maxillary augmentation, allowing good definitive implant-prosthetic rehabilitation that was clinically stable after more than 1 year of function. All these positive findings warrant future long-term clinical and histologic studies and may encourage the use of this grafting technique for reconstructive procedures in the maxilla.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the help of Antonio Scarano, DDS, Giovanna Petrone, DDS, and Giovanna Iezzi, DDS. This work was partially supported by the Ministry of Education, University and Research (MIUR), Rome, Italy, and by the National Research Council (CNR), Rome, Italy.

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