

Calvarial Autogenous Bone Graft for Maxillary Ridge and Sinus Reconstruction for Rehabilitation With Dental Implants

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Autogenous bone grafting is the gold-standard technique for bone augmentation procedures prior to implant placement. If the amount of available intraoral donor bone is insufficient, it is necessary to harvest bone graft from extraoral sites, such as calvaria. Although this technique is well established, only a few case reports show the histological analysis of the grafted bone at the moment of implant placement. This article reports the case of a 48-year-old female patient with a critical atrophic maxillary ridge reconstructed using autogenous calvarial bone graft prior to implant placement, with clinical and histological evaluation. Bone was collected under general anesthesia from the parietal bone. The outer cortical originated the bone blocks, and the medullar bone layer between was collected to be used in the sinus augmentation procedure, together with 5 of the bone blocks triturated. Six months after bone augmentation, 8 implants were placed in the grafted area and 2 biopsies were retrieved (anterior and the posterior regions), allowing the visualization of the bone-remodeling process in the grafted areas. The patient had a stable recovery. Our results showed that although necrotic bone could still be seen in the outer layer of the grafted area, the interface between this necrotic bone and the already remodeled bone was consistent with biocompatibility. Two-year radiographic evaluation showed success of the grafts and the implants in supporting an esthetic and functionally stable prosthesis. Summarizing, calvarial bone grafts are a viable alternative for the attainment of adequate bone volume prior to implant placement.

Key Words: *calvaria, bone graft, atrophic maxilla, dental implants*

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INTRODUCTION

The presence of severely atrophic edentulous ridges in the maxilla is one of the most critical issues for oral and maxillo-facial rehabilitation with dental implants, since loss of teeth leads to a pattern of bone resorption that can contribute to severe jaw atrophy.¹ Many procedures have been suggested for anatomical reconstruction of severely resorbed

ridges, and onlay bone grafting has been documented as one of the most predictable.²⁻⁹

In cases in which large volumes of bone are required, the surgeon has several options to choose from biomaterials and various techniques that could act to conduct the neoformation of bone.¹⁰⁻¹⁵ Autogenous bone grafting remains the gold-standard technique for any bony reconstructive procedure, including bone augmentation prior to implant placement, based on its osteoconduction, osteoinduction, and its capacity for osteogenesis.¹⁶ If the amount of available intraoral donor bone is insufficient, it is necessary to harvest bone graft from extraoral sites, such as the iliac crest, ribs, tibia, or calvaria.¹⁶⁻²⁰ Among these options, the iliac crest bone is the most commonly used, although it presents some disadvantages such as postoperative pain, susceptibility to infection on the donor site, and significant loss of graft size over the remodeling process.²¹

On the other hand, bone graft harvested from calvaria presents advantages such as low postoperative morbidity, low incidence of postoperative complications, and a good-quality bone, when compared with other donor sites in terms of bone volume and quality of available bone. It has a thick cortical layer and dense marrow layer, allied to a lower rate of graft resorption.²²⁻²⁶ As disadvantages, we could mainly cite the risk of neurologic complications, epidural hematoma in case of laceration of the middle meningeal artery, and exposition or laceration of the duramater meninges, in addition to the patient's acceptance being relatively low.²⁷

Some authors state that by using calvarial bone graft, it is possible to avoid iliac bone grafting, which has a higher complication rate, including donor-site pain,²⁸⁻³⁰ gait disturbance,^{21,31,32} high susceptibility to infection at the donor site,^{28,31,33} and significant loss of graft size over the remodeling process.³⁴⁻³⁷

In such extensive bone transplantation, resorption of the graft is a major concern. It can lead to insufficient bone volume and insufficient bone quality for subsequent implant installation.²⁵ It has been reported that resorption of calvarial bone grafts is minimal after alveolar ridge reconstruction, measured either using 2D (linear) or 3D (volumetric) methods.^{25,33,34,38}

When compared with the iliac crest^{37,39,40} or

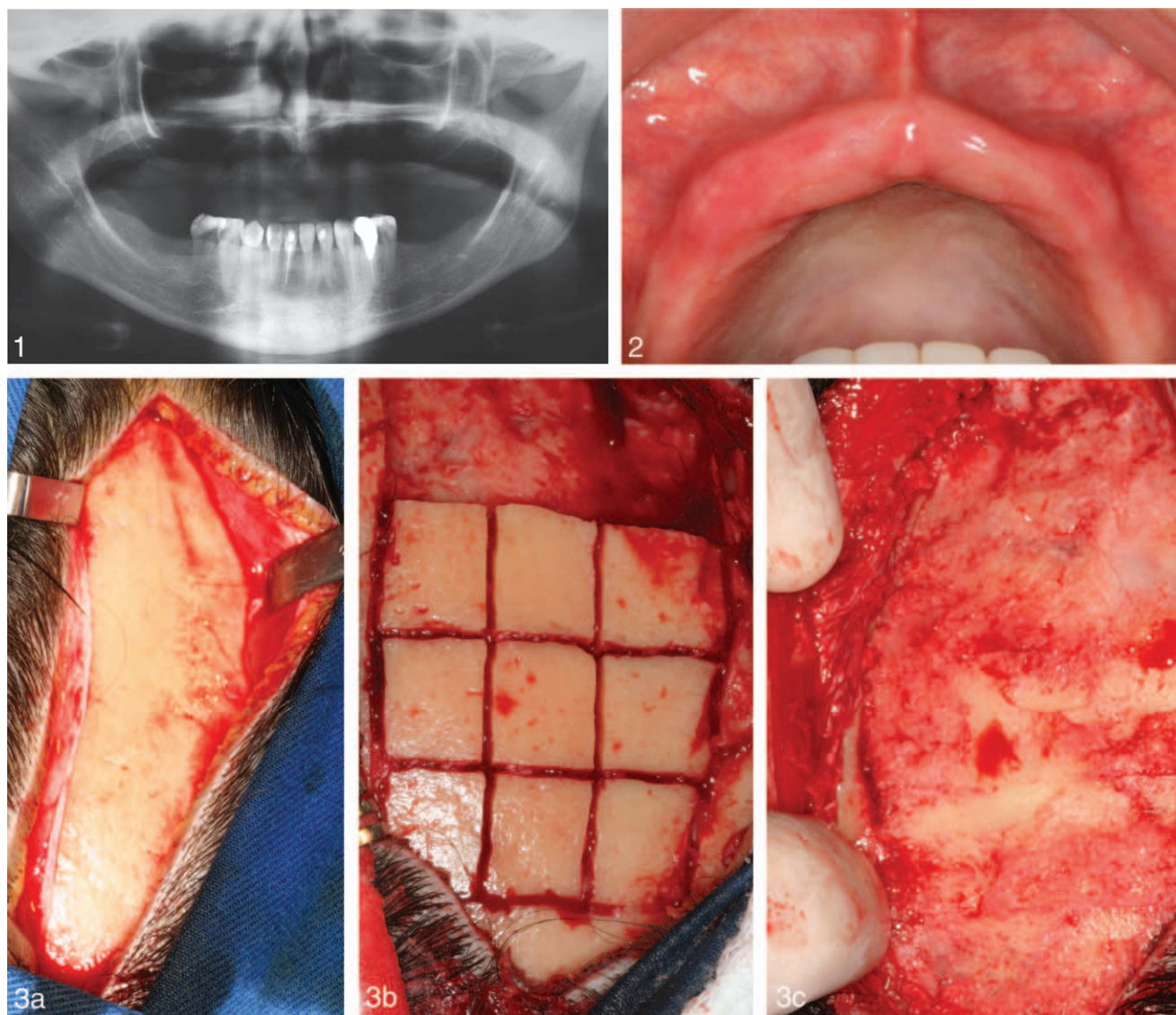
rib⁴¹ bone grafts (endochondral, mesenchymal origin), several studies demonstrate that bone from calvaria (intramembranous, with ectomesenchymal origin) have minimal resorption and better incorporation. These considerations suggest that the type of ossification and/or the embryologic origin could influence the different remodeling patterns of these 2 kinds of grafts.^{16,25,33,42,43} However, other studies show that the embryological origin or the ossification processes separately are not important factors for graft-remodeling fate or success.^{44,45} Besides, biological evidence is still limited regarding the full understanding of bone origin mechanisms and their effects on day-to-day clinics, and there is no evidence of biochemical, morphological, or functional differences between endochondral and intramembranous bone, allied to the fact that bone, after its complete formation, is the same all over the body, apart from the mechanism of ossification, as it contains the same kinds of cells and biochemical composition of extracellular matrix, including growth factors.^{46,47}

Although this technique is well established, only a few case reports provide histological analysis of the grafted bone at the moment of implant placement. The present article reports a case of a 48-year-old female patient with a critical atrophic maxillary ridge reconstructed using calvarial bone graft prior to implant placement, with clinical and histological evaluation.

CASE REPORT

Patient and treatment plan

A 48-year-old female patient presented for full maxillary rehabilitation using dental implants. The review of the patient's medical history revealed no systemic diseases, the absence of smoking habits, and no routine medication use. On clinical examination, there was no pathological condition either intraorally or extraorally. Considering the edentulous condition of the upper maxilla, the patient's complains were also related to poor labial support of the maxilla, which produced a wrinkle-evidencing effect, interfering with the esthetics of her face. After the initial clinical and radiographic evaluation (Figures 1 and 2), the necessity of bone-grafting procedures, both onlay and inlay, was considered in an attempt to achieve a bone volume compatible with the installation of implants and with the



FIGURES 1–3. FIGURES 1–2. Initial clinical and radiographic situation. **FIGURE 3.** A full-thickness flap was obtained (a). The depth limit of the bone harvesting was the internal cortical, and the blocks were designed according to the programmed necessity (b). The inner cortical bone was completely preserved (c).

enhancement of the labial support, according to the patient's desire. To verify the need for bone-grafting procedures in the treatment plan, cone-beam computerized tomography (CBCT) was performed. Based on the CBCT examination, it was clear that the amount of bone necessary for the surgery would lead to the use of extraoral donor sites, such as the iliac crest and the calvaria. As the patient was not comfortable with the possibility of mobility impairments that can result from iliac crest bone graft removal, the calvaria was elected as the donor site. The cost-benefit ratio of choosing the calvaria as the donor source for grafting material was based

on the factors (indications, advantages, and disadvantages) shown in Tables 1 and 2.

Receptor Site Surgery

Under general anesthesia, the surgery started by the accession approach of the receptor site. A total crestal incision was performed accompanying the alveolar ridge anatomy, and vertical incisions were used to attain the final design of the flap, bilaterally, in the posterior maxilla. Using round diamond-coated burs, and always under intense saline solution irrigation, the sinuses were accessed and the membranes carefully suspended using delicate curettes, creating an adequate space to receive the

TABLE 1

Indications, advantages, and disadvantages of extraoral and intraoral donor sites

Site	Indications	Disadvantages	Advantages
Intraoral	Reconstruction of defects of limited size; partial edentulism involving from 1 to 4 teeth gaps ⁴⁸	Limited bone availability, ⁴⁹ neurologic disturbances, ⁵⁰ and changes in the chin profile ⁵¹	Decreased morbidity ⁵⁰ Convenient surgical access, reduced operative time and anesthesia time in a single team effort, ⁴² proximity of the donor and recipient sites, lack of cutaneous scarring, minimal discomfort, ⁴⁹ no anesthesiologist or ambulatory facility fee, which reduce costs to the patient ⁵⁰ 'Ease of harvest, source of intramembranous bone, which has less resorption than endochondral bone ⁵² Minor implant failure rates ⁴⁸ Large quantities of cortical and cancellous bone ^{55,56}
Extraoral	Reconstruction of extended defects (both partial and total edentulism, involving 1 or both jaws ⁴⁸	Distant sites require a secondary sterile preparation and can be associated with severe morbidity ⁵³ Permanent cutaneous scar ⁵¹ High costs, prolonged operatory time, hospitalization, and general anesthesia ^{22,24,54} Except by calvaria, other bone sources have endochondral origin, which can be related to a high resorptive potential ^{25,43}	

grafting material. The buccal cortical bone of the anterior maxilla was recontoured to improve graft adaptation and roughened using cylindrical burs No. 699 and 700, in an attempt to induce bleeding and improve the revascularization of the bone blocks that would be attached to these sites.

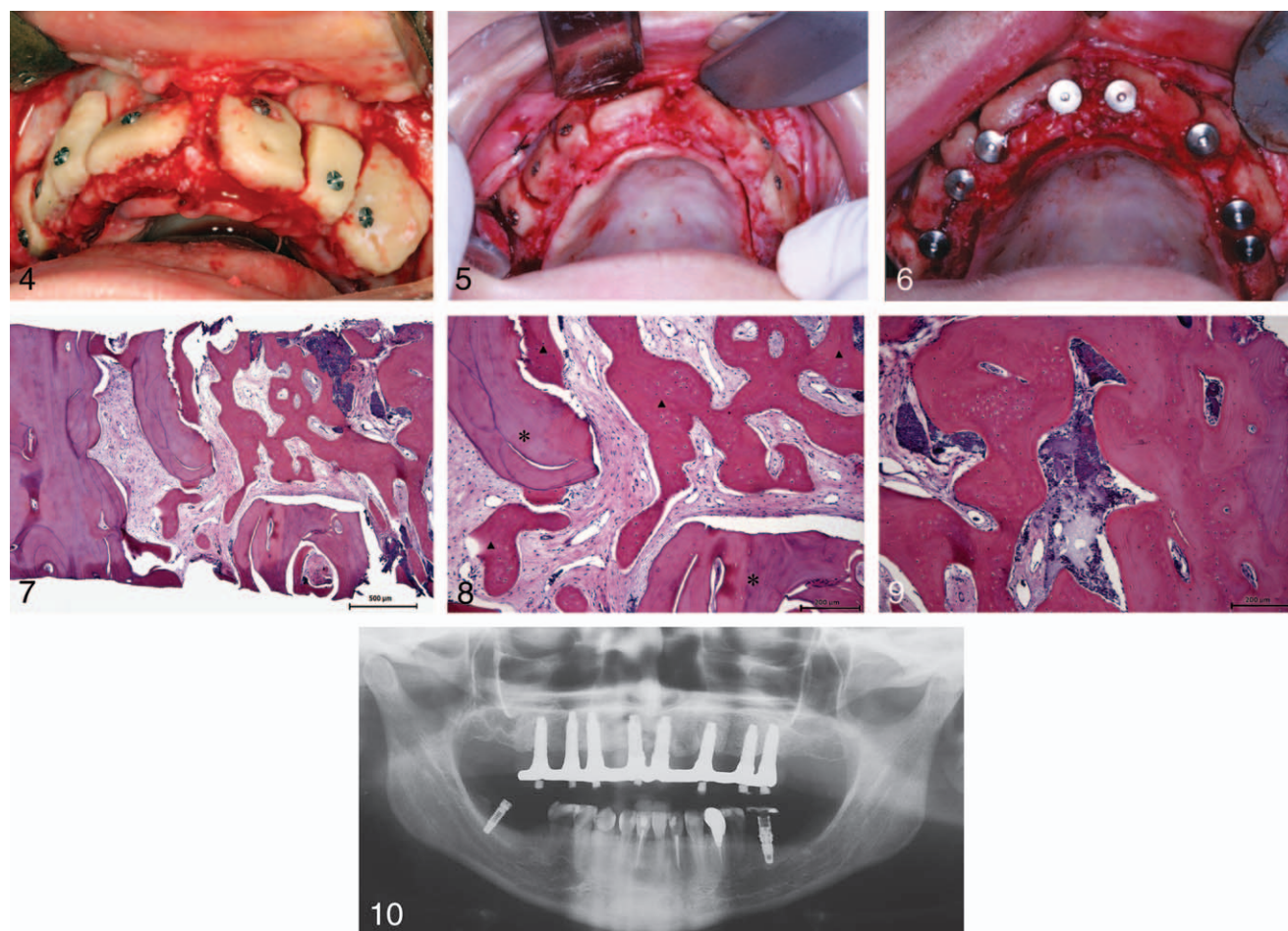
Donor Site Surgery

The bone graft was harvested from the parietal bone by neurosurgeons of the hospital team. For access to the donor site, the patient's hair was cleaned with iodine solution and divided approximately 4 cm from the sagittal midline. A 15-cm sagittal cutaneous incision was performed, distant from the sagittal midline, reaching the parietal bone periosteum. Elevators were used to keep the soft tissue apart while the full-thickness flap was obtained using curettes, allowing the complete visualization of the donor site (Figure 3a). The external cortical craniotomy was performed using No. 701 cylindrical burs, also under intense saline solution irrigation. The depth limit was the internal cortical, and the blocks were designed according to the programmed necessity (Figure 3b). Osteotomes were used to attain the first bone blocks and permit the access of an oscillating saw, which was used in

the interface between the inner and the outer corticals, optimizing the attainment of the other bone blocks and ensuring that the inner cortical bone was completely preserved with no severe bleeding (Figure 3c). The entire medullar bone layer between the 2 corticals was collected to be used in the sinus augmentation procedures, and after the attainment of 12 cortical bone blocks, the surgical site was cleaned and sutured using Nylon 3-0.

Maxillary Sinus Surgery

Five of the bone blocks harvested from the parietal bone were triturated and mixed to the attained medullar bone, and this material was used, bilaterally, to fill the space created into the maxillary sinus after the membrane elevation. The integrity of the sinus mucous membrane was respected throughout the procedure. The other seven blocks were attached to the residual ridge using self-tapping, 10.0 × 1.5-mm screws (Neodent, Curitiba, Brazil). They were inserted until their heads reached the surface of the bone graft and good mechanical stability was reached (Figure 4). Using spherical burs, any sharp angles on the block grafts were smoothed, to avoid perforation of the overlaying flap and to enhance the healing process. The



FIGURES 4–10. **FIGURE 4.** Clinical aspect of the grafted region. Sinus was filled bilaterally, and 7 bone blocks were used to promote width gain. **FIGURES 5–6.** Aspect of the grafts 6 months after the first surgery. The implants placed over this area. **FIGURE 7.** General view of one of the retrieved biopsies, showing the clear difference between the newly-formed bone and the remaining necrotic-bone layer. **FIGURE 8.** The interface between the grafted material, which was still necrotic (*), and the newly-formed bone (▲) was full of exuberant osteocytes and permeated with a highly cellularized connective tissue, with the absence of inflammatory cells. **FIGURE 9.** Biopsy retrieved from the maxillary sinus, in an advanced remodeling stage, showing dense and osteocyte-rich newly-formed bone and small amounts of necrotic bone. **FIGURE 10.** Panoramic radiographic evaluation of the patient, 24 months after prosthesis installation.

amount of collected bone was proportional to the reconstruction. A collagen membrane (Genius Balmer, São Paulo, Brazil) was placed over the bone blocks, and the flap was repositioned and sutured with minimal tension using normal interrupted Nylon 4-0 suture.

Antibiotic, anti-inflammatory, and analgesic medications were prescribed to the patient, who left the hospital 1 day after surgery. Intraoral and extraoral sutures were removed 10 days after surgery, and the soft tissue healing was very advanced at this moment. The patient was prevented from using her total prosthesis for a 30-day period, after which a new prosthesis was made and relined using soft material (Coe Soft, GC America

Inc, Alsip, Ill), enhancing the healing of the soft tissues.

Second-stage Surgery

After a 6-month period, the second surgical phase took place under local anesthesia, and the grafting sites were exposed for implant placement. All block grafts were firmly attached and integrated to the host bone, although the interface between them was still visible (Figure 5). Eight 3.75 × 13.0-mm internal-hexagon implants were installed (Connect AR, Conexão Sistemas de Prótese, Guarulhos, Brazil) with a minimum 35 N.cm final torque, and some of the graft screws were left in place until the implants

TABLE 2

Aspects related to extraoral donor sites

Type	Origin	Quality	Potential Complications	Indications
Calvarium	Membranous	Cortical	Alopecia, hematoma, dural tear, sinus laceration, epidural hematoma, infection, scarring, seroma, wound dehiscence ⁵⁶	Onlay graft
Iliac crest	Endocondral	Cortical/cancellous	Hematoma, seroma, nerve injury, cosmetic deformity, pelvic instability, abdominal hernia, ileus, perforation, infection, persistent pain, and iliac crest fracture ⁵⁶	Inlay/onlay graft
Rib*	Endocondral	Cortical/cancellous	Pneumothorax, hematoma, scars, surface irregularities ⁵⁷ Pleural laceration, postoperative chest infections, wound breakdown, postoperative pain, persistent pleuritic pain ²⁸	Onlay
Tibia	Endocondral	Cancellous	Pain, discomfort, unsightly scarring, wound infection ⁶⁰	Inlay

were installed, ensuring that the grafted blocks did not suffer any mechanical disruption (Figure 6).

At this moment, using a 2.0-mm internal-diameter trephine bur, and under abundant saline irrigation, 2 biopsies were retrieved from the anterior and the posterior regions, allowing visualization of the bone-remodeling process in the grafted areas. Interrupted Nylon 4-0 sutures were used to close the implanted sites, and the total prosthesis was once again relined with soft material. The sutures were removed after 7 days, and healing caps were installed 6 months after this procedure, allowing the patient to receive her definitive prosthesis 12 months after the first surgery. The patient was completely satisfied with the final esthetics and the labial support achieved at this time.

Histology, Sample, and Results

The biopsies that were retrieved soon after the implant installation were submitted to routine histological evaluation. The results showed that although necrotic bone could still be seen in the outer layer of the grafted area, the interface between this necrotic bone and the already

remodeled bone was consistent with biocompatibility. The aspect of the newly formed bone surrounding this interface was full of exuberant osteocytes and permeated with a connective tissue of high cellular density, with the absence of inflammatory cells, suggesting that the remaining necrotic bone could be substituted by newly-formed bone throughout time (Figures 7 and 8). The biopsy retrieved from the maxillary sinus showed a more advanced remodeling stage, with small amounts of necrotic bone surrounded by a dense and osteocyte-rich newly-formed bone (Figure 9). In both biopsies, it was clear that the grafted material worked perfectly in conducting the new bone ingrowths to the areas where bone volume was needed.

Radiographic evaluation of the patient at 24 months (Figure 10) showed success of both the grafts and the implants in supporting an esthetic and functionally stable prosthesis.

DISCUSSION

Reconstruction of large atrophic edentulous ridges has been a challenge when it comes to rehabilita-

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TABLE 2
Extended

Disadvantages	Advantages
Risk of dural tear, Contour deformity, Scarring, Minimal cancellous bone available ⁵⁶	Low morbidity ⁵⁶ Shorter hospitalization ⁵⁷ Decreased resorption compared with Iliac crest ⁵⁶ Less implant failure compared with iliac crest ⁵⁶ Nonvisible scar and no secondary deformity at the donor site ⁵⁷ Rapid revascularization ²⁵ Ease of harvest, close proximity to the surgical site, and availability ⁵⁶ Large quantities of cortical and cancellous bone, ^{55,56} which promotes early vascularization and maximum graft maintenance ^{16,58} Simplicity of harvesting techniques ⁵⁹
High morbidity ⁵⁶ Increased resorption potential ⁴⁸ Associated with most complications after jaw reconstructions ⁴⁸ Depressed and adherent scars, bony contour abnormality, and disturbance of sensibility of the lateral cutaneous nerve of the thigh ²⁸ Prolonged hospitalization and discomfort ⁵⁷ Inferior bone quality and severe resorption observed under the compressive forces of the masticatory apparatus ⁵⁶	Low morbidity ⁵⁶
Limited amount of cortical bone available for harvesting, variable amount of cancellous bone, and the quality of the cancellous bone ⁵⁶	Possibility of the same quality and quantity of cancellous bone can be obtained as from iliac crest grafts ⁶⁰ Safe procedure, low complication rates, short hospitalization ⁶¹ Large amount of cancellous bone available, technically simple procedure, simultaneous harvest and recipient site preparation, less costs ⁵⁶

tion with dental implants, because it requires sufficient bone volume to ensure the appropriate implant tridimensional position. In this way, autogenous bone has been widely used to augment ridges affected by severe atrophy.⁸ However, with such large-volume defects, there is a limited supply of intraoral donor bone, and extraoral sites must be considered as donor site options.^{7,16–18,33,54,62,63} In this article, we report a case of a maxillae reconstruction using unicortical onlay bone grafts and bilateral sinus augmentation procedures using bone retrieved from calvaria.

Some controversies still remain regarding the use of extraoral donor sites such as the iliac crest, ribs, tibia, or calvaria as the best option for alveolar bone grafting. In fact, any surgical harvesting procedure apart from the donor site increases the cost of the treatment as a whole, extends the operation time, and may cause additional morbidity, sometimes even systemically, all of which represent obstacles to patient treatment acceptability.^{22,24,54} Calvarial bone grafts seem to be particularly useful in cases of extreme atrophies. The calvaria provides voluminous bone, a low resorption rate, and satisfactory bone quality for

implant-supported oral rehabilitation. Furthermore, the surgeries are associated with minimal postoperative complaints or visible scars, and (because the dura remains unexposed) the complication rate is very low.^{20,24,25,34,35} In the presented case, and in accordance with what is shown in literature, no cerebral injuries were encountered at the donor site, and the patient recovered uneventfully, with no early or late infections,^{22,24} similar to the patients from the study by Gleizal and Beziat.²⁴

The underlying mechanisms behind bone graft remodeling are still not completely understood, but factors such as the macro-architecture (cortical-cancellous ratio) of the graft, quality of the vascularization during the healing period, and local trauma to the graft might play a fundamental role. The rate of cortical and cancellous bone in grafts can interfere with early revascularization, resistance to mechanical collapse, and maximum graft maintenance.^{16,64}

As presented here, the patient underwent a 2-stage surgical protocol in which the implants were placed 6 months after the grafting procedures, similar to the patients in the Gleizal and Beziat²⁴ study, who underwent maxillary and mandibular

reconstruction using bicortical calvarial bone grafts and after a 5- to 6-month period had the implants placed, without any clinical problems that could contraindicate the use of the exposed technique.

A major task of reconstructive surgery is to ensure the best possible conditions for optimal healing. Regeneration of bone defects, incorporation of bone grafts into existing bone, and implant integration into bone constitute complex healing events, all of which need to proceed in an orderly, regulated manner to achieve a clinically acceptable outcome.⁶⁵ In the present case report, it could be seen through clinical and histological evaluation that the calvarial bone graft was incorporated into the bed site with a minimum loss of volume, in accordance with the existing literature.^{22,23,33,66} Allied to that, if we consider success based on well-defined criteria, such as stated by Barone et al¹⁶—absence of exposure and infection of the graft in the postoperative period, incorporation of the graft to the receptor bed, absence of radiolucent areas, bleeding of the grafted bone when removing the fixation screws, and possibility of placing the dental implants—the achieved outcome can be considered successful. All implants showed a good primary stability at the time of placement, and, macroscopically, there could be seen an advanced incorporation of the bone graft into the existing bone, prone to accomplishing a long-lasting restoration of anatomy, and function could be seen, similar to the findings of the cited authors.^{22,67}

The literature regarding the histological aspects of these grafts demonstrates that calvarial transplants have more osteoblastic and less osteoclastic activity than do iliac bone grafts. Inflammation is normally not associated with this technique, since the initial inflammatory response in calvarial bone grafts is common only for the first 4 months and correlates with the initial phases of graft remodeling.^{25,68} This is compatible with our histological results, which also showed an advanced stage of bone remodeling when implants were placed, with a huge amount of remodeled bone, full of exuberant osteocytes, even next to the interface between the newly-formed bone and the reminiscent necrotic bone. If we consider that the drilling procedure could act as stimuli to the host bone remodeling, taking into account that cancellous bone can be formed under mechanical and physical induced alterations,⁶⁹ allied to the bleeding that it

causes, the necrotic bone could even go through an accelerated remodeling process now that implants are placed.

It is important to be stated that among the factors that can influence the bone-implant interface, a biologically acceptable bone surrounding the implant, as shown in the present histological analysis, was a more important determinant of success than implant-loading factors, especially considering that 75% of implant failures in grafted areas in a 5-year observation period occurred during the first year and before loading.⁷⁰

CONCLUSION

According to the results of this case report, and to the exposed concepts:

1. Autogenous bone graft retrieved from calvaria, when carefully planned and performed, is a viable and safe alternative for attaining bone of good quality and adequate volume, allied to low morbidity.
2. The maxillary bone deficiency was regenerated, clinically and histologically showing that calvaria bone graft was biologically acceptable and allowed the achievement of optimum function and esthetics.

ABBREVIATION

CBCT: cone-beam computerized tomography

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