# Clinical and Histologic Evaluation of a Mineralized Block Allograft: Results from the Developmental Period (2001–2004)

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*This article reports on a multicenter evaluation of a novel, sterile, antigen-inactivated, mineralized block allograft in humans during a 3-year developmental period. Consecutive partially edentulous patients (n = 73) with severe localized ridge defects (n = 82) were treated with the material. After 4 to 6 months of healing, tapered screw implants were placed in the grafted bone and subsequently restored. Patients were monitored 25 to 36 months after prosthetic restoration. A biopsy was taken of one patient and submitted for histomorphometric analysis. Block allograft survival was 93% at 12 months, and resorption ranged from none (69%) to slight (0 to 2 mm) (31%) for all surviving allografts. Seven block allografts failed and were removed because of improper contouring, prosthesis impingement, and/or infection. The sites were successfully re-treated and restored with dental implants. Soft tissue dehiscence was successfully treated in seven other sites. Implant survival was 99%. One implant failed without allograft failure. It was replaced with a larger-diameter implant, treated with guided bone regeneration, and subsequently restored. Histomorphometric analysis showed rapid incorporation of the allograft at 6 months without inflammation or necrosis. The block allografts were more technique-sensitive than autografts, which necessitated meticulous surgical technique and follow-up. Short-term results for the block allografts indicated a high degree of predictability, but long-term follow-up is needed.* (Int J Periodontics Restorative Dent 2006;26:321–327.)

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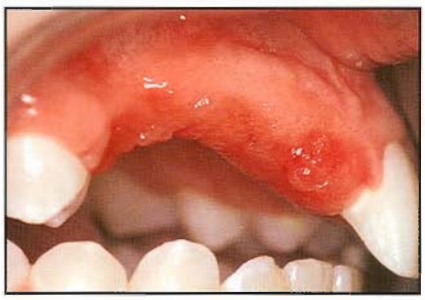
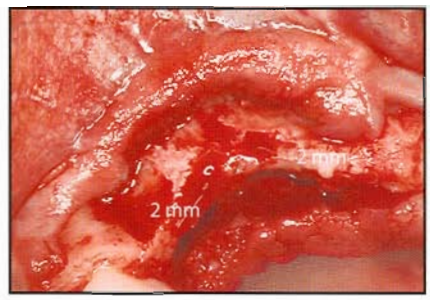
Reconstruction of severe localized ridge defects with block bone grafts is often an essential prerequisite for conventional prosthetic restoration or dental implant placement. Allogenic bone possesses osteoconductive characteristics similar to those of autografts and has been widely used as a bone graft alternative. Demineralized cortical bone (DBM) from the diaphyses of long bones has been reported to also be osteoinductive, at least in small rodents.[1] Testing of commercially available DBM, however, has revealed compromised structural stability and great variance between manufacturers and batches,[2] and researchers have not been able to clinically confirm an osteoinductive effect in humans.[3]

Mineralized block allografts have been used successfully as an alternative to DBM.[4,5] During a developmental period from January 2001 to December 2004, clinical and histologic evaluations of a novel, sterilized, antigen-inactivated, mineralized block allograft (Puros Block Allograft, Zimmer Dental) were conducted. The aim of the present study was to determine optimum handling procedures for the product and to evaluate its clinical effi-





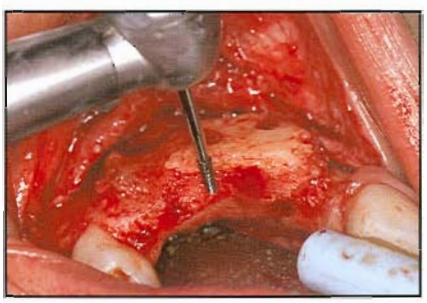



Fig 1 (above left) *Severe localized ridge atrophy precluded orthodontic movement of adjacent teeth into the edentulous area.*

Fig 2 (above) *Surgical exposure revealed a "knife-edge" residual ridge 2 mm in width.*

Fig 3 (left) *The residual ridge was prepared on the coronal aspect for block allograft placement to augment ridge height. Earlier block allograft placement on the facial aspect augmented ridge width.*

**Table 1 Patient distribution**

| Characteristic | No. |
|---|---|
| Health conditions | |
| S | 1 |
| S, M | 1 |
| M, P, T | 1 |
| None | 70 |
| Defect location | |
| Maxillary anterior | 35 |
| Maxillary posterior | 6 |
| Mandibular anterior | 3 |
| Mandibular posterior | 38 |
| Preoperative residual ridge width | |
| 1–2 mm | 17 |
| 2–3 mm | 40 |
| 3–4 mm | 23 |
| 4–5 mm | 1 |
| NR | 1 |

S = smoker; M = menopause; P = psychiatric problems; T = temporomandibular joint disorder; NR = not reported.

cacy in the treatment of severe localized alveolar ridge defects in humans. This article reports on the results of these evaluations.

## Method and materials

### *Clinical evaluation*

Candidates for this prospective study were consecutive partially edentulous patients who presented with severe localized alveolar ridge resorption in one or more edentulous locations in either arch. In all cases, bone grafting was needed to restore natural ridge contours for esthetics and support of one or more implants (Fig 1). Patient data are summarized in Table 1. Seventy-three patients (27 men, 46 women) ranging in age from 16 to 76 years (mean = 47.2; mode = 45) were selected as study participants after clinical evaluations were completed and informed consent was obtained. The patients presented with 82 residual ridge defects; these were evenly divided between maxillae (43% anterior, 7% posterior) and mandibles (46% posterior, 4% anterior). Prior to treatment, 49% of the residual ridges measured 2 to 3 mm in width, 28% measured 3 to 4 mm, 21% measured 1 to 2 mm, 1% measured 4 to 5 mm, and 1% was not recorded.

The allograft was a corticocancellous block from the iliac crest. The tissue was prepared through a proprietary process (Tutoplast Process, Tutogen Medical) and sterilized by low-dose gamma irradiation; this preparation method has been validated for virus and prion inactivation.[6] Other bone allografts subjected to this process have been shown to fully remodel in a manner similar to fresh-frozen bone[7] and have been used as alternatives to autografts in orthopedic[8,9] and oral surgery[10–15] applications. The present allograft had shown promising results in individual cases[4,5,16,17] but had not been subjected to multicenter or histologic evaluation prior to the present study.

In all cases, a staged treatment plan was used to minimize potential surgical complications. The first surgical phase consisted of bone grafting. Under local anesthesia, a mucoperiosteal flap was elevated to clearly expose the ridge defect (Fig 2). To provide the block allograft with maximum bony contact and stability when mortised into position, a rectangular graft inlay site with a flat base and sides measuring 0.5 to 1.0 mm in depth was prepared in the recipient bone using a straight bur with copious external irrigation (Fig 3). Cortical perforations were drilled into the recipient bone to induce bleeding. This may aid in the

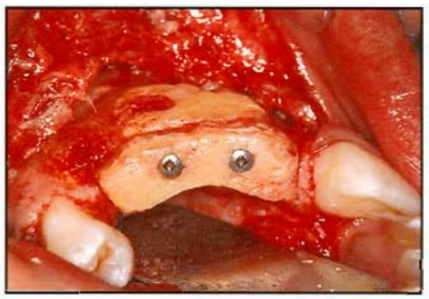
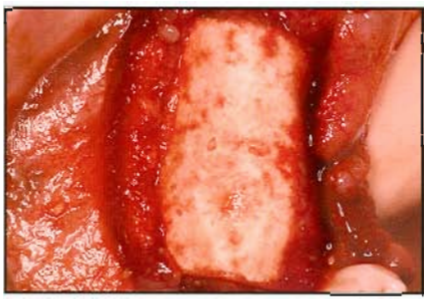


**Fig 4** (left) *The prepared block allograft was attached to the prepared ridge with screws.*

**Fig 5** (right) *A type I collagen membrane (BioMend Extend, Zimmer Dental) was placed over the graft site prior to soft tissue closure.*



proliferation of growth factors and platelets, which are essential for wound healing and revascularization.[18] The allograft was rehydrated in sterile saline solution (0.9%) according to the manufacturer's protocol.

With a water-cooled, high-speed handpiece (KaVo) and a large round fluted bur, the cancellous layer of the block allograft was contoured and intimately adapted to the prepared defect site. The sharp cortical edges of the block were also smoothed to minimize soft tissue trauma, but care was taken to preserve as much of the dense cortical surface as possible for rigid fixation of the graft. In some cases, the allograft was shaped to provide limited ridge-lap coverage of the alveolar crest for vertical augmentation.

The prepared block allograft was thoroughly rinsed with sterile saline solution to remove residual bone particles, delivered to the receptor site, and stabilized in place. Using extreme care, the surgeon drilled a 1.5-mm-diameter screw-access pilot hole through the allograft. This was followed by a second drill, which was inserted through the allograft and used to prepare a 1.1-mm-diameter pilot hole for the fixation screw in the underlying recipient bone. A fixation screw was freely inserted through the graft and screwed into the recipient bone to secure the block allograft in place. To prevent block allograft rotation, at least one additional screw was placed following the same procedures. Care was taken to place the second screw obliquely to the first screw and 4 mm away from it to minimize the risk of stress fracture (Fig 4). All screws were securely tightened, but care was taken not to overtorque them. Final contouring of the block allograft was completed intraorally to remove any sharp corners or edges that could contribute to soft tissue complications.

In most cases, any remaining voids around the graft were filled with particulate allograft material, and the graft site was usually covered with a barrier membrane that may or may not have been saturated in platelet-rich plasma (Fig 5). Soft tissue closure was achieved without tension using 4.0 sutures (Vicryl, Johnson & Johnson/Ethicon). Sutures were removed after soft tissue healing, and the graft was allowed to heal for a minimum of 4 months before implants were placed (Fig 6).

Prior to surgical exposure, incorporation of the block allograft was evaluated radiographically. The graft site was surgically exposed (Fig 7) under local anesthesia, using the same incision and flap designs used for conventional implant placement. Any presence of generalized or localized allograft resorption was carefully noted in the patient's chart. The fixation screws were removed, and the stability of the graft was evaluated by manual percussion with a surgical instrument. Osteotomies were prepared in the grafted edentulous ridges by sequential cutting with irrigated burs in ascending diameters, and implants were placed (Fig 8) according to the standard protocol of their respective manufacturers. The stability of the grafted bone in the regions of implant preparation was carefully monitored for resistance to fracture during implant placement. Surgical cover screws or transmucosal healing collars were placed on the implants. The soft tissues were reapproximated and sutured (Vicryl 4.0) for a one- or two-stage surgical procedure. Sutures were removed after soft tissue healing. The implants were allowed to heal for 2 months in mandibles and 4 months in maxillae.

After the healing period, the submerged implants were surgically exposed under local anesthesia. Osseointegration was evaluated radiographically and via manual percussion for both one- and two-stage implants. Healing collars were placed onto two-stage implants, and the soft tissues were approximated and sutured (Vicryl 4.0) around them. The sutures were

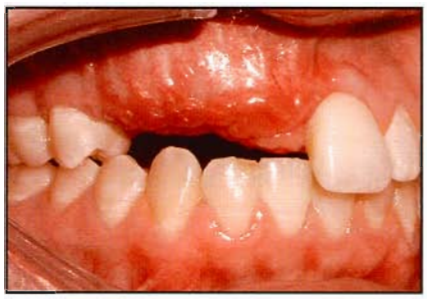


**Fig 6** *The augmented ridge has been restored to its natural contours.*

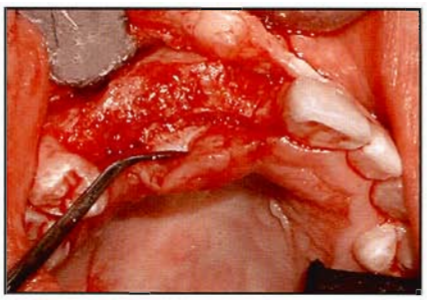


**Fig 7** *At surgical re-entry, the graft was stable and seen to be fully incorporated. Note the restored ridge contours.*

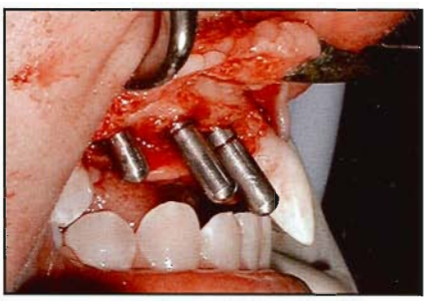


**Fig 8** *Osteotomies for implant placement were prepared in the augmented ridge. Note the drilling depth gauges in place.*

**Table 2 Distribution of grafts and dental implants**

| Material | No. of cases |
|---|---|
| Particulate used* | |
| Puros | 47 |
| DFDBA | 19 |
| None | 16 |
| Membrane used† | |
| BioMend | 42 |
| BioMend X | 18 |
| BioGide | 4 |
| Pericardium | 1 |
| None | 17 |
| PRP used? | |
| Yes | 19 |
| No | 63 |
| Implants placed? | |
| Yes | 52 |
| No | 30 |
| Implant diameter (mm)‡ | |
| 3.25 | 1 |
| 3.3 | 8 |
| 3.5 | 7 |
| 3.7 | 24 |
| 3.75 | 2 |
| 4.0 | 2 |
| 4.3 | 4 |
| 4.7 | 45 |
| 5.0 | 2 |
| 6.0 | 2 |

*Puros = mineralized solvent-dehydrated bone allograft (Zimmer Dental).
†BioMend/BioMend X = type 1 collagen (Zimmer Dental); BioGide = type 1 collagen (Geistlich); Pericardium (Tutogen Medical).
‡Numbers indicate sites, rather than cases.
DFDBA = demineralized freeze-dried bone allograft (Pacific Coast Tissue Bank); PRP = platelet-rich plasma.

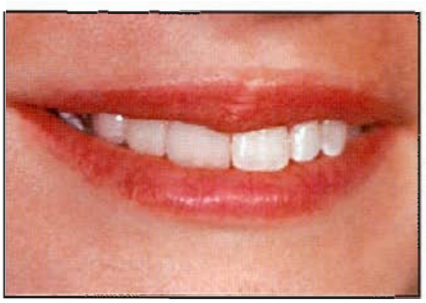


**Fig 9** *The restored dental implants rehabilitated the patient's function and appearance.*

removed after soft tissue healing, and restorative procedures were begun after soft tissue maturation.

Treatment data are summarized in Table 2. Block allografts and dental implants that exhibited radiolucency along the residual bone interface during radiographic examination and/or those that exhibited clinical symptoms (eg, infection, fracture, mobility, severe bone resorption) were deemed failures in this study. A total of 82 block allografts were placed; 68% (n = 56) were standard dimensions (10 × 8 × 18 mm), 28% (n = 23) were wide dimensions (15 × 8 × 18 mm), and 4% (n = 3) were of unspecified dimensions. Particulate allograft materials were used as additional filler around 80% of the block allografts, and absorbable barrier membranes were placed over 79% of the graft sites. Platelet-rich plasma was used in 23% of the cases.

After healing, mean block allograft follow-up time was 14.8 months (range, 1 to 33; mode, 15), of which 39% (n = 32) were followed for 0 to 12 months, 46% (n = 38) were monitored for 13 to 24 months, and 15% (n = 12) were monitored for 25 to 36 months.

The transmucosal healing collars were removed from the implants, impression posts were attached, and final impressions were made and sent to the dental laboratory. Working casts containing implant analogs were fabricated and articulated. Definitive metal-ceramic single-tooth restorations were fabricated and delivered to the patients according to the standard protocol for each implant system used (Fig 9). Patients were provided with comprehensive oral hygiene instructions and dismissed. Recall appointments were scheduled for 6 months and 12 months after prosthesis deliv-

**Table 3 Block allograft resorption, nonadverse events**

| No. of cases* | Amount of resorption | Location | Treatment |
|---|---|---|---|
| 52 | None | None | None required |
| 16 | < 1 mm | Around screw heads | None required |
| 5 | 0.5–1 mm | Minor localized resorption in portions of the block allograft | None required |
| 5 | 1–2 mm | Minor localized resorption in portions of the block allograft | None required |

*Three cases presented with both < 1 mm of resorption around the screw heads and minor localized resorption in portions of the block allograft (two cases with 0.5–1 mm and one case with 1–2 mm).

ery, and then annually thereafter. A total of 97 (47 maxillary, 50 mandibular) implants were placed in 63% of the healed graft sites.

### *Histologic evaluation*

Six months after graft placement, one patient consented to biopsy at the same time as implant placement. A trephine drill was placed perpendicular to the crest of the ridge, and a core sample (3 × 10 mm) was harvested from within the grafted and nongrafted regions and fixed in formalin. The specimen was embedded in methyl methacrylate and ground sections 80 µm in thickness were obtained. Sections were stained with hematoxylin and eosin. A histopathologic evaluation of the sample was conducted.

## Results

### *Clinical results*

Results of block allograft treatment are summarized in Tables 3 to 5. Cumulative block allograft survival was 93% (76/82) after 12 months, with no resorption reported for 69% (52/75) of the surviving blocks. Slight, nonpathologic, localized resorption (range = < 1 to 2 mm) around screw heads and/or limited to small areas of the blocks was reported for 31% (23/75) of the surviving allografts. Implant results are summarized in Tables 4 and 5. Cumulative implant survival was 99% (96/97).

Adverse events are reported in Table 4. Seven block allografts (8.5%) failed because of improper contouring, fracture because of improper placement of the fixation screws, impingement by the provisional prosthesis, and/or secondary infection resulting from soft tissue inflammation and excessive plaque. Only one block failure occurred in the maxillary anterior quadrant, and it was caused by improper block contouring. Most block allografts failed 0 to 12 months after placement (86%, n = 6); only one failure (14%) occurred at 13 to 24 months of clinical follow-up. By location, 71% (n = 5) of the block allograft failures occurred in the posterior mandible. Only one implant failed 13 to 24 months after placement, without any block allograft involvement. There were seven cases of soft tissue dehiscence and/or infection that were resolved without any allograft or implant involvement.

Failed portions of block allografts were removed, treated with guided bone regeneration procedures, and successfully restored with implant-supported restorations. The failed implant was removed, the site was grafted, and a second implant was placed and subsequently restored after graft healing. In cases of soft tissue dehiscence, the necrotic tissue was removed and a regimen of antibiotics was administered.

### *Histologic results*

A photomicrograph of the biopsy specimen is presented in Fig 10. Histopathologic evaluation revealed rapid incorporation of the block allograft at 6 months, as evidenced by newly formed bone containing viable osteocytes. The newly deposited osteoid and woven bone trabeculae surrounded and focally merged with few residual graft particles, which were characterized by empty lacunae and devoid of osteocytes. Because newly

**Table 4 Adverse events**

| Complication | No. of cases by location: Maxillary anterior | Maxillary posterior | Mandibular anterior | Mandibular posterior | Treatment | Result |
|---|---|---|---|---|---|---|
| Block allograft failure | 1 | 0 | 1 | 5 | Block removal, GBR, and secondary implant placement | Successful implant restoration |
| Soft tissue dehiscence with or without infection | 2 | 1 | 0 | 4 | Necrotic tissue removal and antibiotic therapy | Successful implant restoration |
| Implant failure without block allograft complications | 1 | 0 | 0 | 0 | Implant removal, GBR, and secondary implant placement | Successful implant restoration |

GBR = Guided bone regeneration

**Table 5 Life table survival data**

| Time interval (mo)* | No. | No. failed | Interval survival rate (%) | CSR (%) | No. censured† |
|---|---|---|---|---|---|
| Block allografts | | | | | |
| 0–12 | 82 | 6 | 93 | 93 | 26 |
| 13–24 | 50 | 1 | 98 | 91.1 | 37 |
| 25–36 | 12 | 0 | 100 | 91.1 | 0 |
| Implants | | | | | |
| 0–12 | 97 | 0 | 100 | 100 | 7 |
| 13–24 | 90 | 1 | 99 | 99 | 68 |
| 25–36 | 21 | 0 | 100 | 99 | 0 |

*0 mo = Time of graft placement.
†Grafts or implants with follow-up times that did not extend into the next specified time interval.
CSR = Cumulative survival rate.

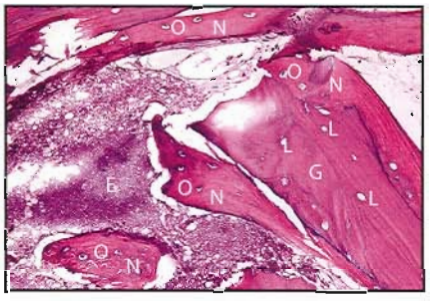



Fig 10 *Rapid incorporation of the block allograft at 6 months was evidenced by new bone formation (N) containing viable osteocytes (O) and few residual graft particles (G) with empty lacunae (L). Eosinophilic material (E) corresponding to platelet-rich plasma was also observed (hematoxylin and eosin stain; original magnification ×200).*

formed bone consists of trabeculae of woven bone, the two structures were indistinguishable. An amorphous eosinophilic material, corresponding to residual platelet-rich plasma components, was seen between the residual graft particles and the trabeculae of new bone. There was no evidence of inflammatory reaction or necrosis.

## Discussion

In the present clinical evaluation, the mineralized allograft maintained its strength with little or no resorption when properly used. The majority of adverse events occurred as a result of improper contouring or inappropriate closure techniques, which resulted in secondary soft tissue dehiscence and infection. Handling errors resulting in adverse events have decreased greatly now that these products are used routinely, but allograft placement is more technique-sensitive than autograft placement. Clinical training is therefore strongly recommended for clinicians unfamiliar with this product.

To achieve successful incorporation, host bone and blood cells must appose to the three-dimensional surface and interweave through the extracellular matrix of the allograft (osteoconduction).[19] This phenomenon is

well illustrated at the histologic level in this study, which found newly formed bone surrounding cancellous fragments of the allograft (see Fig 10). Incorporation of the mineralized allograft may also have been facilitated by the presence of retained collagen, which is known to facilitate fibroblast attachment.[20,21]

## Conclusions

The block allografts were more technique-sensitive than autografts; therefore meticulous surgical technique and follow-up are required. Short-term results indicated a high degree of predictability when the material was properly prepared and a standardized surgical technique was followed. Further research is needed to determine long-term results.

## Acknowledgments

Allograft materials for this study were provided by a grant from Zimmer Dental. The authors thank Timothy M. Lehman, BSE, MBA, for assistance.

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