A histologic study of bone response to bioactive glass particles used before implant placement: A clinical report

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This clinical report describes the microscopic analysis of the postextraction bone response to bioactive glass particles used prior to titanium implant placement, after a healing period of 6 months. The clinical and radiographic follow-up were performed over a 3-year period after implantation. (J Prosthet Dent 2003;90:424-8.)

The purpose of tooth replacement is the restoration of adequate function and esthetics without affecting adjacent hard or soft tissue structures. Current prosthetic treatment options for restoring a single-tooth space include conventional fixed and removable partial prostheses, resin-bonded prostheses, and single-tooth implant-supported restorations.[1,2] Within this context, an implant-supported fixed prosthesis in the rehabilitation of single-tooth spaces is currently considered the best choice because of its noninvasive nature with respect to the adjacent tooth structure.[2,3]

Results of several studies have confirmed a high level of success for single-tooth implant-supported restorations.[2-5] Haas et al[3] consider implant-supported crowns as the first choice in treatment planning for single-tooth spaces.

Single-tooth replacement with dental implants is a frequently used treatment option for the anterior maxilla.[1-3] To ensure long-term success for osseointegrated implants, a sufficient bone quantity and quality should be present at potential implant sites.[6-10] Augmenting hard tissue before implant placement may be a critical part of the therapy.[11,12] Preservation of the alveolar process after tooth extraction is desirable because it facilitates placement of endosseous implants and minimizes adverse esthetic results associated with fixed partial dentures and implant-supported prostheses.[11,12] Several local and systemic factors influencing the restoration of the bone volume after tooth extraction have been studied in experimental models.[13-17] In an attempt to preserve alveolar bone and avoid the necessity of residual ridge augmentation before implant placement, several particulate grafting materials have been used immediately after tooth extraction to fill the socket, including bioactive glasses (BGs).[11,12,18-22]

The ability of BG particles to promote bone repair has been assessed in several experimental models.[22-25] BG particles have been shown to undergo chemical transformation when they are implanted.[26] This process leads to the formation of silica gel on the surface of the particles followed by the precipitation of amorphous calcium phosphate that in turn crystallizes as hydroxi-carbonate apatite by incorporating carbonates from the surrounding medium.[26] A recent study has shown that the release of ions (Na, Ca, and Si) from BG materials control the cell cycle leading to the differentiation and proliferation of bone cells, modulation of the expression of genes that regulate osteogenesis, and the synthesis of growth factors.[27]

The effectiveness of BG particles in preserving alveolar ridge dimensions after tooth extraction and their value as a filling material around implants were demonstrated in clinical and experimental studies.[19-22,24,25] In an experimental model in rats, the repair response of bone tissue induced by the in vivo chemical changes resulting from 45S5 BG glass particles used as a filling material around titanium implants was assessed.[25] The histologic and histometric studies demonstrated an increase in osteogenesis in the presence of BG particles.[25] The microchemical characterization by energy-dispersive x-ray analysis of the newly formed tissue around the particles and the metallic implant evidenced the transient uptake of Si released from the BG particles during the early stages of peri-implantation bone healing (14 and 30 days after implantation) and a rise in the Ca to P ratio in peri-implant bone tissue when BG particles were used.[25]

These data provide evidence for the use of BG particles as a bone grafting material, as a therapeutic alternative to fill postextraction sockets before implant placement. Because histologic data from human studies are limited,[19,20] the aim of this clinical report was to histologically evaluate the postextraction socket bone response to BG particles used before implant placement and perform a clinical and radiographic examination after implantation of a metallic implant.

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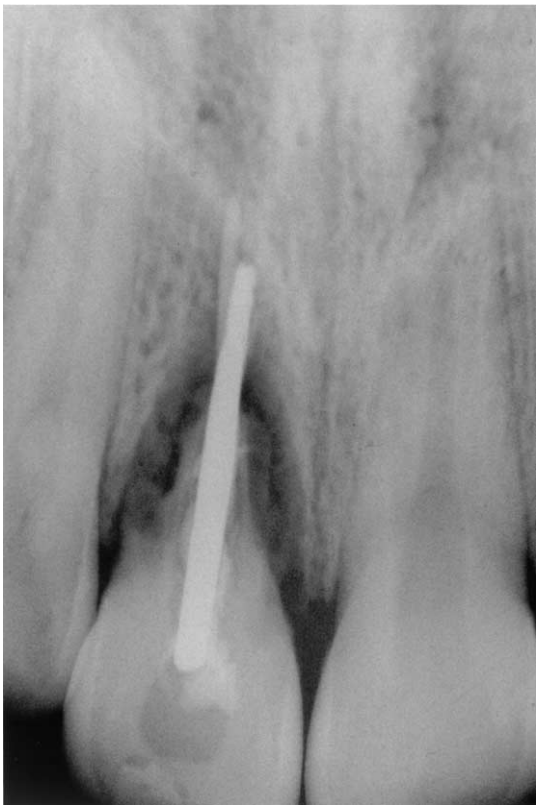

Fig. 1. Periapical radiograph demonstrates marked cementum and dentin resorption.

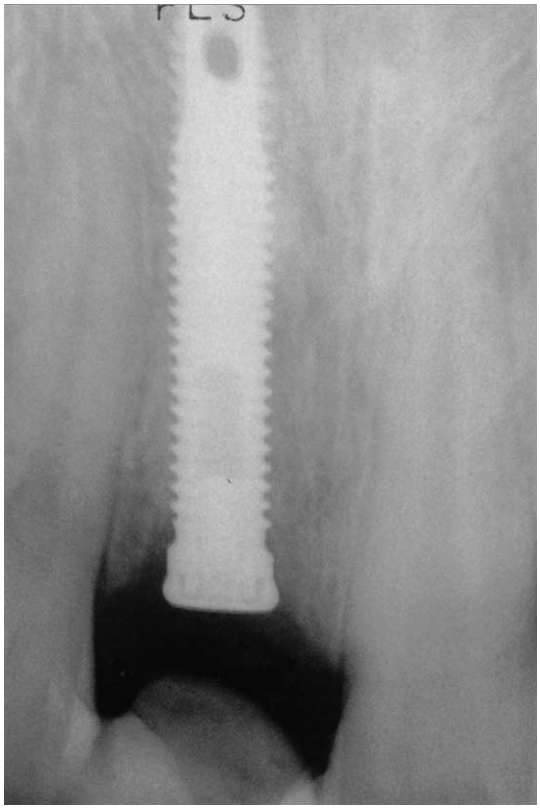

Fig. 2. Radiographic images immediately after implantation and 6 months after extraction and bone grafting.

CLINICAL REPORT

A 25-year-old white man presented with clinical and laboratory parameters within normal ranges. The patient exhibited no medical contraindications to implant placement. Clinical examination revealed mobility of the maxillary right central incisor. The opposing occlusion consisted of an intact mandibular arch that allowed stable occlusal contact.

Radiographic examination demonstrated marked cementum and dentin resorption (Fig. 1). Fifteen years before, the patient had undergone reimplantation and endodontic treatment of this tooth. Under local anesthesia and antibiotic therapy, the tooth was extracted, and after curettage of the bone bed, BG particles of approximately 300 to 350 μm (Biogran Implant Innovations, Palm Beach Gardens, Fla) were hydrated with sterile saline solution and placed into the socket with gentle pressure, completely filling the site. Sutures were removed after 7 days, and a provisional prosthesis was adjusted to minimize pressure on the underlying edentulous ridge.

After a healing period of 6 months, graft consolidation was subjectively assessed before biopsy and dental implant surgery by comparing radiopacity of the grafted area to an intraoral radiograph made approximately 1 month after grafting surgery. Radiographic observations at 6 months after grafting showed the site was almost completely filled by radiopaque tissue, making the socket walls indistinguishable. The vertical interproximal bone height had been maintained. Under local anesthesia and antibiotic therapy, an implant (SDCA 038; Nobel Biocare, Göteborg, Sweden) 18 mm in length and 4 mm in diameter, was placed following the conventional protocol (Fig. 2).[28] A biopsy specimen was obtained of the grafted site at the time of endosseous implant with a 3-mm diameter trephine bur (DIA 082; Nobel Biocare). Specimens were fixed in 10% formalin solution and processed for embedding in methyl methacrylate resin (Prothoplast; Subiton Laboratories, Buenos Aires, Argentina) for undecalcified sectioning after polymerization. The ground sections were stained with 1% toluidine blue to reveal mineralized bone tissue in the ground sections.[29]

After a 9-month osseointegration phase, the implant was exposed according to a conventional protocol[28] and restored with an abutment with a gold screw (SDCA 332, Cera One; Nobel Biocare) and a provisional acrylic crown for progressive loading and modeling of the gingival tissues. Seven months later a ceramic crown was fabricated and cemented with zinc phosphate cement

(Harvard; Richter & Hoffmann Harvard Dental GmbH, Berlin, Germany).

The patient was recalled for clinical examination at intervals of 3 months (during the first year), and thereafter at 6-month intervals. The following clinical parameters were assessed in the recall examinations: pain from implant region, plaque accumulation (yes or no, 4 surfaces), probing depths, bleeding on probing of peri-implant mucosa (yes or no, 4 surfaces), occlusion, and implant stability (tested with the suprastructure removed). Implant stability was assessed by rocking the implant with a rigid instrument or by tapping it back and forth between 2 instrument handles.

Possible loosening of the suprastructure was recorded by palpation of the crown, and the abutment screw was retightened using a torque of 32 Ncm with an electric torque control (Torque Controller; Nobel Biocare). Nonstandardized intraoral radiographs were made using a long cone technique (Kodak Ektaspeed Plus film; Eastman Kodak Co, Rochester, NY). The marginal bone level was assessed at the mesial and distal implant surfaces with reference to the abutment and implant junction.

Implant success was defined by clinical and radiographic evaluation. There was no evidence of implant mobility. No adverse soft tissue reactions or signs of infection or pain were observed. The periapical radiograph suggested osseointegration with the surrounding bone, with no sign of peri-implant radiolucency (Fig. 3). The histologic study of the apical portion of the bone bed to the central area of the socket revealed mature host bone, BG particles attached to the host bone (Fig. 4), and BG particles surrounded by connective tissue with no inflammatory response (Figs. 5 and 6).

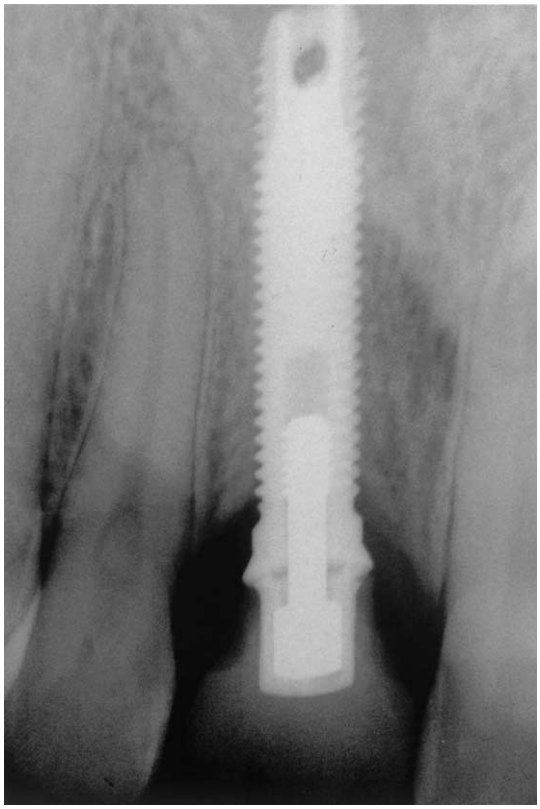

Fig. 3. Radiograph made at 3-year follow-up appointment.

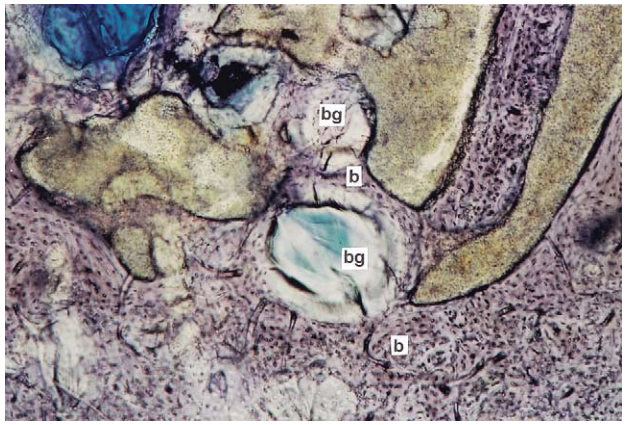

Fig. 4. Apical zone of implant bed: Note laminar bone *(b)* in contact with BG particles *(bg)* (Toluidine blue stain; original magnification ×100).

DISCUSSION

Admittedly, this report is based on the treatment of a single patient and does not include standardized measurements of alveolar ridge dimensions after tooth extraction. Within these constraints, this study provides evidence that, at the time of implant placement, the treatment of extraction sockets with BG particles is of some benefit in preserving alveolar ridge dimensions after tooth extraction. Sufficient bone volume was available to achieve primary implant stability and satisfy both functional and esthetic demands.

Clinical and radiographic re-examination performed over 3 years after implantation in the extraction site grafted with BG particles revealed healthy peri-implant mucosa and implant stability. These results are in keeping with a previous report by Norton and Wilson,[20] who established that "the use of these materials did not compromise implant success." These authors reported a cumulative survival rate of 90% at the 1-year follow-up, and 96.8% for implants in function from 22 to 44 months.[20] These results are comparable to those of other studies of implants placed in regenerated bone,[6,7] other 3-year data from studies of implants in general,[8,9] and to data obtained with single-tooth implants placed in healed and immediate extraction sites and immediately loaded.[5,10]

Bone filling at the time of tooth extraction can be used to minimize alveolar ridge resorption. This ap-

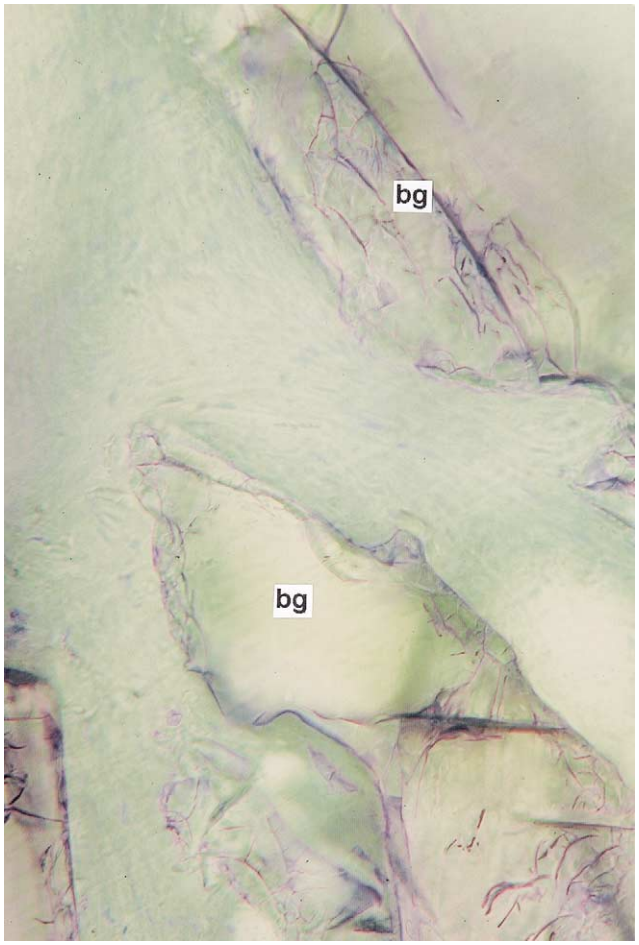

Fig. 5. Central area of implant bed: Note absence of osteogenesis around BG particles *(bg)* (Toluidine blue stain; original magnification ×100).

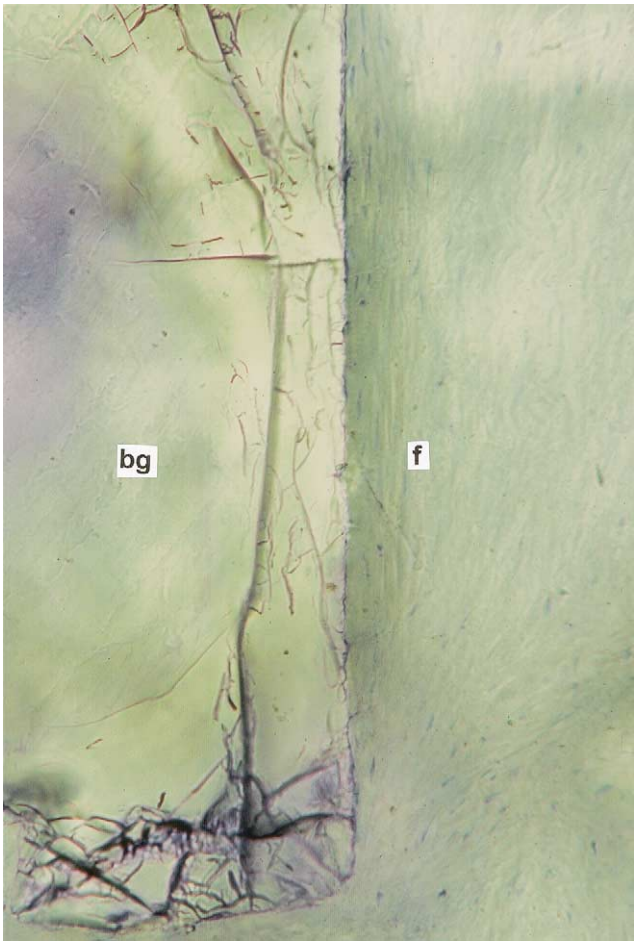

Fig. 6. Higher magnification showing fibrous tissue *(f)* around particles *(bg)* (Toluidine blue stain; original magnification ×400).

proach may be appropriate, especially where esthetics and final bone volume are critical.[11,12] The importance of the biology of the processes involved in bone healing in the presence of bone filling materials must be stressed, because the success of a metallic implant placed in this environment depends on the previous response to the bone filling material.

The histologic findings for this specimen are in agreement with the results of Froum et al[19] and Norton and Wilson[20] in previous human studies. These findings demonstrate typical centripetal postextraction alveolar bone healing response, given the absence of osteogenesis around the BG particles in the middle sector of the implant bed. Centripetal bone formation has been reported in an experimental model of alveolar bone healing, affording a quantitative characterization of the process.[13-16] The presence of bone filling materials[15] or metallic implants[16] in that model produced responses that varied with the biomaterial used but closely resembled the response described in this clinical report. Differences between this report and previous studies may be related to the speed of healing, location of implantation, and the time at which biopsy specimens were obtained.

In this clinical report, the absence of bone tissue in the center of the specimen may be due to micromovement. Becker et al[18] stated that the possibility of micromovement during healing could be discounted, and Carmagnola et al[17] suggested that micromovement of the graft prevented its integration with the host bone. This phenomenon did not affect the success of the procedure because the area was replaced by the implant. However, it must be pointed out that in other applications in which bone grafting is the only therapeutic alternative and the grafted volume ensures that the bone healing response is contiguous and integrates with the adjacent skeleton, the biomechanical performance may be unsatisfactory for the area involved. Future studies are necessary to assess the effect of these variables on repair processes in the presence of bone grafting materials.

SUMMARY

The histologic evaluation of post-extraction socket bone response to BG particles used prior to implant placement in 1 patient has been described. The histologic study of the apical portion of the bone bed to the central area of the socket revealed mature host bone, BG particles attached to the host bone, and BG particles surrounded by connective tissue with no inflammatory response. Clinical and nonstandardized radiographic follow-up revealed healthy peri-implant mucosa and implant stability.

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