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MORPHOLOGICAL EVALUATION OF DOMESTIC BG1D BIOACTIVE GLASS FOR RECONSTRUCTION OF JAW BONE DEFECTS IN AN EXPERIMENTAL STUDY

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Annotation

This experimental study investigated the morphological effectiveness of the domestically produced BG1D bioactive glass for reconstruction of jaw bone defects. Bioactive glass and bioceramic materials based on biogenic silica are widely used in dentistry and orthopedics due to their osteoconductive and regenerative properties. The study focused on evaluating bone tissue response to BG1D implantation using an in vivo rabbit model. A total of 16 adult chinchilla rabbits were included in the experiment and divided according to postoperative observation periods. Histological analysis demonstrated active formation of new bone trabeculae surrounding residual bioactive glass particles, along with gradual remodeling of connective and osseous tissues. At 30 days after implantation, heterogeneous tissue reactions were observed, including osteoid formation, fibrous tissue proliferation, and moderate inflammatory infiltration around residual material fragments. By 60 days, thickening of bone trabeculae and progressive bone remodeling were noted, indicating favorable regenerative activity and integration of the implanted material. The obtained findings confirm the osteoregenerative potential and biocompatibility of BG1D

bioactive glass and support its перспективность for application in maxillofacial reconstructive surgery and bone defect management. Introduction

Keywords

Bioactive glass, BG1D, bone regeneration, jaw bone defects, maxillofacial reconstruction, bioceramic materials, osteogenesis, bone remodeling, experimental study, rabbit model, histological evaluation, dental biomaterials.

Introduction

At present, bioactive glasses and bioceramic materials based primarily on biogenic silica are widely used as bone substitute materials in dentistry and orthopedics [2,5,7,12]. Numerous clinical studies have demonstrated that commercially available bioactive glass materials represent an effective approach for the treatment and reconstruction of bone defects. Early commercial bioactive glass particles measuring 90–710 μm, marketed under the trade name PerioGlas®, were primarily used for the management of periodontal bone defects in dentistry [8–12].

NovaBone® is a commercially available bioactive glass widely applied for the regeneration of osseous tissues in defects up to 20 mm in diameter [6]. In addition, BioGran® is a restorative biomaterial with a composition similar to 45S5 bioactive glass, containing particles ranging from 300 to 360 μm, and has demonstrated high efficacy in the treatment of extraction socket defects [6,13,14].

Recently, a novel form of NovaBone® Dental Putty has been introduced for bone grafting procedures. This material consists of a premixed composite of 45S5 bioactive glass particles and a synthetic resorbable binder designed to improve handling characteristics during clinical application [1]. The development of this product was aimed at simplifying clinical use, as surgeons are no longer required to manually mix glass particles with the patient’s blood to produce a moldable graft material suitable for placement into osseous defects [3,4,6].

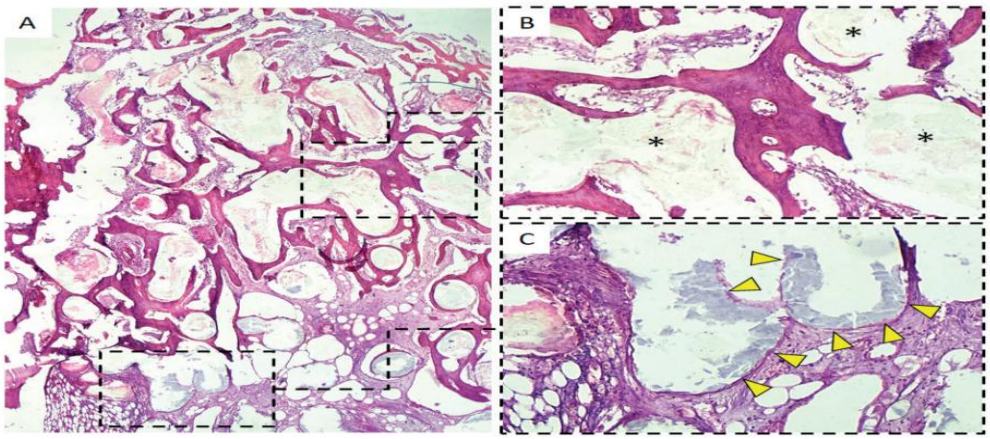

Figure 1. Histological appearance of rabbit tibial bone implanted with a scaffold composed of bioactive glass at 30 days after implantation. **A.** Heterogeneous histological alterations characterized by the presence of areas with newly formed bone trabeculae (indicated by "B"), as well as peripheral zones of fibrous tissue formation ("C") surrounding residual bioactive glass particles (arrows).

B. Osteoid tissue located within central regions between bone trabeculae, represented by pale eosinophilic fine granular material (black asterisks). **C.** Peripheral areas demonstrating larger fragments of azurophilic amorphous material (foreign body giant cells), surrounded by fibrous tissue with moderate mononuclear inflammatory infiltration. Hematoxylin and eosin staining; magnification ×100.

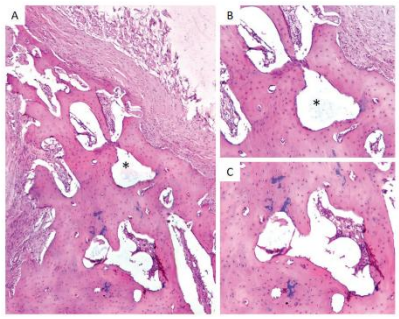

Figure 2. Histological appearance of rabbit tibial bone implanted with a bioactive glass scaffold at 60 days after implantation. Thickening of bone trabeculae and signs of bone tissue remodeling associated with connective tissue formation are observed.

In some cells, fine granular eosinophilic material is identified, possibly representing residual implant particles (black asterisks). Hematoxylin and eosin staining; magnification ×100–200.

Aim of the Investigation

The present experimental study was designed to evaluate the morphological effectiveness of the domestically produced BG1D bioactive glass in the reconstruction of maxillofacial bone defects using an in vivo rabbit model.

Materials and Methods

The experimental protocol included 16 adult chinchilla rabbits, which were allocated into several observational groups according to the postoperative assessment periods. In all animals, a standardized osseous defect was surgically created in the femoral region, followed by implantation of the BG1D bioactive glass material into the defect site.

To assess the regenerative potential of the implanted biomaterial, histomorphological examination of bone specimens obtained from the operated animals was carried out at different stages of healing. Special attention was paid to trabecular bone formation, connective tissue organization, inflammatory response, and integration of the implanted bioactive material with surrounding bone structures.

Results and Discussion

Histological examination of rabbit tibial bone specimens obtained 28 days after implantation demonstrated preservation of bioactive glass fragments in the form of pale eosinophilic fine granular material localized within irregularly shaped structures between newly formed mature lamellar bone trabeculae. In peripheral regions adjacent to the implant, larger amorphous fragments surrounded by fibrous connective tissue with moderate chronic inflammatory infiltration were identified (Figure 1).

At 58 days after implantation, histological analysis revealed almost complete biodegradation of the implanted material accompanied by replacement of the defect area with mature fibrous tissue and newly formed bone trabeculae. In isolated osteocyte lacunae, residual fine granular eosinophilic particles, presumably

representing remnants of the implanted biomaterial, were observed. Bone trabeculae appeared thicker and demonstrated a more organized lamellar architecture with concentrically arranged plates. Occasional focal calcification sites were also identified (Figure 2). The regenerative process observed in the experimental groups confirms the high osteoreparative potential of BG1D bioactive glass in the management of bone defects. Histological findings demonstrated gradual substitution of the implanted material by newly formed bone tissue, indicating active osteoconduction and favorable integration of the scaffold with surrounding osseous structures.

During the early postoperative stages, moderate inflammatory infiltration and formation of immature connective tissue were observed around the implanted particles. Such tissue reactions are considered characteristic phases of physiological reparative osteogenesis and reflect the adaptive response of surrounding tissues to biomaterial implantation. Importantly, no signs of severe necrosis, purulent inflammation, or extensive foreign body reaction were identified throughout the observation period.

As the healing process progressed, active maturation of bone trabeculae was noted, accompanied by increased mineralization and organization of lamellar bone structures. Newly formed trabeculae demonstrated close contact with residual fragments of bioactive glass, suggesting a direct stimulatory effect of the material on osteoblastic activity and matrix deposition. In several specimens, areas of osteoid tissue formation and early calcification were visualized, indicating ongoing mineral metabolism within the regenerating defect zone.

One of the important characteristics of BG1D bioactive glass was its gradual biodegradation. Partial dissolution of implanted particles with subsequent replacement by mature bone tissue reflects controlled resorption kinetics, which is considered a desirable property for modern osteoplastic materials. Preservation of isolated eosinophilic granular fragments in deeper regions of the defect at later stages may indicate prolonged bioactivity of the material and continued stimulation of bone remodeling processes.

Comparative assessment of histological specimens obtained at different postoperative periods demonstrated a progressive reduction in inflammatory manifestations together with increased density and maturity of newly formed bone tissue. Connective tissue components became less pronounced over time and were gradually replaced by organized lamellar bone structures containing osteocytes within well-formed lacunae.

The obtained data are consistent with contemporary concepts regarding the mechanism of action of silica-based bioactive glasses. Following implantation, ionic exchange processes occurring on the surface of the material promote formation of a biologically active hydroxycarbonate apatite layer, which enhances cellular adhesion, osteoblast differentiation, and subsequent bone regeneration. In addition, release of calcium and phosphate ions contributes to activation of local metabolic pathways involved in reparative osteogenesis.

The results of the present study suggest that domestic BG1D bioactive glass possesses satisfactory biocompatibility, osteoconductive properties, and regenerative potential, making it a promising material for application in maxillofacial surgery, implantology, and reconstructive dentistry. The material demonstrated stable integration with host tissues and supported gradual restoration of bone architecture without development of significant pathological inflammatory reactions.

Conclusions

Histological evaluation of rabbit femoral bone at different postoperative periods following implantation of the BG1D bioactive glass scaffold demonstrated progressive remodeling of the implant and gradual restoration of bone tissue. By approximately 2 weeks after implantation, initial reparative changes associated with connective tissue formation and moderate inflammatory infiltration became evident around the implanted particles. At later stages, almost complete resorption of the bioactive glass with replacement by mature bone trabeculae was observed.

The obtained findings indicate favorable biocompatibility and osteoconductive potential of the investigated biomaterial, as well as gradual substitution of the

implant by regenerated bone tissue without pronounced immune-mediated inflammatory reactions.

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