Bioactive glass in the treatment of infected pseudoarthrosis of the distal tibia in a thirty five years old man. Case report

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Abstract—Among the most serious complications of modern osteosyntheses are nonunion and infections. The pathology is challenging even for experienced surgeons, and the treatment often ends in failure. Bioactive glass represents an attractive alternative to conventional methods, as it combines a unique chemical formula (53% SiO$_2$, 23% Na$_2$O, 20% CaO and 4% P$_2$O$_5$) that is osteoinductive and increases the local pH as well as the osmotic pressure, which leads to its antibacterial effect. Herein, we present a clinical case of a 35-year-old man with infected pseudarthrosis of the distal tibia treated with bioactive glass. The excellent clinical and radiological results at the 6-month follow-up and positive data from the literature lead us to be optimistic about the treatment of these severe conditions.

Keywords—bioactive glass, infected pseudoarthrosis, surgical treatment.

1 Introduction

Bone infections can occur in three different ways: after trauma, contamination during surgery, or infection via the hematogenous route. Surgical treatment includes a combination of systemic and local antibiotics in a two-stage procedure. First, necrotic and infected tissue is removed, and thorough debridement is performed. However, a significant bone defect is then formed. To support the healing process and ensure stability, various methods are used to fill the cavity. The most commonly used option is filling the defect with antibiotic-loaded polymethyl methacrylate cement, such as pearl implantation, as well as various antibiotic-loaded spacers. This requires a second operation to remove them and to perform the final osteosynthesis of the fracture and bone grafting.

Another option for filling the cavity is bioactive glass. The most commonly used currently is S53P4. Its composition (53% SiO$_2$, 23% Na$_2$O, 20% CaO and 4% P$_2$O$_5$) is osteoinductive and increases local pH as well as osmotic pressure, which leads to its antibacterial effect.

In 1969, Hench et al. proposed the use of bioactive glass as an alternative to materials used as grafts. Bioactive glass is a synthetic material based on silicon dioxide that...
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has excellent mechanical properties and the possibility of bone integration. These authors present that a particular bioactive glass composition (Na₂O–CaO–P₂O₅–SiO₂) is able to form a strong connection with the surrounding bone that cannot be destroyed without significantly damaging the surrounding bone tissue.

2. Case report.

Herein, we present a clinical case of a 35-year-old man who had an accident as a motorcycle driver three years ago. He was diagnosed and treated for a right distal tibia fracture at another hospital. Open reduction and plate osteosynthesis were performed. Three weeks after the operation, active secretion from the surgical wound was established. It was treated by removal of osteosynthesis material and debridement of necrotic tissue with poor outcome. In February of this year, he was admitted to our clinic with complaints of permanent pain in the right lower leg. The rentgenography presented nonunion of the fracture and large bone defect in the area of complaints (Figure 1). At the first stage, thorough debridement of the necrotic tissues was performed. A microbiological examination revealed a methicillin-resistant Staphylococcus epidermidis infection. Intravenous antibiotics were administered in accordance with the antibiogram for the period of hospitalization. Postoperatively, the patient took 300 mg rifampicin for a month until the second operation. In the second stage, another thorough debridement and aggressive curettage to macroscopically healthy bone tissue was performed. A defect with dimensions of approximately 7 cm³ was formed. The latter was filled with bone substitute Bioglass granules. Thereafter, osteosynthesis of pseudarthrosis with a locking plate for the distal tibia was performed (Figure 2; Figure 3). Due to the presence of a skin defect and the peculiarities of the anatomical area, it was necessary to treat the surgical wound with vacuum dressings. Six months postoperatively, the patient had an excellent clinical, functional, and radiographic outcome (Figure 4), walked without aids, had no pain, and had no difficulties in his daily activities.
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**Figure 1.** Preoperative roentgenography

**Figure 2.** Intraoperative photography
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Figure 3. Postoperative roentgenography

Figure 4. Postoperative roentgenography on the sixth month after operation
3. Discussion

Bone and joint infections are a significant socioeconomic problem, and to date, there are only a few antimicrobial molecules that are effective against pathogenic microorganisms. Increasing the resistance of microorganisms leads to failure of antibiotic therapy and a significant increase in morbidity and mortality. Moreover, long antibiotic therapies and the use of topical antibiotics contribute to the increase in resistance. In the treatment of chronic osteomyelitis, several in vitro studies have shown the effectiveness of bioactive glass in terms of inhibiting bacterial growth while stimulating new bone formation and angiogenesis. One of the advantages of bioactive glass is its antibacterial effect without topical antibiotic treatment. The contact of bioactive glass with biological fluids leads to the release of ions from the surface of the granules, which leads to an increase in osmotic pressure and pH and makes the environment unfavorable for microbial growth. For example, the bioactive glass S53P4 shows antimicrobial activity against a wide range of aerobic and anaerobic microorganisms. Its osteoinductive characteristics are due to the formation of a silicon layer of calcium phosphate precipitate on the surface of the bioglass. These structures crystallize into hydroxyapatite, which then triggers the formation of new bone. This process continues until the bioactive glass is completely absorbed. The antibiofilm activity of S53P4 was reported against a wide range of microorganisms, highlighting the ability of S53P4 to reduce biofilms produced by S. aureus, A. baumannii, K. pneumoniae, and S. epidermidis. Bioactive glass has shown significant antibacterial effects for a wide range of aerobic and anaerobic bacteria due to the increase in pH and osmolarity in the surrounding tissues. To date, no resistant selection has been observed, suggesting that the bacteria cannot adapt to the changed environment created by the bioactive glass. In addition, these compounds are able to affect biofilms and are ideal bone substitutes for the treatment of bone infections. In experimental models, Bortolin et al. showed the time required to suppress bacterial growth in infections by different agents using different approaches. In the S53P4 group, 100% infection control was reported for both Gram + organisms (MRSE, MRSA) and Gram - organisms (K. pneumoniae, E. coli, P. aeruginosa) at 72 hours. The key to reducing morbidity and optimizing socioeconomic factors in the treatment of bone infections is the use of single-stage approaches. In a comparison of the use of bioactive glass and conventional two-stage techniques with bone grafting to fill diaphyseal bone defects in experimental animals, Eriksson et al. showed 100% bone union using S53P4 at the eighth week. These facts suggest that the one-stage treatment of this pathology is sufficiently justified. Lindfors et al. also indicated that the antibacterial, osteoinductive, and osteoconductive properties of bioactive glass are good alternatives in the treatment of chronic osteomyelitis with bone grafting. Treatment of osteomyelitis can be performed in one stage with excellent results. On the other hand, a multicenter analysis by Auregan et al. showed excellent results of the method in its use at a later stage in the treatment of chronic osteomyelitis. Even when another technique was previously used to address this pathology, S53P4 gave excellent results both on infection control and on the healing process of bone and bone fusion.
4. References


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