45S5 Bioglass® used to treat two cases of bone defect from open fractures

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Purpose of the work

Managing bone defects resulting from gunshot fractures or chronic osteomyelitis present a challenge in all species.

Discovered in 1969 by Dr. Larry L. Hench, 45S5 Bioglass® is used extensively in human surgery. This product is known for its osteoinductive and osteoconductive properties. Its principle of action is the creation of a layer of hydroxycarbonate apatite with resorption, allowing for the formation of a solid interface with the host tissue. The biomaterial granules have cohesive, hydrophilic, angiogenic and galenic properties that promote resorption. In addition, the liberation of soluble silica and phosphorus ions in the mineral layer allows for the induction and recruitment of osteoblasts that can fill the bone defect.

Despite many experiments on animal models, to our knowledge, no clinical studies on the use of bioglass have been published. The objective of this study was to test the efficiency of bioglass in contributing to bone repair in cases of high-degree open fractures with a concomitant infection that generated bone deficit.

Regular clinical and radiological follow-up allowed us to assess bone healing and resorption of the granules. A preliminary assessment of the efficiency and integration of the biomaterial in clinical condition was made possible by a biopsy done after bone healing.

Materials and used methods

Two animals were included in this clinical study:

• A 2.5-year-old neutered female German shepherd weighing 35 kg presenting with fractures of the humerus and tibia resulting from an accident with a piece of agricultural equipment. Only the tibial fracture presented bone sequestration and deficit requiring bioglass implantation.

• A 3-year-old neutered European shorthair cat weighing 4.2 kg presenting with an open tarsometatarsal and intertarsal dislocation with loss of the metatarsal II base

In both cases:

• Wound management was done prior to implantation.

• A temporary undersized external fixator was used during this treatment.

• During the osteosynthesis surgery, samples were collected and cultured for an antibiogram.

• Signs of osteomyelitis were uncovered after osteosynthesis, from which bone deficit ensued.

• The osteosynthesis implants were removed once bone healing was complete.

The German shepherd's bone infection was treated with gentamicin-PMMA beads, inserted into the defect created by the sequestrum, 18 weeks post trauma, and left in place for 6 weeks prior to insertion of the bioglass.

The bone defects these animals presented were difficult to quantify with precision due to their irregular nature. The German shepherd's bone defect was considered severe, with the length of sequestrum measured at 2.5 cm and a diaphyseal facing diameter of 1.4 cm.

In the cat, 14 weeks post trauma, we noted a loss of metatarsal bases II, III and IV with an estimated length of 4mm.

The bioglass was implanted in the form of granules:

• Once the osteomyelitis had been controlled

• Mixed with a bone graft in the case of the German shepherd

• A granule size of 0.5 to 1 mm was used in both cases

The implants used for stabilization are listed in the below table:

• German shepherd: 3.5 mm LCP 3.5 plating (neutralization) with two 3.5 mm traction screws/ Second orthogonal 3.5 mm LCP plate at 18 weeks

• European shorthair: linear external skeletal fixator 1.2-2 mm / 1.5 mm LCP plate after removal of the external fixator at 29 weeks

The animals were assessed clinically and radiologically once a month until they showed signs of bone healing. A

bone biopsy was carried out in the German shepherd, the sample taken at the estimated interface between the bone and the implanted biomaterial. Having evaluated the risk to the animal as minimal and with the consent of the owners, we did a single biopsy when the osteosynthesis implant was being removed.

Outcomes

We assessed the resorption of the implanted granules radiologically. The bioglass demonstrated marked opacity on X-rays, which reduced with time, and its granular aspect disappeared, allowing for a subjective assessment of resorption. We estimated it at 50 days for the German shepherd and 80 days for the cat.

The duration of bone consolidation between bioglass implantation and radiological signs of bone consolidation was estimated at 100 days for the dog and 110 days for the cat.

Full removal of implants was carried out at 240 days for the German shepherd and after 190 days for the cat.The biopsy done on the German shepherd was analyzed.The major feature was an integration of the bioglass inside the bone tissue without any signs of inflammation. Some bioglass remnants were still present in the tissue, in the medullary spaces surrounded by normal bone lamellae. Bone spiculae in this area have the histological aspect of mature remodelled bone tissue.

Conclusions

A number of biomaterials have been used to regenerate bone stock in othopedic surgery. Corticospongial allografts are the reference in veterinary surgery. The ideal characteristics for filling biomaterials are osteoconduction, osteoinduction, osteogenesis and biocompatibility.

Bioglass presents all of these characteristics as demonstrated in vitro studies and observed in clinical application in humans. It possesses an antibacterial effect tested primarily on oral cavity germs. Among other things, the latter is due to the alkaline pH occurring during dissolution of the biomaterial. However, it cannot serve as a mechanical support for osteosynthesis.

The bioglass's crystalline structure and hydrophilia promote its dissolution. It has been demonstrated that its dissolution is correlated to its osteoinductive and osteoconductive properties. In our cases, we observed that the majority of the bioglass had dissolved before 90 days. Bone repair was observed radiologically in both cases at approximately 100 days. It appears that there is a clinical correlation between the rate of bone growth and the rate of bioglass particle dissolution, as suggested in vitro. Consequently, as the bioglass resorbs, it is replaced by mechanically competent bone tissue.

Resorption was quick and to limit it, use of the largest possible particle size should be encouraged when there is a large area to fill. In our cases, we used an intermediary particle size.

The use of bioglass cannot replace AO fixation principles and classic bone infection management without running the risk of bioglass resorption without the creation of competent bone tissue. That is why we managed bone infection and wounds prior to implantation.

To our knowledge, bioglass has never been reported used under clinical conditions in dogs or cats. It has, however, been used in maxillofacial and spinal surgery in humans, demonstrating the same clinical efficacy as the iliac crest .

Bioglass has been tested experimentally in rats, goats, and canines, with the following results, among others:

- Creation of an interface with the host bone tissue that was more solid than native bone in goats
- Formation of bone in an intramuscular bioglass implantation in dogs
- The promotion of synthesis and mineralization of canine osteoblast extracellular matrix.

We obtained a satisfactory clinical result, with bone repair and regeneration of bone stock.

The latter is due solely to the bioglass in the case of the cat, although the addition of a bone graft in the German shepherd introduced a doubt in that case. The bone biopsy provided confirmation that in a critical deficit, Bioglass could be integrated without any signs of inflammation, leading to bone regeneration.

In view of these preliminary results, we conclude that bioglass can be considered for treating bone defects in dogs and cats. Additional studies are required to assess a recommended quantity and the efficacy in clinical cases of severe defects.

Bibliography

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