RESEARCH ARTICLE

Radiographic Evaluation of Bioglass and Polymethylmethacrylate for Long Bone Fracture Repair in Dogs

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Abstract

Long bone fracture fixation with various techniques, *viz.,* internal fixation, external fixation, external coaptation has been adapted since long time in veterinary practice. Despite of such advancements complications like implant loosening, migration resulting in malunion, non-union and delayed union are being observed later on. Various biomaterials have been identified and used in fracture management to improve the implant stability by holding bone and implant in position, enhancing and accelerating the bone healing via callus formation. Bioglass and Polymethylmethacrylate (PMMA) bone cement are a few of the biomaterials being used in the veterinary orthopaedics. This study was conducted on clinical cases of long bone fracture repair in 12 dogs, divided equality into two groups. Group I dogs were treated with Locking Compression Plate with bioglass putty as filling agent at interfragmentary spaces, while those in Group II were treated with Locking Compression Plate with PMMA as filling agent at interfragmentary spaces. The bone formation and bone union scores were significantly improved at 15th, 30th and 60th day interval of observation in both the groups. There was no statistically significant difference in scores between two groups, yet the scores were found to be better in group I, which might be attributed to the osteostimulative and osteoconductive properties of bioglass bone cement. PMMA bone cement is non-biodegradable and has numerous potential uses, but has serious disadvantages due to its adverse effects also.

Key words: Bioglass, Dogs, Locking compression plating, Long bone fracture, PMMA bone cement.

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Introduction

Fracture healing is an important biological process necessary for the injured animal›s survival. Bone is a unique tissue and its repair is of great biological importance, as it aims to fully restore the lamellar bone to its original condition, thereby regaining the initial bone strength (Brandi, 2012). The fracture repair establishes proper alignment and firm fixation of the bone fragments to allow well-timed and maximized return to their function. Modern methods of fracture treatment in animals often require the filling of extensive bone defects. The use of synthetic bone substitutes, *i.e.,* Ceramics with properties similar to natural osseous tissue is increasing rapidly, but the autogenous bone graft is still regarded as a "gold standard". Ideally a synthetic bone graft mimics the native bone in both mechanical and osteogenic properties (William, 2001).

Osteopromotive silica-based bioactive glasses induce accelerated local bone turnover, adjunct anti-resorptive agents may affect the process. When bioglasses comes in contact with body fluids, bioglasses converts to a silica-CaO/P_2O_5-rich gel layer which subsequently mineralizes into hydroxycarbonate in a few h (Neo, 1994). When implanted in bone tissues, the bioglass show a strong bond to bone and withstand removal from the implantation site as well (Krishnan *et al.,* 2013). Based on these observations, bioactive glasses are a promising group of unique biomaterials to act as bone graft substitutes for the treatment of fractures with bone loss (Fujishiro *et al.,* 1997).

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Polymethylmethacrylate (PMMA) is a Polymer-based non-biodegradable bone substitute widely used bone cement for implant fixation in various orthopaedic and trauma surgeries (Nandi, 2010). PMMA acts as a space-filler that creates a tight space that holds the implant against the bone and acts as a 'grout'. Bone cement has no intrinsic adhesive properties, but they rely instead on a close mechanical interlock between the irregular bone surface and the prosthesis (Vaishya *et al.,* 2013). This research was aimed at radiographic evaluation of bioglass and PMMA for long bone fracture repair in dogs.

Materials and Methods

The present study was conducted in two groups of six dogs each. Twelve patients irrespective of age, sex, and breed suitable for bone plating presented to Bai Sakarbai Dinshaw Petit Hospital for Animals (BSDPHA) affiliated with Mumbai Veterinary College, Parel, Mumbai were included. The majority of dogs were non-descript (11/12), male (8/12), with age ranging from 1 to 2.5 years. All dogs had history of automobile accident as a cause of fracture of long bones, and the time elapse since injury and surgery varied from 1 day to 40 days.

The Group I dogs were treated with Locking Compression Plate with bioglass putty as filling agent at interfragmentary spaces (Fig. 1), while those in Group II were treated with Locking Compression Plate with PMMA (Polymethyl methacrylate) as filling agent at interfragmentary spaces (Fig. 2, 3). Two radiographs, *viz.* cranio-caudal view and medio-lateral view were taken preoperatively to evaluate status of bone fracture, number of fracture fragments, direction of fracture fragments, diameter of medullary cavity, length of fracture fragments to predict the size of bone plate and screw (Langley-Hobbs, 2003). The radiographic evaluation was again carried out on day 15th, 30th, and 60th post-operatively to access bone healing in all cases. The bone formation score (BFS) and the bone union score (BUS) in dogs of group I and group II were assessed according to the system given by Lane and Sandhu (1987). The Mann-Whitney test was used for statistical data analysis.

Results and Discussion

Bone Formation and Bone Union Scores

The periodical post-operative radiographic examination revealed satisfactory plate and screw position in all cases. The details of bone formation score (BFS) and the bone union score (BUS) in dogs of group I and group II are given in Table 1. The data revealed that the bone formation and bone union scores were significantly improved at 15th, 30th, and 60th day interval of observations in both the groups (Fig. 4, 5).

Comparison of bone formation scores and bone union scores in Group I and Group II concluded that there was no-significant difference in bone formation scores and bone union scores. However either of the scores were found to be better in group I, which might be attributed to the osteostimulative and osteoconductive properties of bioglass bone cement, leading to early migration of mesenchymal cells resulting into callus and bone formation. Valimaki *et al.* (2005) opined that the bioactive glasses result in significant intramedullary new bone formation and high local bone turnover. The biocompatibility and osteoconductive properties offer a porous structure which promotes their resorption and bone ingrowth (Chai *et al.,* 2011). Gadhafi (2016) also found that the bioglass readily forms the scaffold for new bone formation, resulting in early formation of bridging callus and early healing.

Main disadvantage in the use of PMMA bone cement is its exothermic reaction during curing and the inability of the cement to be remodelled, the risk of inhibiting fracture healing and difficulty in removing if revision surgery is required (Larsson *et al.*, 2006).

Post-operative Complications

In one of the cases of group II (case no.6), the wound dehiscence due to soft tissue, muscle and bone necrosis

Table 1: Data regarding the bone formation score (BFS) and bone union scores (BUS) observed in dogs of group I and II

Groups of dogs	Case No.	Post-operative period							
		0th day		15th day		30th day		60th day	
		BFS	BUS	BFS	BUS	BFS	BUS	BFS	BUS
Group I (P=0.002) LCP	Case 1	0	0	3	2	4	2	3	4
	Case 2	0	0	2	2	3	4	4	4
	Case 3	0	0	3	2	4	4	4	4
	Case 4	0	0	3	2	4	4	4	4
	Case 5	0	0	3	2	4	4	4	4
	Case 6	0	0	2	2	2	4	4	4
	Mean ± SE	**0 ±0.00**	**0 ±0.00**	**2.66^{a} ±0.37**	**2.00^{A} ±0.00**	**3.50^{ab} ±0.73**	**3.66^{B} ±0.61**	**3.83^{b} ±0.22**	**4.00^{B} ±0.00**
Group II (P=0.001) PMMA	Case 1	0	0	1	2	3	2	4	4
	Case 2	0	0	2	2	3	4	4	4
	Case 3	0	0	2	2	3	4	4	4
	Case 4	0	0	3	2	4	4	4	4
	Case 5	0	0	3	2	4	4	4	4
	Case 6	0	0	2	1	3	2	2	2
	Mean ±SE	**0 ±0.00**	**0 ±0.00**	**2.16^{a} ±0.78**	**1.83^{A} ±0.16**	**3.33^{b} ±0.20**	**3.33^{B} ±0.42**	**3.66^{b} ±0.61**	**3.66^{B} ±0.61**

Means with different superscripts in lower and upper case differ significantly for BFS and BUS, respectively.

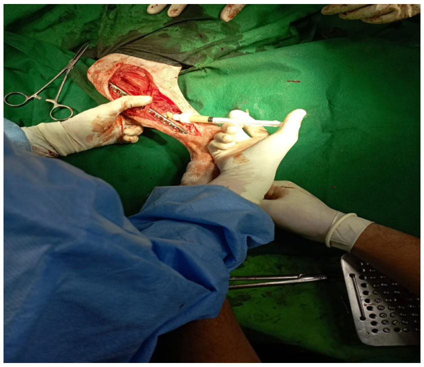


Fig. 1: Filling of Bioglass at fracture gap in case no. 3 of group I

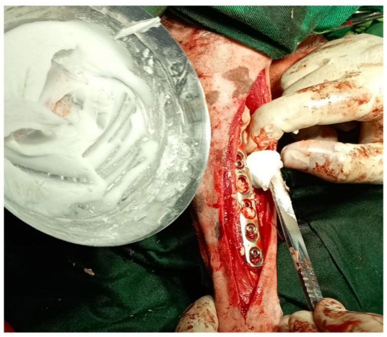
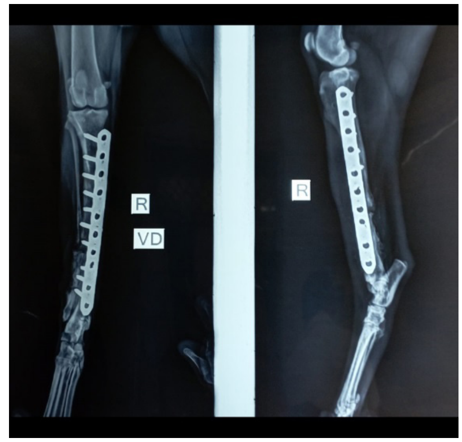


Fig. 2: Application of PMMA at fracture gap using sterile spatula in case no. 2 of group II

Fig. 3: Wound dehiscence noted in case no.6 of group II due to exothermic reaction of PMMA bone cement

Radiograph showing transverse fracture at right tibia-fibula in cranio-caudal and lateral view in case no.2 of group I.



Mild periosteal reaction at fracture site at right tibia-fibula in cranio-caudal and lateral view on 15th day after surgery in case no.2 of group I, with BFS:2 and BUS:2.

Soft callus formation at fracture site at right tibia-fibula in cranio-caudal and lateral view on 30th day after surgery in case no.2 of group I, with BFS:3 and BUS:4.

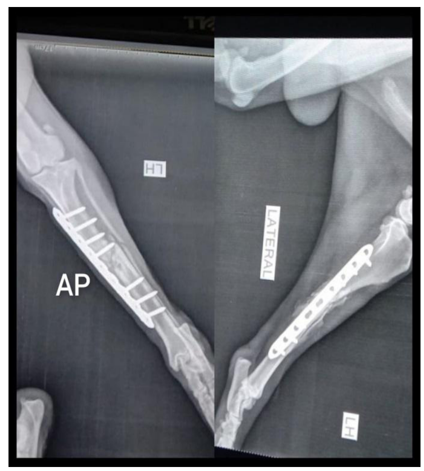
Bridging callus formation at fracture site at right tibia-fibula in cranio-caudal and lateral view on 60th day after surgery in case no.2 of group I, with BFS:4 and BUS:4.

Fig. 4: Radiographic evaluation of bone healing in case no.2 of group I

Radiograph showing oblique fracture at mid shaft at left tibia-fibula in cranio-caudal and lateral view case no.3 of group II

Bridging callus formation at fracture site at left tibia-fibula in cranio-caudal and lateral view on 15th day after surgery in case no.3 of group II, with BFS:2 and BUS:2.

Soft bridging callus formation at fracture site at left tibia-fibula in cranio-caudal and lateral view on 30th day after surgery in case no.3 of group II, with BFS:3 and BUS:4.



Bridging callus formation at fracture site at left tibia-fibula in cranio-caudal and lateral view on 60th day after surgery in case no.3 of group II, with BFS:4 and BUS:4.

Fig. 5: Radiographic evaluation of bone healing in case no.3 of group II

was noted due to the exothermic reaction exhibited by PMMA during curing (Fig. 5). The correction was done by debridement and resection of the affected part. On the contrary, bioglass does not induce an inflammatory response in body, and it gets resorbed completely in 6 months (Moimas *et al.,* 2006). Adverse reactions with PMMA bone cements reported in humans include transitory fall in blood pressure, elevated serum gamma-glutamyl transpeptidase, thrombophlebitis,superficial or deep wound infections, short term cardiac conduction irregularities and heterotrophic new bone formation (Ranjan *et al.,* 2015).

Conclusion

Based on present study it is concluded that the bone formation scores and bone union scores were better with bioglass bone cement group as compared to PMMA bone cement. Biodegradable Bioglass bone cement was found efficient to stabilise fractures, to hold implants against the bone with osteoconductive and osteo-inductive properties. On contrary PMMA bone cement is non-biodegradable and has numerous potential uses, but has serious disadvantages due to its adverse effects.

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