In vivo studies for MgO nanoparticles added bone-cement-implant interfaces

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Introduction: This study aimed to determine whether adding magnesium oxide nanoparticles (MgO-NP) in Cobalt^{HV} Poly Methyl Methacrylate (PMMA) bone cement (CBC) improves the quality of bone-cement union in vivo. This study also aimed to develop a finite element model of a bone-cement-implant interface for cemented orthopedic nail applications based on the in vivo test results. Biomedical grade titanium (Ti-6Al-4V-eli) wire (2.2 mm diameter×12 mm length) was implanted in the femoral condyle of New Zealand White Rabbits (NWR) without and with MgO-CBC. This study found that Ti/CBC samples having MgO NP with CBC (0.58 ± 0.16 MPa, n = 6) have higher shear strength compared to only CBC cemented Ti/Bone samples (0.34± 0.14 MPa, n = 6) (p=0.12). The study outcome shows the potential of replacing screws with cemented orthopedic nails for fracture fixation.

Methods: A total of six eight-week-old New Zealand White Rabbits (NWR) were divided into two CBC-Ti implanted animal sample groups, where the first group has Ti anchored by CBC, referred to as Ti-CBC-bone, and the other group has Ti anchored by MgO-NP added CBC, referred to as Ti-CBC+MgO-bone. All procedures for the animal studies were approved by the University of Oklahoma Health Science Center IACUC committee. A Bilateral implantations was performed at the distal end of the femurs after anaesthetization at the epiphyso–metaphyseal junction. The operation sites of the rabbits was shaved and sterilized, and followed by decortication. Each group of rabbits received an implant in femoral condyle. For a Ti/CBC specimen, a 3 mm diameter and 6 mm deep hole was made by a hand drill at the lateral epicondyle by a minimally invasive approach and each group of PMMA cement was filed in to the hole. Subsequently, a sterilized Ti wire was implanted into the prepared holes on either the left or right femur of the rabbits with the prepared CBC and CBC+MgO pastes. The animal was euthanized after eight weeks of implantation.

Results and Discussion: All animals recovered successfully with complete osseointegration of bone cement with bone. as shown in the X-ray image (Figure 1). All samples from the mechanical tests broke at the Ti-cement interface. Similar load vs. displacement behavior of a Ti-CBC-Bone and Ti-CBC+nMgO-Bone has observed with a gradual increase of load with displacement before sudden fracture (Figure 2). This study found that the average interface fracture strength of Ti-CBC+nMgO-Bone samples (0.66 ± 0.16 MPa, n = 6) were almost two times higher than the interface shear strength of Ti-CBC-Bone samples (0.33 ± 0.14 MPa, n = 6). However, the difference was not statistically significant (p=0.12) due to the high variance of interface contact length Table 1.

Significance/Clinical Relevance: This study has demonstrated that the incorporation of nanoparticles of MgO to PMMA enhanced the interface fracture strength of Ti-PMMA interfaces. This finding suggests that adding MgO particles to PMMA should be further investigated with respect to applications in cemented total joint arthroplasty (TJA) and interlock nails. The optimal concentration of MgO particles to PMMA to enhance mechanical and biological performances is currently under investigation.

Fig. 1 X ray image after the surgery of implants,

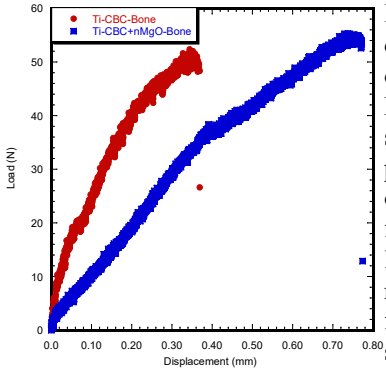

Fig 2. Load vs. displacement of the curve of a Ti-CBC-Bone and BC+nMgO-Bone samples showing similar fracture patterns of the sudden drop of load after reaching the fracture load. The fracture load was recorded to measure the interface fracture strength of each sample.

Table 1. Experimental and FEA test parameters for interface shear strength determination of the Ti-CBC-Bone (n=6) and Ti-CBC+nMgO-Bone specimen from the tensile test.

Sample Types	***Insertion length (mm)***	***Fracture load (N)***	***Interface shear strength (MPa)***	
Ti-CBC-Bone	8.01 ± 0.79	22.46 ± 7.94	0.39 ± 0.12	0.36 ± 0.11
Ti-CBC+nMgO-Bone	6.76 ± 0.27	30.92 ± 5.74	0.66 ± 0.11	0.31 ± 0.05