Differential blood contamination levels and powder-liquid ratios can affect the compressive strength of calcium phosphate cement (CPC)

- A study using a transpedicular vertebroplasty model -

Study design: *Ex vivo* biomechanical study

Summary of background data: Transpedicular kyphoplasty and vertebroplasty for osteoporotic vertebral fractures by injecting polymethylmethacrylate (PMMA) or calcium phosphate cement (CPC) into fractures are minimally invasive surgical strategies. Unlike PMMA, CPC is both biocompatible and osteoconductive without producing heat from polymerization, but it has lower compressive strength compared to PMMA.

Objectives: The objective of this study was to perform an *in vitro* model experiment examining how different ratios of mixed powder to liquid (P/L ratios) of CPC and methods of injection under blood contamination conditions may result in changes in compressive strength of CPC materials. The findings will help us ascertain how to achieve superior support through injecting CPC via the pedicle in cases of osteoporotic compression fractures.

Methods: (1) CPC of three different P/L ratios (P/L = 4.0, 3.5 and 3.2) was equally mixed with or without freshly-obtained human venous blood of 1.0 mL, 2.5 mL or 4.0 mL, producing cylindrically-shaped CPC samples (7 mm in diameter and 14 mm high). (2) We devised a cylindrical vertebroplasty model (16 mm in diameter, 32 mm high with a superior surface 5 mm high and featuring 2 small holes). After injecting 3 mL of freshly-obtained human venous blood, CPC was injected into the bottom of the container through one of the holes using a cement gun (3.7 mm in diameter). CPC pastes of different P/L ratios were injected with the nozzle of an injection gun affixed either to the bottom (Bottom method) or to the top of the container (Top method). All cylindrical CPC samples thus obtained were immersed in simulated body fluid and then underwent compressive strength tests at 3 hours to 7 days post-immersion.

Results: In experiment (1), the maximum compressive strength of the CPC cement samples in the Blood (-) group increased significantly until Day 7, irrespective of P/L ratio type. In contrast, the compressive strength values of samples in the Blood (+) group plateaued at Day 3 onwards and at Day 7, compressive strength decreased in conjunction with a decrease in P/L ratio and an increase in blood contamination. In CPC equally mixed with blood, lower P/L ratios and a larger amount of blood contamination reduced compressive strength more significantly. In experiment (2), at Day 7, compressive strength values were significantly higher in the Bottom group than in the Top group, in both the Blood (-) and Blood (+) groups and in both the low P/L ratio (P/L = 3.2)

and high P/L ratio (P/L = 4.0) sample groups. More specifically, there was a slight difference in compressive strength in the bottom group between the Blood (-) and Blood (+) groups (69.9 ± 2.8 MPa vs. 65.6 ± 4.8 MPa, respectively). Of the two methods of CPC injection, the 'Bottom method' produced significantly greater compressive strength values than the 'Top method' in both cases of injecting into areas with and without blood.

Conclusions: The P/L ratio of CPC cement and the level of blood and air bubble contamination are both important factors which regulate the compressive strength of CPC after hardening. When performing vertebroplasty, a high level of compressive strength and load-bearing support can be achieved by preparing CPC cement made using a high P/L ratio, by removing as much blood as possible from the site of injection into the vertebral body, and by injecting into the deepest part of the space inside the vertebra.