Mechanical and *in vitro* evaluation of low-modulus bone cement - Osteopal®V modified with linoleic acid

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INTRODUCTION: Adjacent vertebral fractures are a common postoperative complication upon vertebroplasty [1]. Some clinical and biomechanical investigations associate the risk for adjacent vertebral fractures with the usage of high stiffness bone cements [2]. The development of viable low-modulus cements has been a major challenge, since modification of commercial formulations typically results in poor cell viability or particle release [3]. Literature concerning *in vitro* evaluation of acrylic cements is scarce. In this work, we evaluate the mechanical behaviour of a commercial bone cement that, with minimal modification, can reach more bone-compatible mechanical properties. In addition, we report indirect cytotoxicity *in vitro* using a human osteoblast-like Saos-2 cell line.

METHODS: Osteopal®V (OP, Heraeus Medical, Hanau, Germany) cement was used as a base and modified with 9-*cis*,12-*cis*-linoleic acid (LA) dissolved in the liquid component. The following concentrations, with respect to the total weight of material, were analysed: 0 (OP), 0.75 (OP-0.75), and 1.50 (OP-1.50) wt% LA. Six groups of 14 specimens (∅=10 mm, h= 20 mm) were prepared. Three groups consisted of cement only, whereas the other three consisted of cement-augmented bovine bone cores. The stress-strain behaviour was determined by uniaxial compression testing using an Instron machine at a crosshead speed of 6 mm/min. For the cytotoxicity assay, three groups of 15 specimens (∅=12 mm, h=2 mm) were prepared. Extracts were prepared by placing specimens in cell medium at 3 cm^2/ml [4]. Every 1, 6, 12 and 24 h, extracts were collected and medium was refreshed. Cells were seeded at 20000 cells/cm^2 and after 24 h, extracts were added undiluted or 4-fold diluted [4]. The cells were incubated with extracts or complete media for 24 h or 72 h. Cell viability was quantified using the AlamarBlue assay.

RESULTS: Figure 1 illustrates the general stress-strain behaviour of all cement groups. The Young's modulus (*E*-modulus) and yield strength (σ_y) decreased as the LA concentration increased up to 1.50 wt%. For the cement-only group, the *E*-modulus and σ_y decreased by 74% and 83%, respectively. For the bone-cement group, the *E*-modulus and σ_y decreased by 33% and 47%, respectively.

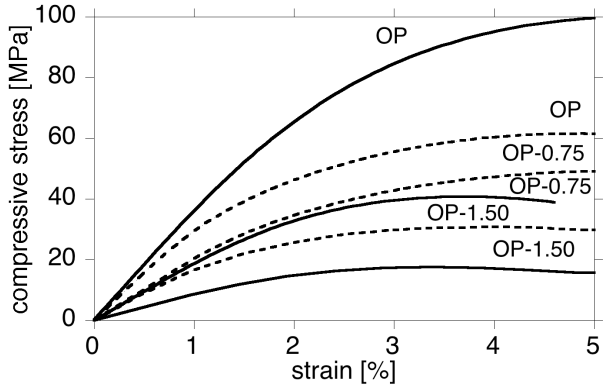

Fig. 1: Stress-strain curves for the cement-only (full) and bone-cement (dashed) groups.

Regarding cytotoxicity, for undiluted extracts, cell viability decreased for LA-modified cements in a dose-dependent manner. However, no significant differences were observed for LA-modified cements in 4-fold diluted extracts. In diluted extracts, the cells proliferated over time.

DISCUSSION & CONCLUSIONS: The addition of very small concentrations of LA can significantly reduce the *E*-modulus of commercial bone cement making it more bone-compatible. This is accompanied by a reduction of the *E*-modulus of the treated bony structure. The change in properties is thought to occur due to incorporation of LA into the polymer network by methacrylation via chain transfer mechanism. Although LA reduced the cytocompatibility of Osteopal®V, it is expected that fluid exchange would compensate this effect as observed for diluted extracts.

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