Bone Cements in Orthopaedic Surgery-Can A Leopard Change its Spots?

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INTRODUCTION: PMMA bone cement is susceptible to mechanical failure. We have reported that the addition of MWCNTs significantly improved the static mechanical performance, in addition to reducing the cellular thermal necrosis cause by the exothermic curing reaction of the cement [1-2]. However, the effect of MWCNTs on the dynamic mechanical properties and the cellular response of these nanocomposites are unknown. The objective of this study was to investigate the dynamic mechanical properties and cellular response of PMMA/MWCNTs nanocomposites.

METHODS: Unfunctionalised (NC7000-C), carboxyl (NC3151-COOH) and amine (NC3152-NH_2) functionalised MWCNTs (Nanocyl S.A., Belgium) (0.1, 0.25 wt%) were incorporated into Colacryl B866 (Lucite International Ltd., UK) cement [2]. Fatigue properties were determined using a pneumatically controlled testing machine (Zwick-Roell., UK) and cycled continuously in load control until failure [3]. Fatigue results were analysed using the probability of fracture method [3]. For the cell study, MG63 cells (Rockville, MD, USA) were cultured in Minimum Essential Medium supplemented with 10% foetal calf serum and antibiotic/antimycotic (penicillin-G sodium100 U/ml, streptomycin 100µg/ml, amphotericin-B 0.25µg/mL, (PAA Laboratories GmbH, Austria). A crystal violet attachment assay and 1, 3 and 7d MTT viability assays were carried out to determine the effect of MWCNTs on cell growth. Statistical significance was evaluated using one-way ANOVA with $p<0.05$ denoting significance. Post-hoc tests were conducted using the Student-Newman-Keuls and Duncan methods (SAS Institute, NC, USA).

RESULTS: Significant improvement in the fatigue performance ($p<0.001$) was recorded when MWCNTs were incorporated into the cement (Fig 1). PMMA cement with 0.1wt% NC3151-COOH and 0.1 wt% NC3152-NH_2 failed after 25,790±11,649 cycles and 12,905±4800 cycles, respectively. The addition of 0.25 wt% NC3151-COOH failed after 13,341±6099 cycles, while 0.25wt% NC3152-NH_2 reduced the fatigue life (8,824±4,483cycles). Using the probability of fracture method, the Weibull parameter estimated a 132% increase in the Weibull characteristic fatigue life (N_a) for the addition of 0.1 wt% NC3151-COOH, with a Weibull slope (b value) 33% higher than the control. 0.25 wt% NC3151-COOH provided an increased N_a value (42%), and b value (75%). Results from the cell study showed that after 4h, all PMMA-MWCNT cements exhibited a statistically significant increase ($p<0.05$) in cell attachment. After 7d culture all PMMA-MWCNT cements showed a statistically significant reduction ($p<0.05$) in cell viability.

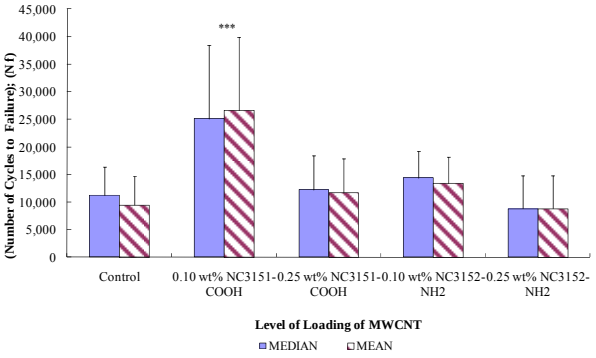

Fig. 1: Effect of MWCNTs on fatigue properties.

DISCUSSION & CONCLUSIONS: Incorporating MWCNTs (≤0.1 wt%) into PMMA cement significantly improved the dynamic mechanical properties. The extent of the improvement was dictated by MWCNT functionality and dispersion, with the NC3151-COOH providing the most significant improvements. Adding MWCNTs significantly increased cell attachment after 4h, but after 7d culture a decrease in cell viability was noted. Initial observations indicate this may be due to the surface area of the samples being insufficient to support the proliferation rate of the cells for the duration of this study. Flow cytometry will used to determine if cell necrosis is taking place.

REFERENCES: [1] Ormsby R, *et al.,* (2009) *J Mater Sci-Mater Med* ; DOI 10.1007/s10856-009-3960-5. [2] Ormsby R, *et al.,* (2010) *J Mech Behav Biomed Mater* **3**(2);136-45. [3] Dunne *et al.* (2003) *Biomaterials* **24** (2): 239-45.

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