

## Modification of PMMA using NMP in a stiffness-adapted bone cement for vertebroplasty

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**INTRODUCTION:** Percutaneous Vertebroplasty with polymethylmethacrylate (PMMA) achieves effective pain relief in 80% to 90% of cases. Because of PMMA's high stiffness, an increased fracture risk has been found for the adjacent vertebral bodies [1]. It seems reasonable to assume that the optimal stiffness of a cement is close to native cancellous bone (100- 700 MPa). Using an additive which acts as a plasticizer on the PMMA may decrease stiffness. 1-methyl-2-pyrrolidone (NMP) is an organic solvent which is miscible with the liquid component of PMMA. NMP's miscibility with water allows for a full exchange of NMP with body fluids after implantation. NMP has previously shown to have potentially favourable properties on bone growth [2]. A new cement design must also take viscosity [3] into account. The goals of this study were to determine the mechanical properties of the new PMMA as a function measure the viscosity during hardening.

**METHODS:** The modification of the PMMA cement to less stiff material was performed by partly substituting the fluid MMA by NMP (Fluka AG, Switzerland). Cement preparation was done by manual mixing. 21 g of PMMA powder were mixed with 10 ml of liquid component. The liquid component consisted of 100% MMA in the control group and of 80%, 70%, 50% and 40% MMA with the rest substituted by NMP in the test groups. Cement samples were produced according to ISO 5833. For each material composition, 24 samples were produced for the mechanical investigations. Materials were hardened in the mould for 2 h and removed. Subsequently, the samples were stored in PBS at  $37 \pm 1^\circ\text{C}$  for 48 h. Young's modulus and yield strength were then measured on all samples.

Mechanical testing was carried out in compression by means of a 10kN load cell and a crosshead speed of 5mm/min. The determination of the Young's modulus and yield strength was made according to ISO 5833. The viscosity of the cement during hardening was measured using a rheometer (Rheolab QC, Anton Paar, Austria) equipped with a double gap measurement system. Viscosity measurement as well as cement preparation was conducted at  $22 \pm 2^\circ\text{C}$ .

**RESULTS:** Measurements of the viscosity vs. time showed that NMP leads to a substantial reduction of the speed of the curing reaction. The time needed to reach a viscosity of 1100 Pas is approximately doubled when 60% of the MMA are substituted by NMP.

Characterization of the stiffness and yield strength of the material with and without substitution of MMA by NMP give further insight into possible effects of the NMP on the material. Both the stiffness and the yield strength are reduced by the addition of NMP. Young's

modulus ranged from  $2.3 \pm 0.023\text{GPa}$  to  $320 \pm 29\text{MPa}$  and yield strength from  $78 \pm 0.8\text{MPa}$  to  $24 \pm 4\text{MPa}$ , when the amount of NMP was increased from 0 to 60%.

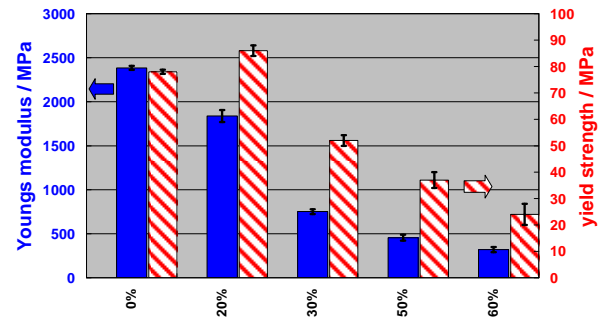


Fig. 2: Young's modulus and yield strength of NMP-modified PMMA cement.

**DISCUSSION & CONCLUSIONS:** Adjustment of the mechanical properties of PMMA is expected to reduce the fracture risk of adjacent vertebral bodies. This study shows that adding NMP to regular PMMA bone cement provides a possible solution: substitution of around 40% of the MMA content by NMP was able to yield a cement stiffness comparable to that of cancellous bone. The viscosity measurements showed a reduced speed in the curing reaction. This is an advantage in that it gives a clinician more time for injecting the cement, as opposed to the standard cement formulation without NMP. The fatigue properties will be analyzed in the future.

**REFERENCES:** <sup>1</sup> F. Grados F et.al. (2000) *Rheumatology (Oxford)*, 39:1410-1414. <sup>2</sup> FE. Weber FE et.al. (2006) *Proceeding, AO Biotechnology Symposium (Lausanne)*, p. 37. <sup>3</sup> G. Baroud G et. al,(2003) *Medical Engineering & Physics* 25(4), 283-288.

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