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Low Stiffness Biopolymer used for Mechanical Bone Augmentation in Osteoporotic Vertebrae

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INTRODUCTION: Bone cements generally used for vertebroplasty are PMMA or CaP based. Both materials are at least a magnitude stiffer (4-10 GPa) than vertebral trabecular bone (100-300 MPa). Adjacent segment fractures, a problem of vertebroplasty, is a likely result of this stiffening. A novel biopolymer, without this stiffening drawback, was biomechanically tested.

METHODS: 42 human vertebral bone cores were cut, characterized (BMD, porosity) and augmented with a three-part biopolymer, comprising a donor and acceptor with thiol and acrylic active groups, and a base reaction starter. A Teflon® mold held the bone core tightly while the polymer was injected, infiltrating the bone core completely. Augmented cores were kept in 37^{O} C saline. At seven time intervals (1h, 2h, 8h, 1d, 3d, 7d, 14d), the cylinders were compressed at 0.1% strain per second to failure. For controls, pure biopolymer samples at the same seven time intervals (n=21) and non-augmented bone cores (n=10) were tested. Failure strain, strength and stiffness were measured for the different time intervals.

RESULTS: Native bone shows a strength and stiffness strongly (r^2 > 0.9) linked to its porosity. Augmented cores, a composite of polymer and bone, showed a characteristic load-displacement curve with two linear elastic sections showing a distinct stiffness. The first leg was always stiffer, with a value comparable to the stiffness of native bone. At around 2% strain, the curve shows a knee, followed by a second leg with a lower stiffness. The composite's ultimate strength was 6.1 MPa after one hour, 12.7 MPa after eight hours and 15.5 MPa after two weeks (in comparison, native bone of average porosity is 2.7 MPa). Remarkable was the high failure strain at 9.1%, 16.1% and 20.3% (native bone, in comparison, is 2.2%). The stiffness of the augmented cores was 33.7 MPa, 67.3 MPa and 74.3 MPa, again for the same time intervals (native bone with average porosity is 145.1 MPa). Stiffness and failure strain curves were very similar for the bone-polymer composite and the polymer alone.

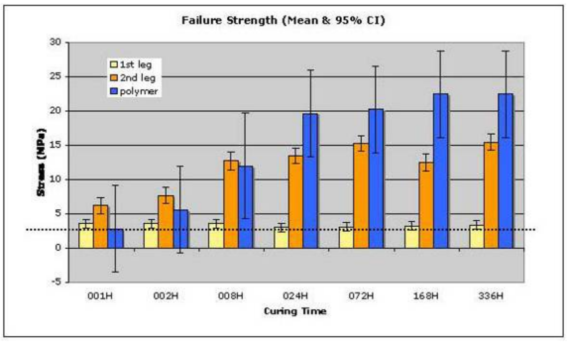

Fig 1: Ultimate strength of composite (1st and 2nd leg) and the polymer, plotted from left to right for increasing curing times, bars indicating group means ± 95% confidence intervals. The dashed line shows the average strength of native trabecular bone.

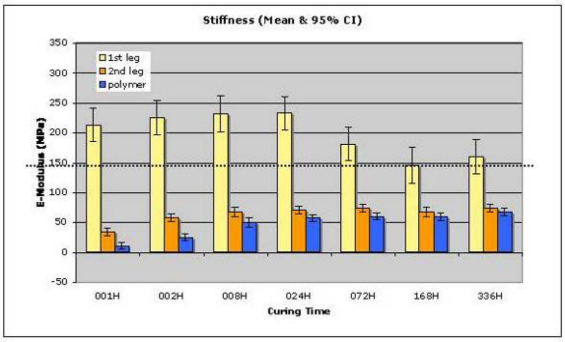

Fig 2: Stiffness of composite (1st and 2nd leg) and the polymer, plotted from left to right for increasing curing times, bars indicating group means ± 95% confidence intervals. The dashed line shows the average stiffness of native trabecular bone.

DISCUSSION & CONCLUSIONS: Nearly 80% of the fully cured augmented bone's ultimate strength and stiffness is reached after eight hours. Already after one hour, the composite's strength is double that of native trabecular bone (~ 2.7 MPa). Fully cured, the polymer's second leg stiffness is remarkably similar to that of very osteoporotic vertebral bone (~ 60-80 MPa). The novel biopolymer strengthens but does not stiffen osteoporotic bone. Whether cement with a lower stiffness will result in a lower incidence of adjacent segment fracture can only be shown clinically.