European Cells and Materials Vol. 11. Suppl. 1, 2006 (page 29) ISSN 1473-2262

Vertebral Cancellous Bone Augmented with Stiffness-adapted PMMA Cement does not Show Acute Failure under Dynamic Loading

A.Boger[1], P.Heini[2], M.Bohner[3] and E.Schneider[1]

[1] *AO Research Institute, Davos, CH.* [2] *Department of Orthopaedic Surgery, Insel Hospital Bern, CH.* [3] *Robert Mathys Foundation, Bettlach, CH*

INTRODUCTION: An increased fracture risk has been reported for the adjacent vertebral bodies after vertebroplasty[1,2], which may be due to the high stiffness of PMMA. Using stiffness-adapted porous PMMA[3] might reduce this risk. But the reduced failure strength of the porous cement could deteriorate under dynamic loading. The task of this study was to determine stiffness, acute failure, height loss and subsidence of cancellous bone augmented with porous PMMA under dynamic loading.

MATERIALS & METHODS: BMD of 12 human lumbar vertebrae (T11 or T12) was measured using pQCT. Two cylindrical biopsies (diameter 10.6 mm) were cored out from the central part of each vertebral body perpendicular to the endplates. The biopsies were randomly assigned to two groups. Each group contained one biopsy of each vertebra to assure identical density distribution in each group. The endplates of the cylinders were removed with a band saw to allow augmentation. Then the biopsies were sawn coplanarly to a length of 20mm. After removing the marrow, one group was augmented with regular PMMA (Vertecem, Synthes Inc.) and the other one with porous PMMA. The porous cement was prepared as described by Boger et. al[3]. For augmentation the biopsy was put into a tube and then cement was infiltrated with a plunger. Young`s modulus (YMm) and yield strength (YSm) in compression for the cements[3] are listed in Table 1. After 4h the infiltrated biopsy was rinsed and stored in demin. water at room temperature for 2 days. A dynamic compression test was performed in demin. water (Bionix; MTS Systems). The sinusoidal load controlled cycles had a frequency of 4 Hz and an amplitude from 3.9 N to 390 N corresponding to max. stress of 4.4 MPa (normal disc pressure 1-1.5 MPa). The total test duration was 60min (14.400 cycles). Stress-strain diagrams were analyzed for the initial (YMi) and final stiffness (YMf) of the bone/cement composite as an average of the first and final 10 loading cycles. Height loss was determined from initial and final height. Subsidence was determined as difference in strain at max. load between the average of final and initial 10 cycles. A quasi static compression test was performed to failure (velocity 5mm/min) (Instron 5866, 10 kN load cell). From the static compression test YMs and YSs were determined according to ISO 5833. Statistical differences between the groups were analyzed using ANOVA, dependent t-test, $\alpha < 0.05$.

RESULTS: BMD of the vertebrae/biopsies ranged from 0.078 to 0.29 g/cm3 (mean±SD: 0.21±0.06). No failure occurred during dynamical testing. Stiffness of the composite increased with porous and decreased with regular cement, both around 34% compared to cement alone. All variables were significantly different comparing the two groups. No linear correlation between BMD and height loss, subsidence could be found ($R^2<0.3$). A significantly higher height loss and subsidence was found for the biopsy group with porous compare to the ones with regular cement. All constructs showed stiffening due to dynamic loading by 17%.

Table 1. Subsidence, height loss, stiffness and yield strength values (mean ± SD)

PMMA	Porous	regular
YMm / MPa	480 ± 65	1900 ± 40
YSm / MPa	11.6 ± 3.3	100 ± 5
YMi / MPa	647 ± 106	1223 ± 127
YMf / MPa	761 ± 158	1422 ± 204
YMs / MPa	642 ± 131	1262 ± 183
YSs / MPa	21.1 ± 4.1	62.5 ± 10.8
height loss / %	0.53 ± 0.21	0.16 ± 0.1
subsidence / %	0.43 ± 0.23	0.11 ± 0.05

DISCUSSION & CONCLUSION: The bone/cement construct with stiffness adapted cement retains the mechanical properties in failure strength and preserves elasticity similar to trabecular bone alone. Nevertheless, the porous cement will prevent the accumulation of further damage without altering significantly the stress distribution under physiological loading. These data provide baseline data for the human application.

REFERENCES: [1] Grados F et. al, (2000), *Rheumatology (Oxford),* 39:1410-1414. [2] Ferguson SJ et. al, (2002) *J. Bone & Joint Surgery* 84-B: 748-752. [3] Boger et. al, (2005) *Biomedical Material Research Part B,* submitted. The authors thank Synthes Inc. for providing the materials.