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MECHANICAL INVESTIGATION OF A PROXIMAL TIBIAL SLOT DEFECT MODEL

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INTRODUCTION: Ceramic bone cements are often used in trauma surgery to fill large defects in comminuted fractures in the near joint area. In an *in vivo* study[1], the performance and resorption patterns of two different injectable cements (biphasic DCPD - β-TCP and monophasic HA) were investigated in different defects. In a drill hole in the femoral condyles, both cements showed the expected results with different resorption patterns: the hydroxyapatite cement showed minor superficial resorption with good integration in the surrounding bone; the biphasic β-tricalcium phosphate / dicalcium phosphate dihydrate cement revealed a corresponding resorption pattern with faster degradation of the matrix as compared to the granules, which were then surrounded by newly formed bone. In a highly loaded proximal tibial slot defect, cracks started to form in the anterior part, which were immediately filled with new bone. However, the mechanical competence of this situation and the reason for the crack occurrence – mechanically and/or biologically induced – are not known. A mechanical ex vivo test should investigate this question.

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MATERIALS AND METHODS: The tests were carried out on 16 tibiae of sheep with an average age of 60 (31 – 112) months. As implant materials, Norian®SRS® and calcium sulphate dihydrate were used. The shaft of the tibiae was embedded in Beracryl®. The defects underneath the tibial plateaus were created according to Gisep et al., using landmarks (attachment sites of medial and lateral tendons) for the position. The defects were 6 mm high, penetrating about 50% of the a-p depth of the tibia. The posterior cortex was left intact. The bones were divided into five groups:
1 defect filled with Norian®SRS®
2 defect filled with calcium sulphate
3 Norian®SRS®, 1 mm gap on the proximal side
4 calcium sulphate, 1 mm gap on the prox. Side
5 empty defect
All mechanical tests were carried out on an Instron 4302 testing machine with a 10 kN load cell. The empty or entirely filled defects were tested in a static mode until failure of the tibial plateau or the cement; the specimens with a gap were tested in a dynamic manner, 1000 cycles at 1500 – 2000 N. The load was chosen for the tibial plateau to touch the cement surface at every cycle. Crosshead speed in the static test was 1 mm/min, in the dynamic test 15 mm/min. An optical video system was used to measure the real deformations in the defect (Kappa CF 15DSP RGB video cameras with AxioVision Ver. 3.1 software, Zeiss).

RESULTS: The static tests gave the following results:

Table 1. Compression forces taken by empty or entirely filled defects in the static test.

	Defect	Compr. force [kN]
Bone 01	Empty	1.08
Bone 02	Empty	1.05
Bone 03	Empty	1.49
Bone 05	Norian SRS	3.09
Bone 06	Norian SRS	4.10
Bone 08	Norian SRS	3.97
Bone 11	Gypsum	3.87
Bone 12	Gypsum	4.52
Bone 16	Gypsum	2.91

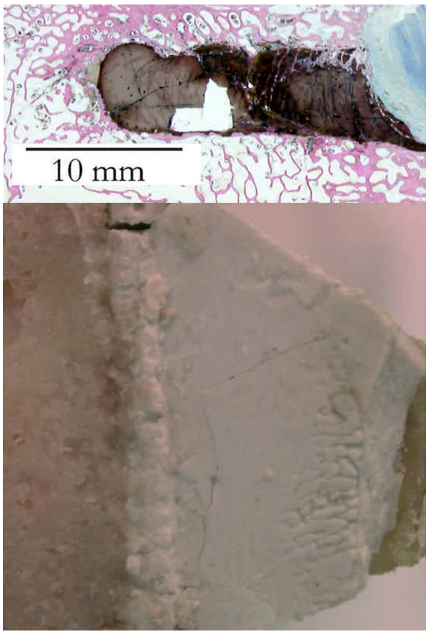

Figure 1. Cracks occurring in the cement after 20 weeks implantation (top, sagittal section through tibial slot defect) and after 1000 cycles in the dynamic ex vivo test (bottom, view on transver-

sal plane, top of the implanted cement). Small cracks in the anterior part, large cracks posterior.

The empty defects held forces of 1.21±0.25 kN. Filled with either Norian SRS or calcium sulphate, the average load taken until failure of the bone/cement system was 3.7 kN, which corresponds to about 5 times body weight of the sheep. The optical system revealed no deformations in the defects up to the maximum load, when the cement failed. In the dynamic tests, a similar crack pattern formation could be observed as in the *in vivo* study with only 1000 cycles at loads of 1.5 – 2.0 kN.

DISCUSSION & CONCLUSIONS: All empty defects failed at loads between 1.0 and 1.5 kN. This load corresponds to less than 2 times body weight of a sheep. This is by far exceeded during a gait cycle on uneven ground, running or jumping[2]. Failure strength of the filled specimens was about 3 times higher as compared to the empty specimens. The dynamic tests showed, that a highly loaded defect with a small gap fails after only a few cycles with much lower loads than the above mentioned. Such a small gap could result from an incomplete filling of the defect or a disturbed balance of bone formation and cement resorption in the initial healing phase of the fracture. Large comminuted intraarticular fractures with a loss in cortical structure and therefore reduced load bearing capacity should be stabilized with metallic implants before the resulting void is filled with ceramic bone substitute materials.

REFERENCES: [1]A. Gisep et al. (2003) *Resorption patterns of calcium-phosphate cements in bone*, J Biomed Mat Res, accepted for publication. [2]GN. Duda et al. (1998) *Analysis of interfragmentary movement as a function of musculoskeletal loading conditions in sheep*. J Biomech.