INTRODUCTION: Calcium phosphate cements (CPC’s) are produced by mixing a powder containing one or more solid compounds of calcium and phosphate salts with an aqueous solution. Norian Skeletal Repair System® (Norian SRS®; Synthes Inc PA) is a commercially available, injectable CPC which hardens to form a carbonated apatite. The crystallinity and chemical composition of Norian SRS® are similar to the mineral phase of human bone and it has a high compressive strength. To improve shear and tensile strength, fiber reinforced CPC’s have been developed by the addition of polyacrylic acid and polydiactylene fibers. The improved mechanical properties of these materials could increase the indications of CPC’s in clinical practice.

In this study the in vivo bone tissue reaction to fiber reinforced CPC’s was compared to that of conventional commercially available CPC’s. It is hypothesized that the addition of the reinforcing fibers to CPC’s will not affect their osteoconductivity and their biocompatibility in terms of cellular response.

METHODS: Five implant materials were evaluated. They were: Norian SRS® Fast Set Putty (SRS-FSP); Norian SRS® Fiber Reinforced-Fast Set Putty (FRN-FSP); Norian SRS® Fiber Reinforced-Rotary (FRN-RY); Norian SRS® Fast Set Putty with Hyaluronate (SRS-HY); Stryker® Hydroset™ (Hydroset). A ultra high molecular weight polyethylene (UHMWPE) plug was used as a non-resorbable inert control. Samples were implanted into cancellous bone of the distal femur and proximal tibia of eighteen mature female Swiss Alpine sheep in a bilateral model. Implantation sites were randomised such that 6 of each implant type were implanted for an in vivo duration of 3 and 6 months. The cancellous bone defects measured 5mm in diameter x 15mm in deep. Test samples were injected or press-fit into each defect. All procedures performed in this study were approved by the local government authorities (Amt für Lebensmittelsicherheit und Tiergesundheit GR, Tierversuche 02/2007). Immediately after euthanisation, 12mm diameter bone cores, centered over the implants, were collected. Overlying soft tissue and 5mm of bone were removed from the surface of the core bone. The remaining bone implant was submitted for histological analysis on Giemsa-Eosin (G-E) stained sections. Histological outcomes included qualitative assessment of the cellular response to the implant material and histomorphometric measurements in defined regions of interest, where the relative distribution (%) of bone and implant material was determined by image analysis software (KS400 version 3.0, Zeiss, Germany). Prior to statistical analysis, normality and homogeneity of the data was checked. Statistical analysis for the comparison of each individual implant type at 3 and 6 months was performed using a Student t-test. A Univariate Anova with a normality and homogeneity of the data was checked. Statistical analysis and implant material was determined by image analysis software in defined regions of interest, where the relative distribution (%) of bone for histological analysis on Giemsa-Eosin (G-E) stained sections.

RESULTS: For histomorphometry data (Figures 1 & 2), it was found that using the Univariate Anova, the factors time and material were significant (p ≤ 0.005). Using a t-test, it was found that the % bone in the former defect increased significantly from 3 to 6 months for the FSP-RY group (p = 0.034). No further significant differences were detected between the % bone and the % implant in the defects at 3 and 6 month (p ≥ 0.068). Using post hoc tests, it was found that at 3 months it was found that % bone in the defect treated with UHMWPE was significantly lower than % bone in the defects treated with FRN-RY, SRS-FSP, and SRS-HY (p ≤ 0.033). At 6 months the % bone in the defect treated with UHMWPE was significantly lower than the defects treated with FRN-RY and hydroset (p ≤ 0.05). No further significant differences were detected for the % bone in the defect at either 3 or 6 months time points (p ≥ 0.07; observed power ≥ 86 %). The % implant material in the defect treated with UHMWPE at the 3 month time point was significantly higher than defects treated with FRN-RY, SRS-FSP and SRS-HY (p ≤ 0.028). No further significant differences were detected for the % implant in the defect at either 3 or 6 month time points (p ≥ 0.122; observed power ≥ 78.2 %). Although there was an observed minimal to mild focal inflammatory response in some sections at the 3 month time point, these were not widespread and there was no obvious difference between CPC groups. All CPC groups showed improved cellular responses from 3 months to 6 months post-implantation. Active bone formation and remodelling was visible, and bone attachment and implant incorporation was observed in all CPC groups (Figure 3).

DISCUSSION: The use of CPC in orthopedic surgery has been shown to be advantageous in clinical practice. CPC’s are reported as being osteoconductive, i.e. they resorb slowly and transform simultaneously into new bone tissue, when placed in a bony environment. It is widely reported that CPC’s have good compressive strength. However, fiber reinforcement of CPC’s and the resultant improvement in mechanical properties could potentially expand the clinical indications of CPC’s. In this study the bone tissue response to fiber reinforced CPC’s was compared to conventional CPC’s. It was found that all CPC’s showed apparent signs of resorption between 3 and 6 months implantation. There was also a corresponding apparent increase in the percentage bone in the defects. The CPC resorption occurred in a manner which resembled bone remodeling where osteoclastic and osteoblasts were visible in all CPC sections. In conclusion, this study has shown that in terms of implant resorption, osteoconductivity and the hard tissue reaction, fiber reinforced CPC’s appear to be comparable to conventional CPC’s.