ABSTRACT INTRODUCTION:

Osteoporotic fracture is one of the commonest geriatric orthopaedic problems. The deterioration in microarchitectue and decrease in bone mineral density (BMD) in osteoporotic bone reduce its “holding power” to implants. Subsequently, osteoporotic fractures are difficult to be fixed and remain major challenge to surgeons (1). Intensive in vivo studies are necessary for testing the development of new techniques and new designs of implants for osteoporotic fracture fixation. Increasing the contact area between the osteoporotic bone and the implants is postulated to increase the “holding power” of the bone and reduce the failure rate of fixation. In this study, we analyzed the mechanical performance and biological response of an injectable bone cement on implant fixation using our established osteoporotic goat model.

METHODS:

Osteoporotic goat model was used for this study (2) with the approval by the Animal Ethics Committee of the Chinese University of Hong Kong. Briefly, skeletal mature Chinese mountain goats were ovariectomized (OVX). They were kept for 6 months and fed with low calcium diet to accelerate their bone loss. The decrease in BMD was confirmed using peripheral Quantitative Computed Tomography (pQCT).

10 goats were used in the current study. Screw insertion was started 6 months post-OVX. Femoral condyles and lumbar vertebrae (L3 to L6) were utilized in this study. One of the hind limbs and two of the lumbar vertebrae were augmented with bone cement during screw fixation as experimental group (Expt). The remaining had plain-screw insertion as control group (Cont). When the goat was under general anesthesia, the femoral condyles and the vertebral bodies of L3 to L6 were drilled with a 2.7mm drill bit in the frontal plane. The drill holes were standardized with 12mm in depth and were perpendicular to the longitudinal axes of the femur and the spine.

The injectable bone cement was prepared by mixing 10g of bone cement powder (a mixture of tetracalcium phosphate and dicalcium phosphate anhydrous) with 4.2ml 0.25M sodium phosphate solution under a high mixing speed (1000rpm) for 15 seconds. 0.15ml of bone cement was injected into the predrilled hole of the bone assigned as Expt. Small cancellous screws (4mm in diameter) were then inserted into the predrilled holes.

The goats were euthanized after 1 week (W1), three months (M3) and six months (M6) of screw insertion. Bone specimens were collected for screw pullout test and histomorphometrical analysis. Micro-CT was also used to analyze the distribution of bone cement around the screw.

RESULTS:

From the screw pullout test, the screw pullout energy in Expt group was significantly higher than the Cont at all time points (W1, M3 and M6) by 46.0%, 28.2% and 58.4%, respectively (p<0.05 for all)(Figure 1). It was found that the screw pullout energy in both groups increased with time after the screw insertion but that in control group remained constant after 3 months.

After the screw had been pull out, it was observed that there was bone packing tightly within the threads of the screw in M6. On the other hand, bone was packed loosely within the threads of the screw in W1.

Histomorphometrical analysis showed that the contact length between the screw and the trabeculae with bone cement increased significantly after bone cement was augmented (Figure 2). The bone cement filled almost all the space between the screw and the trabeculae as well as some trabecular space. It expanded the contact area of the trabeculae to the screw among the screw threads (Figure 2). The analysis with micro-CT also showed that the cement was distributed into the trabecular space around the screw inserted (Figure 3).

DISCUSSION:

From this in vivo study, we demonstrated that the bone cement did improve the holding power of the bone for at least 6 months as indicated by the significant higher pullout energy in the Expt group at all time points. The largest difference of the pullout energy was found in W1. It reflected that the augmentation of bone cement could provide significant improvement in the early stability for osteoporotic fracture fixation. With the new bone formation afterwards, the screw pullout energy in both groups increased continuously. After 3 months, bone formation around the screw of the Cont tended to be stable but that of the Expt continued. This observation could be explained by the osteoinduction and osteoconduction properties of this hydroxyapatite bone cement. This is an important biological property as compared with PMMA augmentation.

In conclusion, the injectable bone cement is able to improve the holding power of the osteoporotic bone and hence strengthens the screw fixation of osteoporotic fractures by inducing more bone formed around the well formed screw-cement complex.

REFERENCES: