Introduction: Cementless porous coated femoral prostheses rely on bone ingrowth of the coating for long term fixation. Bone ingrowth is promoted by close contact between the implant and the bone. However, in the clinical situation, direct bone/implant contact is limited to only a very few localized areas [1-3], depending on the instrumentation and surgical precision. Hence, considerable gaps exist at the bone/implant interface. Initial bony ingrowth is also affected by relative motions between the implant and the bone bed. Too much relative motion leads to ingrowth of fibrous connective tissue rather than bone [4]. We hypothesized that the initial stability of cementless devices can be improved by filling the existing gaps between the implant and the bone with a bioactive and biodegradable calcium phosphate (Ca-P) cement [5]. The success of this method depends obviously on (initial) mechanical and (long-term) biological factors. The purpose of the current in vitro study was to assess whether the use of a Ca-P gap filler cement has a significant favorable effect on the initial mechanical stability of plasma sprayed femoral stems.

Material and Methods: Femora: Six pairs of freshly frozen Beagle femora were collected. Beagle femora were used to allow for future extension of the project to an in-vivo experiment. Donor Beagles were all healthy at sacrifice, aged ± 1 year and weighted 10-12 kg. Femoral stems: Femoral prostheses of a commercially available canine total hip system (stem #5, Biomedtrix, Allendale, New Jersey, USA) were customized and provided with a commercially available titanium plasma spray coating of 550-600 µm in thickness (CAM implants BV, Leiden, The Netherlands). A tantalum pellet (Ø 0.8 mm) was glued to the tip of the prosthesis. Calcium Phosphate cement: The Ca-P cement powder contained 61% α-TCP, 26% CaHPO₄, 10% CaCO₃, and 3% precipitated HA. The cement liquid was a 2% aqueous solution of Na₂HPO₄ and the liquid/powder ratio was 0.35. The cement was injected into the medullary canal immediately after mixing in a retrograde fashion. Surgical procedure: After thawing overnight the femora were resected just above the condyles and embedded in PMMA. One femur of each pair was used for press-fit placement of a prosthesis without Ca-P cement, the other was used for press-fit placement with Ca-P cement. Tantalum pellets (Ø 0.8 mm) were glued to the medial and lateral side of the proximal end of the femoral stem. A small PMMA rod, containing tantalum pellets was glued to the neck of the prosthesis. Mechanical testing and RSA: Implanted prostheses were placed in an MTS testing machine. After a 17 mm femoral head, the construct was dynamically loaded. Relative to the vertical position, the femora were tilted 15 degrees in the lateral direction (adduction) and internally rotated 15 degrees, in order to obtain a physiological load on the femoral head. The load was applied stepwise from zero to a maximum of 100, 250 and 400 N. At each loading step, the load was removed to allow elastic recovery. After 10 minutes, the loading was continued with the next step in the loading regime. RSA exposures were made at the beginning and at the end of each loading interval and during the recovery periods. The accuracy of the measurements was determined by double examinations and was found to be 46 µm for the translations and 0.11°-0.23° for the rotations. Statistical analysis: An F-test and a paired t-test were applied to evaluate the differences in variability and migration values between the cemented and non-cemented press-fit prostheses, respectively.

Results: In both cemented and non-cemented specimens, mean values for rotations around the medial-lateral axis, axial rotations and translations in the anterior-posterior direction were negligibly small. In contrast, varus rotations (Fig 2), and medial-lateral translations as well as axial subsidence showed a clear trend. For the non-cemented implants, the mean values of the measurements increased (all in negative direction) when the load increased from 100 via 250 to 400 N. Also, within each loading step the displacements increased. The variations between the non-cemented specimens were relatively high, but all showed the same trend. Mean varus-valgus rotation increased from -0.17 degree at the start of 100 N loading to -1.2 degree at the end of loading with 400N. Mean values for medial-lateral translation during this loading trajectory were -108 µm to -818 µm. The subsidence values increased from -22 µm to -588 µm.

In contrast with non-cemented implants, the cemented prostheses showed very small migration values in all 6 degrees of freedom. Despite the clear trends, the paired t-test revealed only significant differences in the varus-valgus rotation for the loading step of 400 N (begin 400N and end 400N) and the subsequent unloaded situation (P < 0.05). Also, for the medial-lateral translation significant differences were found at these three measuring points (P < 0.05). The F-test showed that the variations found between the measured values were significantly smaller for the press-fit+Ca-P cement, versus the press-fit prosthesis without Ca-P cement at all loading steps (P < 0.05).

Discussion: With the Ca-P cemented prostheses, the varus rotation and subsidence were almost nihil during the whole loading regime. This suggests that the Ca-P cement has had a strong beneficial effect as it provided a perfect initial stability in this test. The Ca-P cement apparently corrects for the high variability in migration found with press-fit insertion of femoral hip prostheses. This is very important, because in this way the Ca-P cement might add to a more predictable outcome of press-fit femoral hip placement despite the inevitable differences in fit at time of surgery. In conclusion, the current results indicate that Ca-P cement can enhance the initial stability of a press-fit inserted titanium plasma-sprayed femoral hip stem. The results merit further research using in-vivo animal experiments to assess whether the behavior of the Ca-P stems remains superior on the longer term.


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