Pulsed Lavage Improves Mechanical Stability of Cemented Tibial Components

+1Schlegel, U J; 2Gebert de Uhlenbrock, A; 2Bishop, N E; 2Siewe, J; 2Püschel, K; 3Morlock, M M
ulf.schlegel@gmx.net

1University of Heidelberg, Heidelberg, Germany; 2Hamburg University of Technology, Hamburg, Germany
3University of Cologne, Cologne, Germany, 4University of Hamburg-Eppendorf, Hamburg, Germany

INTRODUCTION:
Despite proven advantages [1], pulsatile lavage seems to be used infrequently during bone bed preparation in cemented total knee arthroplasty (TKA). This is surprising, since aseptic loosening of the tibial component represents the main reason for revision and the technique has been suggested to improve radiological survival in cemented TKA [2]. Furthermore, a potential improvement of fixation strength for the tibial tray achieved by increased cement penetration, can be expected. In this study, the influence of pulsed lavage on bone cement penetration and mechanical stability of the tibial component was analyzed in a cadaveric setting.

METHODS:
Six pairs of cadaveric, proximal tibial specimens underwent computed tomography (CT) for assessment of bone mineral density (BMD) and exclusion of osseous lesions. Following surgical preparation, on one side of a pair, the tibial surface was irrigated using 1800ml of normal saline and pulsatile lavage, while on the other side, syringe lavage using the identical amount of fluid was applied. After careful drying, bone cement was hand-pressurized onto the bone surface. Tibial components were inserted according to manufacturers specifications (PFC Sigma, Depuy Orthopaedics, Warsaw, Indiana, USA). After curing of the cement, specimens underwent a post-implantation CT analysis. To reduce artefacts caused by the titanium implant, CT images were filtered. Cement distribution was assessed using three-dimensional visualization software (Avizo 5.0, VSG, Burlington, MA, USA) and a calibration normal. Trabecular bone, cement and implant were segmented based on an automatic thresholding algorithm, which had been validated in a previous study [3]. This allowed the median cement penetration to be determined for the entire cemented area (Figure 1).

Fixation strength of the tibial trays was determined by a vertical pull-out test using a servohydraulic material testing machine. Testing was performed under displacement control at a rate of 0.5mm/sec until implant failure. Data was described by median and range. Results were compared by a Wilcoxon matched pairs signed rank test with a type 1 error probability of 5 %.

RESULTS:
Median BMD was 74 mg/cm³ (range 31–110) for all specimens. There was no difference in BMD between lavage groups (p=0.312). Median pull-out forces in the pulsatile lavage group were significantly higher than in the syringe lavage group: 1275N (range 864-1391) vs. 568N (range 243-683); p=0.031. Cement penetration was similarly increased in the pulsed lavage group: 1.32mm (range 0.86-1.94) vs. 0.79mm; (range 0.51-1.66); p=0.031. Figure 2 shows the cement penetration depths for an exemplary specimen of the pulsed lavage group. Failure during mechanical pull-out occurred exclusively at the implant-cement interface in the pulsatile lavage group and at the bone-cement interface in the syringe lavage group (Figure 3).

DISCUSSION:
Improved bone-cement interdigitation and increased mechanical stability of the tibial tray implant was found in the current study for pulsed lavage. In the syringe lavage specimens, failure was observed at the bone-cement interface, indicating that the fixation strength between implant and bone is lower than between implant and cement. Pulsed lavage shifts the failure surface to the implant-cement interface with a higher failure load, demonstrating that the fixation between implant and cement is the limiting stability factor – as long as the cement – bone interface is strong enough, which can be achieved by good cement interdigitation.

The pull-out test performed in this study represents an unphysiological loading condition, as the tibial implant primarily transfers compressive and shear forces. However, pull-out presents a practical method by which the mechanical competence of the interface can be determined in a relative manner for paired specimens, rather than in an absolute manner. Enhanced fixation strength has been suggested to be a key to improved survival of implants [4]. Pulsatile lavage should consequently be considered as a mandatory preparation step for cemented tibial components in TKA.

REFERENCES:
[3] Püschel et al. 56th ORS Annual Meeting 2010

Figure 1: Tibial bone surface plane defined by manually placed landmarks. Cement distal to this plane was attributed to cement penetration (interdigitation), cement proximal as cement layer thickness.

Figure 2: Anterior-posterior projection of the cement penetration depth (mm) for one specimen (pulsed lavage).

Figure 3: Failure mechanism. Left side: Syringe Lavage; Right side: Pulsed Lavage.