INTRODUCTION:
The replacement of damaged knee joints is a reliable way of treating osteoarthritis with a current revision rate of 5% at 10 years [1]. However, considering the increasing number of procedures performed especially in younger patients, the low failure rate already constitutes thousands of patients per year [2]. Aseptic loosening is the most dominant factor for revision [1] and the underlying mechanism is still widely discussed.

This study was undertaken to characterize the mechanical stability of well-functioning, post-mortem retrieved, cemented and cementless tibial components and to relate their mechanical competence to the time in situ, cement mantle morphology and wear of the polyethylene (PE) inserts.

METHODS:
Human knee joints treated with unlinked, condylar total knee arthroplasty (TKA) were retrieved post mortem with permission of the relatives (n = 21, random retrieval over a 6 month period). Patient as well as clinical data were collected. Axial pullout tests of the tibial component were performed at a rate of 20 N/s to determine the strength of the implant/cement/bone compound. CT scans (PHILIPS, voxel 0.15x0.15x0.40mm) were performed to determine the cement thickness and cement interdigitation under the tibial tray. This was done prior to pullout with the implant in place for titanium implants (n=4), or after pull-out for cobalt chromium implants, for which the cement mantle had remained intact (n=3). Bone mineral density (BMD) was measured for all specimens after pull-out, calibrated from a phantom.

Four modes of PE wear were documented for the articulating surface: pitting, scratching, polishing and delamination. They were scored qualitatively according to previous studies with 4 levels of severity in each of 6 subregions [3, 4]. Overall scores were normalised to the maximum possible. Pullout force was compared with time in situ, type of implant, location of failure, BMD, cement mantle morphology, and PE wear (SPSS 15.0, α = 0.05).

RESULTS:
Specimens were retrieved after a mean of 6.2 years in situ (range 1 day - 14.7 years). Two cemented implant types were most commonly retrieved: 4 titanium PFC (DePuy), 6 cobalt chrome LCS (DePuy). A further 12 individual types from other producers were found, four of which were uncemented. Pullout forces ranged from 10 N to 2800 N (Figure 1). One of the cementless implants could not be pulled out (max. force: 3000 N). A linear correlation between pullout force and time in situ was found (R² = 0.43, p = 0.002). This finding was independent of implant type. No relation between pullout force and BMD was observed.

Failure occurred at the cement-implant interface in 4/6 LCS implants independent of time in situ (Figure 2 a-b). In contrast, the failure location of the PFC implant shifted from the cement/implant to the cement/bone interface with increasing time in situ (Figure 2 c-e).

The median cement layer thickness was 1.9mm, ranging from 1.1mm to 2.4mm. Median cement interdigitation was 1.5mm (1.1mm to 2.5mm). Pullout force increased with cement interdigitation beneath the tibial tray (R²=0.85, p=0.001, one outlier), but not with cement layer thickness. BMD was 96mg/cm³, ranging from 25mg/cm³ to 242mg/cm³. No correlation was found between cement interdigitation and BMD.

DISCUSSION:
All samples were well-functioning at retrieval. The decreasing pullout force over time in situ suggests a weakening process of the tray fixation. Although conclusive mechanisms for this process cannot be drawn from this data, due to a small heterogeneous sample size and such a variety of factors, various possibilities could be considered: A shift in failure mode from the implant-cement interface to the cement-bone interface with time in situ suggest that the bone at the interface may become weaker. Since pull-out strength increased with cement penetration, weakening of this interface might be decreased by suitable preparation of the bony bed, using modern techniques such as jet lavage. Differences in implant design may also influence the implantation strength. More frequent failure of the PFC implant at the bone interface in comparison to the LCS implant may be explained by the ‘re-entrant’ design of the rim of the cement pockets in the PFC implant, in which some cement always remained after pull-out.

Weakening of the interface was not related to the PE wear scores, or the BMD, despite the accepted effect of osteolysis by wear particles [5]. However, it is clearly favourable to minimise wear. Delamination remained low for both LCS and PFC implants with time in situ, in contrast to the other implants retrieved (Figure 3). This could be related to the different bearing designs retrieved (rotating platform, meniscal bearing, or fixed bearing) and thickness (4 to 16mm). This finding needs further investigation.

This study comprises one of the largest retrieval studies undertaken. The main finding that pull-out forces decrease with time in situ encourage further efforts in improving the cement fixation of tibial trays.

REFERENCES:

ACKNOWLEDGEMENTS:
Supported by BSG Hamburg and CMW/DePuy International