Cement mantle morphology in TKA

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INTRODUCTION:
Cement anchorage is the “gold standard” in fixation of total knee arthroplasty (TKA) implants. The quality and morphology of the cement mantle have a large influence on the long-term clinical performance [1]. Defects in the cement or regions of thin cement mantle compromise the strength of fixation. X-ray is so far the standard tool to assess the cement mantle in situ. However, x-ray images can only be used to describe radiolucent lines and are not suitable for assessing the shape, volume and thickness of the cement mantle. With the use of polymeric replicas of implants the cement mantle morphology can be assessed 3-dimensionally based on CT scans, which has been investigated for hips [2].

In this study a methodology assessing the cement morphology for titanium TKA implants in situ was developed and its accuracy determined. This method was then used to assess the cement mantle morphology of functional TKA in relation to the bone quality.

METHODS:
Eleven human knee joints treated with total knee arthroplasty (TKA) were harvested during autopsy (mean time in situ 4.2±3.2 years (0-8years), mean age 77±3years) and CT-scanned (Philips; voxel size 0.15mm × 0.15mm × 0.4mm) with a calibrated phantom both with and without the implant in place (Figure 1A). The extraction of the implant was realized by heating (<80°C) during a constant pull-out force of 150N, leaving the cement layer intact (Figure 1B). The scans were filtered (Philips), reconstructed 3-dimensionally based on the Hounsfield units (HU) and were aligned along the stem axis (Avizo 5.1; Figure 1C).

Four specimens with titanium implants were used to determine the accuracy of the method and to choose a suitable threshold, enabling segmentation between bone and cement. The threshold between cement and implant was set based on the known volume of each implant. These specimens were cut, using a diamond-coated bandsaw, twice transversely through the stem and once in the frontal plane 5mm posterior to the stem axis. The cement thickness was measured at various distinct positions in each section and compared with the cement thickness in the reconstructed CTs for varying thresholds (400HU, 600HU and 800HU, n=52; Figure 1D).

RESULTS:
The accuracy of the cement mantle thickness estimation by CT ranged from 10-20% for 400 and 600HU (Figure 3). The threshold used for further investigation was 600HU.

DISCUSSION:
The evaluation of the cement mantle morphology with an implant in situ has been inadequate so far, due to artifacts introduced in the CT images by scatter around the metal. In this study the CTs were filtered using an exclusive technique (Philips) to eliminate such artifacts around titanium implants. This method was demonstrated to be suitable for the evaluation of the cement mantle to ~20%, which exceeds criteria proposed by others [3]. This allowed a preliminary assessment of retrieved samples.

All the retrieved specimens showed an interdigitation of at least 0.5mm (median 1.5mm) across the whole plateaus, which may be sufficient for good fixation, since all samples were well-functioning. It is unclear whether the low BMD values already existed pre-implantation or whether they were due to the development of osteolysis. The unexpected lack of an inverse relationship between interdigitation and BMD may suggest that the bone quality decreased over time. The tilt in the cement layer thickness below the tray deviated by more than 0.5mm from the lateral to the medial side in 4/11 samples. At least 75% of each tibial plateau area had an interdigitation greater than 0.5mm. The mean cement mantle thickness around the stem was 2.7mm, and was greatest for the most proximal and most distal sections in 10/11 samples (~3.1mm).

Mean BMD was 99±30mg/cm³. There was no correlation between BMD and the parameters investigated (p>0.05).

REFERENCES: