Increased Initial Cement-bone Interlock Correlates With Reduced TKR Micro-motion With In Vivo Service

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Disclosures:

Introduction: Goals of good cementing technique in total joint arthroplasty are to achieve sufficient interlock between cement and bone, to support loads across the cement-bone interface, and to minimize micro-motion. While initial interlock is often achieved, our group has recently shown [1] that trabeculae that originally interlock with cement often resorb with in vivo service (Fig. a). How this in vivo loss of interlock affects interface micro-motion is not known. From a clinical perspective, if interfaces lose interlock with in vivo service, does achieving good initial interlock affect the fate of fixation? That is, if we start with more initial interlock, does this result in more stable constructs with in vivo service?

The goal of this study was to determine if the amount of initial interlock between cement and bone, created at the time of surgery, could affect the amount of micro-motion with in vivo service. We used a series of postmortem retrieved total knee replacements (TKR) that had functioned normally, but also lost interlock due to biologic trabecular remodeling and resorption at the cement-bone interface. We took advantage of the fact that the initial interlock between cement and bone could be identified by the mold shape, created by the cement layer, that flows around the interlocking trabeculae during the cementation process [1]. Using this approach, we hypothesized that 1) TKRs with greater initial interlock below the tibial tray have less micro-motion following in vivo service, and 2) TKRs with greater current interlock have less micro-motion.

Methods: Ten fresh-frozen postmortem TKR retrievals were obtained from the Anatomical Gift Program at SUNY Upstate Medical University (time in service: 1 to 16 yrs, mean = 5.8 years). Two additional cadaver knees with TKRs cemented in the lab were referred to as lab prepared TKRs and represented time of surgery or 0 years in service. The 12 knees were from 9 females and 3 males with ages ranging from 61 to 87 years. The tibial polyethylene inserts were removed, tibiae were stripped of soft tissue, and sectioned in the sagittal plane, 20 and 30mm from the central axis of the implant. This produced a 10 mm thick section from the medial and lateral plateaus (2 sections/TKR). High resolution (0.0057 mm/pixel) reflected white light images of the specimen faces were used to document the interface morphology. The initial interdigitation depth (inID) of cement into trabecular bone was determined by constructing a piecewise segmented line that followed the initial extent of penetration of trabeculae into the cement (Fig. b) and a second line that followed the extent of cement penetration into the trabecular bone. The average distance between the two lines was calculated using a local minimum point-to-point measurement algorithm. The current interdigitation depth (curID) was calculated in a similar fashion except the segmented line followed the extent of penetration of the existing bone into the cement mantle. The loss of interdigitation depth (lossID) was calculated as a fractional measure using (inID – curID)/inID.

The sagittal sections were potted and loaded in compression with 1 body weight (BW) equivalent load coincident with the wear patches on the PE insert through a ball bearing and loading transfer block. During loading, a camera captured high-resolution images (~8 micron/pixel) of micro-motion at the cement-bone interface. Digital imaging correlation (DIC) was used to quantify relative motion (micro-motion) between the cement and bone at 10 locations along the interface (5 on each face). To measure the micro-motion for the entire specimen, the camera was translated along the interface and the procedure was repeated. The median micro-motion of the 10 micro-motion measurements was used as the primary outcome measure.
a. 9 years of implant service

scale bar = 4 mm
B - Bone, C - Cement,
RBC - Resorbed Bone Cavities,
T - Tibial Tray, ST - Soft Tissue

b. 2.5 years of implant service

scale bar = 2 mm
inID - initial interdigitation depth (at time of surgery)
curID - current interdigitation depth
(after in vivo service)

Results: The postmortem retrievals had cement-bone initial interdigitation (inID) of 1.10 ± 0.64 mm (0.08 - 2.65 mm) but with in...
The current interdigitation depth (curID) decreased to 0.46 ± 0.50 mm (range 0.00 - 1.62 mm) which represents a loss of ID of 64.4 ± 30.4 % (range 2.3 - 100.0%). Lab prepared specimens had an inID of 1.60 ± 0.24mm (range 1.32 ± 1.97mm), and curID of 1.56 ± 0.23mm (range 1.27 -1.93mm). The lossID in the laboratory specimens of 2.7 ± 2.0% (range 0.0 - 5.6%) represents the error in curID, since bone in the lab prepared specimens did not resorb. The loss of interdigitation (lossID) was positively correlated (Fig. c) with time in service ($r^2 = 0.61$, $p < 0.0001$). The micro-motion for the post mortem retrievals (20.7 ± 42.8 μm; range 0.8 - 177.9 μm) was greater than the lab prepared constructs (2.0 ± 0.8 μm; range 0.8 - 2.5 μm). TKRs with greater initial interdigitation (inID) at the time of surgery had less interface micro-motion ($r^2= 0.40$, $p = 0.0012$) (Fig. d). Further, TKRs with greater current interdigitation (curID) also had less micro-motion ($r^2= 0.59$, $p<0.0001$) with in vivo service.

Discussion: This study gives the first direct evidence, using a series of postmortem retrieved TKRs, that the amount of initial interlock between cement and bone at the time of surgery is correlated with the amount of micro-motion following in vivo service. Because there is a loss of interlock with time in service, starting with more initial interlock between the trabecular bone bed and the cement layer, results in constructs with more current interlock, and thus better fixation. These findings are consistent with clinical data that show that improved cementing techniques (more interlock) result in reduced radiolucencies at the interface and reduced risk of aseptic loosening [2].

Significance: Loss of implant fixation leads to clinical loosening and need for TKR revision. This work shows that achieving good initial interlock between trabecular bone and cement can result in reduced micro-motion, in the context of in vivo service where
there is resorption of trabeculae that interlock with cement.

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**References:**
1) Mann, J Biomechanics 45: 711-715, 2012

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