

Femoral Component Osseointegration Varies with Polyethylene Liner Constraint in Cementless Total Knee Arthroplasty

Morgan Roegner, Julia Hochstatter, Jennifer Wright, E. Bailey Terhune, Robin Pourzal, Robert A. Burnett, Deborah J. Hall,
Rush University Medical Center, Chicago, IL.
Morgan_g_roegner@rush.edu

Disclosures: Roegner (N), Hochstatter (N), Wright (N), Terhune (3B-DJO, 9-AAHKS), Pourzal (2-CeramTec, 5-Stryker, 6-Zimmer Biomet, Enovis), Burnett (N), Hall (N).

INTRODUCTION:

It is widely accepted that total knee arthroplasty (TKA) is a safe and extremely common procedure with an annual prevalence of 700,000 in the US. Cemented technique has historically been the gold standard, however, there has been a recent increase in the number of cementless TKA procedures done, offering potential for increased implant longevity in younger, active patients. Additionally, the corresponding polyethylene (PE) bearing insert offers varying degrees of constraint to assist in knee stability and improve knee kinematics. These vary across manufacturers; however, they include cruciate retaining (CR) conforming or stabilized liners (CS), and posterior stabilized (PS) liners. These correspond to the lowest, mid-level, and higher levels of constraint (Figure 1). We hypothesize that increasing levels of constraint from the various geometries of the PE inserts introduce secondary loads at the articulation, which result in higher loads and micromotion at the bone-implant interface, thus inhibiting bone ongrowth. The purpose of this study was to determine the amount of bone ongrowth compared to constraint articulation on retrieved implants categorized by their polyethylene liner type.

METHODS:

A cohort of 18 cementless femoral TKA implants was selected under IRB approval: 6 CR implants, 6 CS implants, and 6 PS implants. These retrieved implants cover a variety of patients, male (n=10) and female (n=8), with a variety of reasons for removal and revision, including PJI (n=6), loosening (n=6), instability (n=3), EM rupture (n=1), and arthrofibrosis (n=1), unknown (n=1), and are from various manufacturers, Stryker (n=7), Zimmer (n=3), and DePuy (n=8). The median implantation duration was 1.6 years with a range of 0.4 to 22.7 years. The implants were first visually assessed, catalogued, and imaged for pre-processing analysis (Figure 2A). The CoCrMo alloy femoral components were sectioned using a cut-off machine (Secotom, Struers) with an Al₂O₃ abrasive wheel into five flat sections (Figure 2B, 2C). From there, each segment was imaged with a digital microscope (VHX-6000, Keyence) (Figure 2D). Area of bone ongrowth was then assessed with Image J software (NIH) (Figure 2E). Areas of bone ongrowth on each section were summed up. Statistical analysis for group comparisons was done using Mann-Whitney U, Kruskal-Wallis, Spearman test (SPSS software) with a significance level of $\alpha = 0.05$.

RESULTS:

To date, 11 components have been sectioned and analyzed (n=4 CR, n=3 CS, n=4 PS). Across all components, the median (range) percent area of bone ongrowth was 54.4% (15.2, 82.4). By group, bone ongrowth was CR = 61.5% (42.9, 72.9), CS = 38.6% (29.9, 46.7), and PS = 69.9% (15.2, 82.4). The CR group had more bone ongrowth compared to the CS group ($p = 0.034$) (Figure 3). There was more observed bone ongrowth on the medial condylar sections compared to lateral with a median ongrowth in the medial condyles of 46.3% (7.4, 84.8) and lateral ongrowth of 41.6% (3.7, 78.9). This difference was also observed for each individual component type. The CR component lateral ongrowth was 44.7% (15.7, 58.4) and medial was 46.0% (16.3, 64.9), the CS component lateral ongrowth was 22.4% (9.8, 34.5) and medial was 29.7% (7.4, 54.4) and the PS component lateral ongrowth was 53.9% (3.7, 78.9) and medial was 60.0% (44.0, 84.8). The results also indicated other differences in the areas of bone ongrowth along the different sections/pieces of the components. The PS components had the highest percentage of bone ongrowth on the most inferior portions (3a and 3b, Figure 2C) with the pegs at an average of 72.4% (4.0, 95.1), in comparison to the CR and CS components which had their highest bone ongrowth on the anterior superior sections (1 and 2, Figure 2C) at 73.8% (42.4, 99.7) for the CR and 66.8% (34.7, 90.8) for the CS. For the entire cohort, the results indicate a higher level of bone ongrowth on the anterior portions, 64.2% (4.9, 99.7) than the posterior condylar portions, 23.2% (0.7, 86.8).

DISCUSSION:

Our preliminary results demonstrated more bone ongrowth in the CR compared to the CS group, thus partially confirming our hypothesis. However, the PS group exhibited broad variability, and no difference was observed in comparison to the other two groups. The lower area of bone ongrowth on the lateral side for the PS and CS group may also result from larger micromotion at the bone-implant interface due to larger motion trajectories on the lateral bearing surface and higher loads at the medial surface. This study had several limitations. First, the cohort size was small, allowing only for cautious conclusions. Additionally, other confounding factors such as patient BMI, activity level, as well as the type of porous coating on the femoral component were not yet considered. These factors will be assessed moving forward as our study cohort grows. Finally, bone ongrowth does not equal bone ingrowth, which is a better indicator of a well-fixed component. Thus, this ongoing study will also incorporate cross-sectioning of the single implant sections.

CLINICAL RELEVANCE:

This pilot study shows that implant aseptic loosening may be impacted by the level of constraint at the articular surface and should be further explored to be able to inform surgical decision-making regarding technique and implant selection in cementless TKA. This study is ongoing to increase the sample size of each group to improve statistical power. In addition, we will explore other confounding factors such as implantation duration, reason for failure, patient BMI and age, as well as the type of porous coating.



Figure 1. Images showing CR, CS, and PS polyethylene components of TKA retrieved samples. Top images show the anterior view and bottom images show the lateral view, illustrating differences in constraint level, least (left) to most (right).

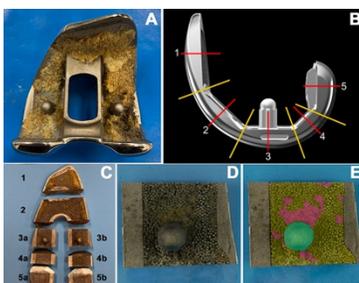


Figure 2. A: Pre-processing image of femoral component; B: Diagram of cutting lines to create flat sections; C: Layout of labeled, sectioned component; D: individual section (3b, in C); E: Digital assessment of the bone ongrowth (pink).

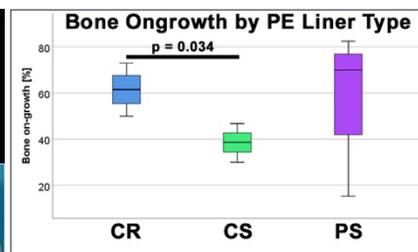


Figure 3. The average bone ongrowth between the groups CR, CS, and PS showing a significant difference between the CR and CS groups.