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Comparison of articular and backside polyethylene wear in mobile bearing unicompartmental knee replacement

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ABSTRACT

Background: Unicompartmental knee replacement (UKR) is an alternative to total knee replacement for selected patients with isolated medial or lateral compartment osteoarthritis. One of the most popular UKR implants was introduced as a mobile-bearing design in part to reduce polyethylene wear. However, backside wear of the mobile-bearing implant has not been examined independently from the articular surface.

Methods: Sixteen retrieved polyethylene inserts from a medial mobile-bearing UKR from 16 patients were examined after an average of 4.2 years implantation (range 1.5 to 10.0 years). Reasons for revision included aseptic loosening, pain, and progression of osteoarthritis. Each retrieved insert was evaluated using visual damage scoring across the articular and backside surfaces. Inserts were also micro-CT scanned and compared to a reference insert of the same size, to measure wear on the articular and backside surfaces.

Results: The total damage scores were greater ($p = 0.01$) on the articular surface (27.2 ± 5.7 (standard deviation)) than the backside surface (23.8 ± 6.2). Burnishing, abrasions, and pitting were the most common damage modes on both surfaces, with only pitting greater ($p = 0.03$) on the articular surface than the backside surface. There was no difference ($p = 0.46$) in wear rate between the articular surface (0.028 ± 0.025 mm/year) and backside surface (0.029 ± 0.017 mm/year).

Conclusions: The retrieved mobile-bearing UKR polyethylenes demonstrated good overall wear resistance, with no evidence of severe damage. However, backside wear was equal to articular wear, suggesting that the backside surface is a potential source of polyethylene wear debris.

1. Introduction

Unicompartmental knee replacement (UKR) has become an increasingly popular alternative to total knee replacement (TKR) for patients with osteoarthritis isolated to the medial or lateral compartment of the knee [1,2]. Concerns remain regarding the longevity of these implants, with polyethylene wear one of the leading reasons for revision following aseptic loosening and progression of osteoarthritis [3,4]. Like TKR, both fixed and mobile bearing designs are available for UKR, with the mobile bearing

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designs offering a polished tibial tray that is thought to decrease backside wear [5,6]. Although a number of studies have examined wear in these implants [7–9], the existing literature has not independently compared articular and backside surface wear.

The purpose of the present study was to examine wear and damage in retrieved medial mobile bearing UKR implants across the articular and backside surfaces. We hypothesized that there would be greater wear and damage on the articular surface than on the backside surface.

2. Methods

We examined all Oxford mobile bearing UKR implants (Biomet Inc., Warsaw, Indiana) available in our institutional implant retrieval laboratory. Approval was first obtained from our institutional research ethics board. Implants that were in place for less than one year were excluded from the analysis.

A total of 16 implants from 16 patients were included in the analysis, with an average implantation time of 4.2 years (range 1.5 to 10.0 years). All retrieved implants were performed as medial UKRs. Of the 16 liners, five were sized small, nine were medium, and two were large. The patients had an average age at surgery of 62.4 years (range 53 to 78 years) with an average body mass index of 31.3 kg/m^2 (range 22.8 to 40.1 kg/m^2). Reasons for revision included pain (eight cases), aseptic loosening (six cases), and progression of osteoarthritis (two cases). No cases had a dislocated polyethylene. The post-operative radiographs for each patient were reviewed and revealed an average tibial slope of 5.5° (range 0 to 8.9°) and average tibial coronal alignment of 6.7° of varus (range 0 to 20° of varus).

Visual damage scoring was performed in the well established manner of Hood et al. [10]. The articular and backside surfaces of each insert were divided into anterior, posterior, medial, and lateral zones. Within each zone, seven different damage modes were evaluated: burnishing, abrasion, cold flow, scratching, pitting, embedded debris, and delamination. Each mode was scored based on severity from 0 to three, with 0 being not present and three being present in greater than 50% of the surface area.

All retrieved inserts along with representative never-implanted inserts of the same size were scanned with a laboratory micro-CT (computed tomography) scanner to reconstruct their three dimensional (3D) surface geometries, following a previously described protocol [11]. Using commercial 3D metrology software (Geomagic Control, 3D Systems Inc., Rock Hill, South Carolina), the articular and backside surfaces were isolated and co-registered between each retrieved and appropriate never-implanted insert following a previously-validated technique, with the damaged regions excluded from the registration [12]. Deviations between the retrieved and reference surfaces were mapped, and the maximum deviation between surfaces (representing the greatest depth of penetration due to wear and creep) was measured. This value was divided by the implantation time of the insert to calculate a yearly wear rate. Measurements were performed in this manner for both the articular and backside surfaces independently.

Descriptive statistics were calculated for all variables, and normality of the data was assessed with a D'Agostino and Pearson normality test. Damage was compared as a combined score between zones on each of the articular and backside surfaces using a repeated measures analysis of variance (ANOVA), and between the articular and backside surfaces using a paired t-test. The magnitude of each individual damage mode was also compared within surfaces using either a repeated measures ANOVA with Tukey multiple comparison test or a Friedman test with Dunn's multiple comparison test as appropriate to the normality of the data. Wear rate was compared between the articular and backside surfaces using a Wilcoxon matched-pairs signed rank test. Correlations between wear or damage and factors including alignment, slope, and implantation time were performed using Spearman or Pearson correlation as appropriate to the normality of the data.

3. Results

The total combined damage scores were greater ($p = 0.01$) on the articular surface (27.2 ± 5.7) than the backside surface (23.8 ± 6.2). There was no difference within the articular surface ($p = 0.85$) or the backside surface ($p = 0.15$) in damage between the anterior, posterior, medial, or lateral zones (Table 1). There were differences in the magnitude of the individual damage modes on both the articular ($p < 0.0001$) and backside ($p < 0.0001$) surfaces (Table 2). On the articular surface, burnishing was greater ($p < 0.001$ in all cases) than the other six damage modes, abrasion was greater ($p < 0.001$ to 0.02) than all but burnishing, pitting was greater ($p < 0.001$ to 0.005 in all cases) than scratching, delamination, and embedded debris, and finally scratching was greater ($p = 0.003$ in both cases) than delamination and embedded debris. On the backside surface, burnishing was also greater ($p < 0.0001$ to 0.0003) than all other modes, abrasion was greater ($p < 0.0001$ to 0.0002) than all modes but burnishing, pitting was greater ($p = 0.001$ to 0.006) than cold flow, delamination and embedded debris, and finally scratching was greater ($p = 0.006$ to 0.02) than cold flow, delamination, and embedded debris. Comparing the articular and backside surfaces, only pitting was different ($p = 0.03$) between the two, with the articular surface having greater pitting.

Table 1
Total damage scores by zone location on the articular and backside surfaces (mean ± standard deviation). The maximum score for each zone is 21.

Surface	Anterior	Medial	Posterior	Lateral	p Value
Articular surface	6.8 ± 1.5	6.9 ± 1.1	6.6 ± 1.7	6.9 ± 2.2	0.85
Backside surface	6.3 ± 1.7	6.0 ± 2.0	6.0 ± 1.6	5.6 ± 1.5	0.15