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Comparison of Tibial Insert Polyethylene Damage in Rotating Hinge and Highly Constrained Total Knee Arthroplasty: A Retrieval Analysis

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ABSTRACT

This study compared the damage scores and damage patterns in 19 tibial inserts from rotating hinge (RH) implants with 19 inserts from highly constrained (HC) implants. Each insert was divided into 16 damage zones and each zone was subjectively graded from a scale of 0–3 for seven different damage modes. The overall damage scores were comparable for the two groups (RH: 64.1 ± 15.4; HC: 66.1 ± 29.0; $P = 0.59$). The HC group, however, had greater post damage (compared to the post-hole of RH) while the RH group had greater backside damage. The pattern of damage was also different, with burnishing and cold flow being more common in HC group while pitting, scratching and embedded debris were more common in the RH group.

Total knee arthroplasty (TKA) has generally shown good patient satisfaction and very high survivorship rates after implantation, even for young patients [1–3]. Tibial insert wear continues to be problem however, and can result in mechanical and biological complications leading to eventual failure of TKA [4–6]. Although multiple factors can influence wear in TKA [6–11], prosthetic design has increasingly been shown to be an important factor for wear generation in TKA [12–16]. This may be particularly relevant with increased degree of constraint as in rotating hinge (RH) and unlinked highly constrained (HC) implant designs [17–19].

With rising need of TKA, RH and HC implants will likely be used with increasing frequency in years to come. Although most surgeons tend to use HC type of implants for medial-lateral instability, this can also be addressed with an RH implant [17–20]. However, it is important to understand that a high degree of coronal instability combined with a significant mismatch of flexion-extension gaps during revision TKA is an indication for RH type of implant instead of the HC implant [19]. Medial collateral ligament insufficient that is non-reconstructable is also an indication for an RH implant instead of the HC implant [20]. As these implants become more popular, polyethylene wear is likely to ensue [21]. It is likely that the tibial post will remain a major source of polyethylene wear as some retrieval studies have reported post wear in 100% of the posterior stabilized implants [14]. This is perhaps even more relevant for HC implants characterized by a more robust and larger tibial posts compared to posterior stabilized implants. For RH implants, backside wear and post-hole wear are potential additional sources of polyethylene debris [22].

The wear characteristics of the articular side of tibial polyethylene inserts of less constrained implants (posterior stabilized, PS or cruciate retaining, CR) have been reported extensively by retrieval studies [22–26]. However, there is very little published on wear in implants with increased constraint (RH and HC). The patterns and amount of damage for these inserts with increased constraint associated with RH and HC implants may be entirely different as compared to the inserts for primary TKA. Wear analysis of retrieved inserts from HC and RH type of TKAs may help predict specific wear patterns such as pitting and delamination resulting from material fatigue or scratching caused by embedded debris. This information may be useful to understand possible failure mechanisms of these inserts, and may aid in improving the design of these implants in the future.

Furthermore, although rotating platform TKAs have shown no wear related [22,27–30] or clinical [31–34] benefits over fixed bearing TKA in primary setting, there exists no published study comparing the clinical or wear related differences between RH and fixed bearing HC tibial designs. Therefore, the objective of this retrieval study was to evaluate the patterns of tibial insert damage in mobile bearing RH and fixed bearing HC implants to allow comparison with respect to articular, backside, and tibial post polyethylene damage. Our hypothesis was that, by virtue of their design differences, there would be significant differences in the

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pattern and/or amount of polyethylene damage between retrieved HC and RH inserts.

Methods

The study involved visual damage scoring of all the fixed bearing HC and mobile bearing RH tibial polyethylene inserts from our institutional review board approved implant retrieval laboratory. These inserts had been collected during revision TKA surgeries performed at our institution between 1996 and 2013. Demographic data were obtained from patient records for each retrieved tibial polyethylene insert. The following variables were collected: age at the time of revision, patient gender, operative side, time in vivo (TIV) for the inserts, body mass index (BMI) and the number of revision at the time of retrieval of the tibial insert.

A total of 22 HC and 26 RH inserts were available for damage scoring. Inserts that had been implanted for less than 6 months were excluded from the analysis. This included 3 HC inserts and 4 RH inserts. Nineteen retrieved HC inserts were matched to a similar cohort of 19 RH inserts based on BMI and TIV. Due to limited numbers of available inserts, we included inserts from three different manufacturing companies and therefore did not restrict the study to any single implant manufacturer. All 19 HC implants were Smith and Nephew designs (Smith and Nephew, Memphis, TN), manufactured with conventional GUR 1050 polyethylene sterilized with ethylene oxide. Of the 19 RH implants, 12 were Stryker designs (Howmedica, Rutherford, NJ), and 7 were Biomet designs (Biomet, Warsaw, IN). Both designs were manufactured with conventional polyethylene and sterilized with gamma irradiation. Visual damage scoring was therefore performed on a total of 38 tibial inserts.

Two independent examiners were blinded to the demographic data of patients and performed damage scoring of the polyethylene inserts. The tibial inserts were divided into 16 zones for damage scoring. This was similar to that previously used by published retrieval studies [13,23]. The medial and lateral articulating surfaces were divided into 4 quadrants. The backside (inferior) surface of the insert was divided into 4 quadrants. The tibial post (for HC implants) or post-hole (for RH implant) was divided into anterior, posterior, medial and lateral zones (Fig. 1).

Each zone was subjectively graded from a scale of 0–3 for seven different damage modes (burnishing, abrasion, cold flow, scratching, pitting, delamination and embedded debris). The damage score was 0 for no damage, 1 for <10% area affected, 2 for 10–50% area affected and 3 for >50% of area affected. The scoring system was based on previously established protocols for damage scoring in retrieved polyethylene specimens [13,23,35]. The maximum possible damage score by this method was 336. The mean score for the two observers for each insert was used for analysis of the results.

Statistical analysis was performed with SPSS (Statistical Package for the Social Sciences) software (version 11.0; SPSS, Chicago, IL). Univariate analysis was performed with chi-square or the Fischer's exact test for comparison of proportions between two categorical data. The Mann–Whitney *U* test was used to compare the non-parametric data between two independent samples. $P < 0.05$ was considered significant.

Results

The demographic profile of the two groups of inserts is summarized in Table 1. Both the RH and HC groups were matched for TIV (mean 3.0 for RH vs 4.1 for HC, $P = 0.335$) and BMI (mean 31.1 for RH vs 32.3 for HC, $P = 0.731$). The mean age of the patients was higher in the HC group (69.3 years in HC vs 61.5 years in RH, $P = 0.034$) while the RH group had a higher number of revision procedures at the time of retrieval (mean 3.7 in RH vs 2.5 in HC, $P = 0.019$). There were more male patients in the RH group (84%) compared to the HC group (53%) ($P < 0.0001$). Reasons for revision were similar in both groups, with the RH group having more revisions due to implant fracture or failure, and the HC group having more revisions due to instability.

Analysis of mean visual damage scores revealed comparable total damage in both the groups (64.1 for RH vs 66.1 for HC, $P = 0.549$). Distribution of the visual damage has been summarized in Table 2. The HC group was found to have higher post damage (Fig. 2A) as compared to the damage in the post-hole of the RH (8.8 in RH vs 21.7 in HC, $P < 0.0001$). For the post of HC inserts, maximum damage was observed on the posterior aspect of the post. The damage scores were slightly higher in the RH group (Fig. 2B) in the medial articular zones (19.5 for RH vs 15.8 for HC, $P = 0.023$) but comparable for the lateral articular zones (19.1 for RH vs 20.5 for HC, $P = 0.515$). Damage scores on the backside were higher in the RH group (Fig. 2C) as compared to the HC group (16.7 in RH vs 8.2 in HC, $P = 0.001$).

Table 3 summarizes the damage scores in both the groups based on damage modes in the tibial inserts. The most common damage mode

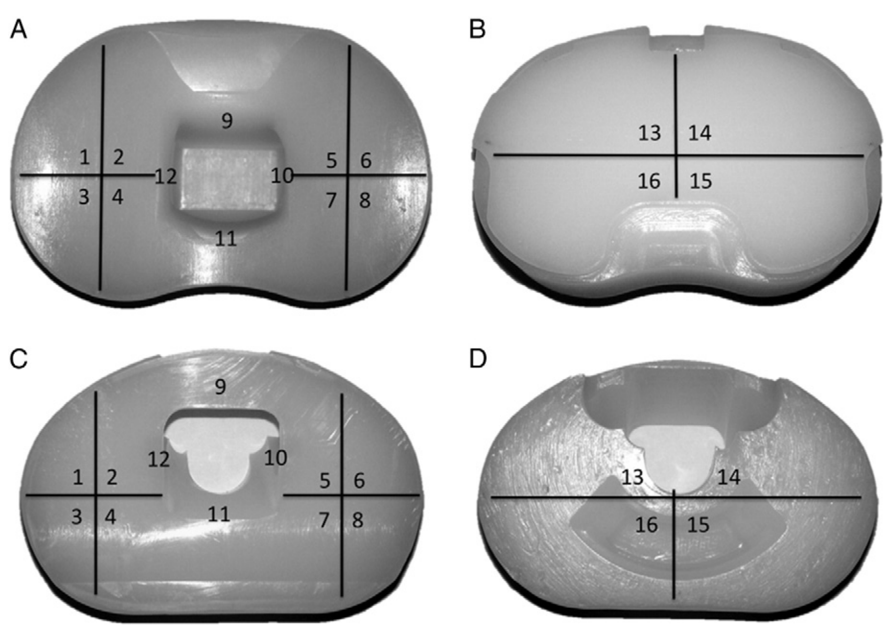

Fig. 1. The sixteen zones used for damage scoring on the retrieved polyethylene inserts. (A) Articular surface of the constrained inserts. (B) Backside surface of the constrained inserts. (C) Articular surface of the hinged inserts. (D) Backside surface of the hinged inserts.