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# The Impact of Wear and Lift-Off on Coronal Plane Alignment in TKA and Implications to Future Constrained Revision: A Retrieval Study

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ABSTRACT

Current discussion exists whether to position a total knee arthroplasty (TKA) in slight undercorrection in varus osteoarthritis. The goal of this study was to analyse the effect of wear and lateral lift-off in primary TKA on coronal plane alignment and the implication to future constrained revision TKA. Seventy-six retrieved tibial inserts were analysed for the ratio of wear (RW), lateral lift-off and implications for future constrained revision surgery according to the coronal plane alignment. The RW significantly affects the coronal plane alignment in TKA. Progressive wear and lateral lift-off were seen with progressive varus alignment. However, there was no difference in constrained revision between mild varus and moderate varus aligned TKAs.



Neutral alignment of total knee arthroplasty (TKA) components is the standard of care, with controversy regarding the role of physiologic alignment [1–12]. Data from laboratory, cadaver and radiologic studies have shown that varus alignment after TKA results in higher medial stresses and loads, which contribute to medial polyethylene wear and a lower survivorship [1–10]. However, literature also indicates good survivorship and superior clinical outcomes in under-corrected TKAs for varus osteoarthritic knees [11,12].

A cycle may exist where increasing varus alignment in TKA contributes to increasing wear medially, which leads to an increased mechanical varus alignment. This could potentially lead to a higher lift-off in the lateral compartment between the tibial and femoral component. Increased lateral lift-off may subsequently result in ligamentous damage and compromise, requiring the use of a constrained implant during revision surgery [13,14].

Based on retrieval data, the goal of this study was to analyse the effect of wear and possible lateral compartment lift-off between the tibial and femoral components on coronal plane alignment in neutral and varus aligned TKAs. The secondary goal was to correlate the use of constrained implants in revision TKA of previously neutral and varus aligned primary TKAs.

## Materials and Methods

Ethics approval was provided by The University of Western Ontario Ethics Board for Health Sciences Research Involving Human Subjects (HSREB). All retrieved polyethylene inserts of primary TKAs performed between January 2005 and December 2013 were screened for inclusion and exclusion criteria. Inclusion criteria were the retrieval of the polyethylene tibial insert of a primary TKA, a pre-revision surgery digital full-leg standing radiograph and a minimum time in vivo of five years. Exclusion criteria for the study were poor quality radiographic images, gross radiographic instability and anything that affects coronal plane alignment including component subsidence or trauma.

A total of 76 polyethylene tibial inserts were identified for further analysis. Implant designs included were: Kinemax (Howmedica), Kinematic II (Howmedica), MG I&II (Zimmer), NexGen (Zimmer), Genesis I (Smith and Nephew), Genesis II (Smith and Nephew), AMK (Depuy), Sigma (Depuy) and Scorpio (Stryker). Data on body mass index (BMI), gender and age were available for all patients.

The thickness of the inserts was measured with the use of a calibrated micrometer (Digimatic; Mitutoyo Corporation) with an accuracy of 0.01 in., as previously described [15,16]. The thinnest point at the articulating lateral and medial compartment was measured, as well as the distance between both points. Based on these three points the proportion of medial and lateral wear of the insert was calculated. This was defined as the ratio of wear (RW). A negative value of RW related to varus

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**Table 1**
Number of Patients, Mechanical Alignment, Time In Vivo, BMI and Age per Alignment Group.

| | Neutral | Mild Varus | Moderate Varus | *P* Value |
|---|---|---|---|---|
| Number of patients | 28 | 28 | 20 | |
| Alignment (°) | −0.54 ± 1.36 | −4.39 ± 0.89 | −8.96 ± 2.6 | <**0.001** |
| Time in vivo (years) | 11.22 ± 3.41 | 11.16 ± 4.95 | 12.35 ± 3.3 | 0.16 |
| BMI | 32.45 ± 4.41 | 33.14 ± 6.87 | 36.97 ± 8.32 | 0.13 |
| Age (years) | 73.1 ± 7.9 | 68.5 ± 8.9 | 73.5 ± 10.0 | 0.09 |

wear (thinner medial side), while a positive value related to valgus wear (thinner lateral side).

Full-leg standing digital radiographs were assessed using the established methodology by Cooke et al [17]. The Hip–Knee–Ankle (HKA) and Condylar–Plateau (CP) angles, defined as the intra-articular deformity, were measured. Based on the RW, the HKA and CP angles were corrected to a New-HKA angle (N-HKA) and a New-CP angle (N-CP). As the N-CP allows the contribution of wear to be eliminated, and the implants measured initially had symmetric thicknesses medially and laterally, this N-CP angle indicates the magnitude of lift-off. The impact of the RW and N-CP angle on the coronal plane was subsequently assessed for neutral (0 ± 3°), mild varus (>3°–6°) and moderate varus (>6°) TKAs based on the mechanical axis.

All patients were also reviewed for the type of revision surgery after the failed primary knee arthroplasty. The three subgroups of coronal plane alignment were compared whether the revision performed was a constrained (varus–valgus constrained or hinged implant) or a non-constrained prosthesis.

Descriptive statistics (included mean and standard deviation) were calculated for each group. The D'Agostino and Pearson omnibus normality test was applied to determine the distribution of the data. For normally distributed data, a one-way ANOVA with Tukey's post-hoc multiple comparison test was applied, and for all others the Kruskal–Wallis test with Dunn's multiple comparison test was applied. Where linear regression was performed, both the goodness of fit ($r^2$) and the difference of the slope from zero (*P* value) were calculated. A chi square test was used to evaluate distribution. Power analysis for RW between the 3 groups (with n = 20 per group, alpha 0.05, two-sided test, and SD of 0.79°) using a one-way ANOVA, detects differences of 0.78° at a power of 0.8. Above this, a Kruskal–Wallis test was performed to analyse the impact of implants on wear implants individually.

## Results

The three subgroups groups showed no difference in the distribution of the implants, BMI, age, gender or time in vivo (Table 1). The mean overall mechanical alignment of the neutral group was 0.54° ± 1.36° varus, 4.39° ± 0.89° in the mild varus group and 8.96° ± 2.6° in the moderate varus group. The mean time in vivo in the neutral group was 11.2 ± 3.4 years, 11.2 ± 4.9 years in the mild varus group and 12.3 ± 3.3 years in the moderate varus group ($P = 0.16$). BMI ($P = 0.74$) and age ($P = 0.48$) did not differ between groups. Time in vivo of the implant did significantly ($P = 0.016$) affect the RW. The reason for revision and the type of implant, in relationship to the coronal plane alignment, are evenly distributed among all groups (Tables 2 and 3).

**Table 2**
Reason for Revision in Relationship to the Preoperative Alignment.

| | Neutral | Mild Varus | Moderate Varus |
|---|---|---|---|
| Aseptic loosening | 6 | 6 | 9 |
| Infection | 4 | 3 | 2 |
| Instability | 8 | 4 | 2 |
| Insufficiency extensor mechanism | 1 | 1 | 0 |
| Malposition | 1 | 1 | 0 |
| Osteolysis | 1 | 1 | 1 |
| Pain | 1 | 4 | 0 |
| Polyethylene wear | 6 | 8 | 6 |
| **Total** | **28** | **28** | **20** |

**Table 3**
Type of Implant Failure According to Preoperative Alignment.

| | Neutral | Mild Varus | Moderate Varus |
|---|---|---|---|
| AMK | 6 | 1 | 7 |
| Genesis I | 3 | 7 | 2 |
| Genesis II | 2 | 2 | 0 |
| Kinematic II | 7 | 1 | 3 |
| Kinemax | 2 | 2 | 0 |
| MG I&II | 2 | 1 | 5 |
| Nexgen | 2 | 7 | 0 |
| Scorpio | 4 | 5 | 0 |
| Sigma | 0 | 2 | 3 |
| **Total** | **28** | **28** | **20** |

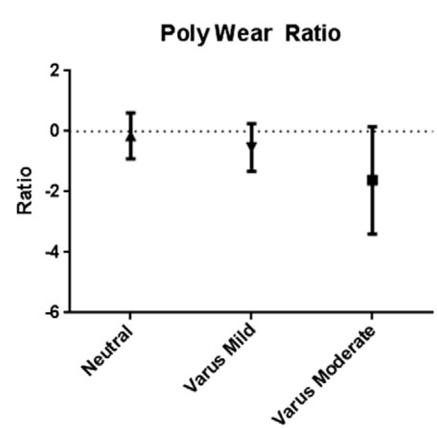
**Table 4**
Ratio of Wear (RW), CP-Angle, N-CP Angle, Change from CP to N-CP Angle and Contribution of Polyethylene Wear to the Change in Angle.

| | Neutral | Mild Varus | Moderate Varus | *P* Value |
|---|---|---|---|---|
| Ratio of Wear (°) | −0.15 ± 0.76 | −0.54 ± 0.79 | −1.62 ± 1.78 | <**0.001** |
| CP-angle (°) | −0.15 ± 0.87 | −0.86 ± 1.21 | −2.57 ± 2.17 | <**0.001** |
| N-CP angle (°) | 0.004 ± 0.87 | −0.32 ± 0.94 | −0.95 ± 1.13 | <**0.001** |
| Change in CP to N-CP (p-value) | 0.45 (**NS**) | **0.001** | <**0.001** | / |
| Contribution wear to change CP/N-CP (%) | 21.9 ± 157.0 | 63.2 ± 125.4 | 43.7 ± 78.8 | <**0.001** |

In all groups the medial compartment of the polyethylene insert was thinner on average than the lateral, indicating more medial wear (Table 4). The RW of the inserts showed a mean medial wear pattern of 0.15° ± 0.76° in the neutral group, 0.54° ± 0.79° in the mild varus group and 1.62° ± 1.49° in the moderate group. The RW correlated with frontal plane alignment, with increased wear being related to progressive varus alignment ($P < 0.01$) (Graph 1).

The change in CP angle and HKA angle to respectively N-CP and N-HKA angle is shown in Tables 4 and 5. The difference from CP to N-CP was significant for the mild varus ($P < 0.01$) and moderate varus ($P < 0.01$) group. The change in angle was not significant for the neutral group ($P = 0.46$). Similarly, the change to N-HKA angle was non-significant for the neutral group ($P = 0.30$) and significant for the mild varus ($P < 0.01$) and the moderate varus group ($P < 0.01$) (Table 5 and Graph 2).

The CP angle was significantly different between all subgroups ($P > 0.01$). The N-CP angle, representing the intra-articular lift off, was 0.004° ± 0.87° valgus in the neutral group, 0.32° ± 0.94° varus in the mild varus group and 0.95° ± 1.13° in the moderate varus group. The




**Graph 1.** Polywear ratio per alignment group.