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Original Article

Does Achieving High Flexion Increase Polyethylene Damage in Posterior-Stabilized Knees? A Retrieval Study

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ABSTRACT

Background: Increased range of motion to higher degrees of flexion following total knee arthroplasty has been postulated to increase implant damage and revision rates, even in designs modified to accommodate high flexion.
Methods: We examined posterior-stabilized and high-flexion retrieved tibial inserts to look for differences in polyethylene surface damage with light microscopy and 3D deviation with laser scanning between inserts from patients who achieved a high degree of flexion (≥120° postoperatively) and inserts from patients who did not reach a high degree of flexion.
Results: No differences were found in damage scores on the articular and backside surfaces, except for abrasion in the posterior articular regions, or in 3D deviations between patients who reached a high degree of flexion and patients who did not. These results were independent of the reason for revision.
Conclusion: In our series, reaching a high degree of flexion did not influence surface damage or 3D deviation of the polyethylene inserts.

Patients reaching 120° to 125° of flexion are generally considered to have achieved a high degree of flexion following total knee arthroplasty (TKA) [1,2]. However, younger and more active patients may expect more motion, and in some cultures deep bending and kneeling are common activities of daily living. Despite the emphasis placed on achieving high flexion, the relationship between attaining deep knee flexion and patient satisfaction remains unclear [3-6].

High-flex (HF) designs for posterior-stabilized (PS) TKA attempt to accommodate increased range of motion (ROM) through modifications to the design of the implant components. Although the intention of these modifications is to accommodate a higher degree of flexion, they alone cannot lead to greater ROM [1,7]. Several randomized prospective studies failed to demonstrate increased average ROM when HF TKAs were compared to traditional PS implants [3,8-15]. Seon et al [3] found no difference in maximum flexion between patients with HF cruciate-retaining inserts, HF PS inserts, and standard cruciate-retaining inserts in a matched cohort study. Similarly, in a multicenter prospective randomized trial assessing differences in pain, function, loosening, and ROM between patients with HF and PS TKAs, no difference in flexion was found immediately postoperatively or at 2-year follow-up [15].

Nevertheless, concern remains that increased ROM to higher degrees of flexion can result in increased implant damage and higher revision rates, even in designs modified to accommodate high flexion [16,17]. A recent retrieval study by Paterson et al [18] noted increased backside wear and post damage in HF inserts compared to traditional PS inserts, which were attributed to increased ROM in the HF insert group as compared to the PS group. A retrieval study from our laboratory assessed 60 inserts from 3 different HF designs with no differences found in either ROM or overall polyethylene damage compared to traditional PS-matched controls [7]. Although small regional differences emerged among designs, these differences were related to posterior design changes in the HF inserts and revision diagnoses such as instability.

In our previous study, we did not find differences in the pre-revision ROM between patients with PS and HF designs; however,

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Table 1
Insert Design and Patient Demographic Information for the 30 Patients Who Had Achieved Pre-Revision High Flexion.

#	Manufacturer	Design	Age at Implantation (y)	BMI (kg/m^2)	Sex	L/R	LOI (mo)	Reason for Revision	Maximum Pre-Revision Flexion
1	Zimmer	NexGen LPS-Flex	64	31.8	M	R	1	Infection	120
2	Zimmer	NexGen LPS-Flex	44	28.8	F	R	39	Pain	120
3	Zimmer	NexGen LPS-Flex	58	30.0	M	L	12	Instability	125
4	Zimmer	NexGen LPS-Flex	54	28.4	F	L	36	Cobalt-chrome allergy, pain	130
5	Exactech	Optetrak Logic	72	36.6	F	R	1	Infection	120
6	Exactech	Optetrak Logic	58	25.1	F	R	85	Loosening	125
7	Exactech	Optetrak Logic	51	27.9	M	L	3	Instability	120
8	Exactech	Optetrak Logic	59	24.4	F	L	10	Instability	125
9	Exactech	Optetrak Logic	59	28.6	M	L	25	Instability	120
10	Exactech	Optetrak Logic	68	35.3	M	R	13	Instability	125
11	Exactech	Optetrak PS	48	31.3	M	R	118	Mal-alignment	120
12	Exactech	Optetrak PS	54	36	F	R	167	Instability	120
13	Exactech	Optetrak PS	47	22.9	F	L	10	Instability	120
14	Exactech	Optetrak PS	61	28.8	F	R	31	Dislocation	120
15	Exactech	Optetrak PS	67	28.3	F	L	15	Dislocation	120
16	Exactech	Optetrak PS	75	24.4	M	L	14	Flexion contracture	122
17	Smith & Nephew	Genesis II HF	63	30.5	M	L	11	Instability	140
18	Smith & Nephew	Genesis II HF	68	26.5	F	R	40	Instability	130
19	Smith & Nephew	Genesis II HF	89	22.6	F	R	8	Pain	120
20	Smith & Nephew	Genesis II PS	65	22.9	F	R	22	Instability	130
21	Smith & Nephew	Genesis II PS	65	24.7	F	L	12	Cobalt-chrome allergy	130
22	Smith & Nephew	Genesis II PS	58	32.3	F	R	5	Loosening	120
23	Smith & Nephew	Genesis II PS	49	23.4	F	L	53	Loosening	130
24	Smith & Nephew	Genesis II PS	70	24.9	F	L	22	Instability	140
25	Smith & Nephew	Genesis II PS	71	32.9	F	L	8	Dislocation	125
26	Smith & Nephew	Genesis II PS	53	36	F	R	58	Loosening	120
27	Smith & Nephew	Genesis II PS	78	29.5	M	R	5	Infection	120
28	Smith & Nephew	Genesis II PS	60	40.3	M	L	14	Stiffness	125
29	Smith & Nephew	Genesis II PS	65	23.0	F	R	14	Infection	120
30	Smith & Nephew	Genesis II PS	82	22.4	F	R	15	Infection	120

BMI, body mass index; L/R, left/right; LOI, length of implantation; HF, high flex; PS, posterior-stabilized.

we suspect that patients who did achieve high ROM, irrespective of implant design, may have generated greater wear in the posterior articular and posterior post regions compared to matched controls. Therefore, we sought to further examine the polyethylene damage and the 3D deviation patterns of the posterior articular and posterior post regions as well as the backside surfaces in the subgroup of tibial inserts retrieved from patients who achieved a high degree of flexion and to compare the results to those found on inserts retrieved from patients who did not reach a high degree of flexion. We also examined the influence of revision diagnosis on polyethylene damage and 3D deviation patterns on the articular surface, an analysis that we did not perform in our previous study [7].

Materials and Methods

From our previous study of 60 HF TKAs matched with 60 PS TKAs obtained from our institution's IRB-approved implant retrieval program [7], we identified 15 polyethylene inserts from patients who achieved a high ROM, defined as documented postoperative flexion $\geq$120°. From the 3583 total knee revisions from which these original inserts were retrieved, we collected 15 additional polyethylene inserts of the same designs that had been retrieved from patients who had also achieved high ROM before revision. Each high ROM insert (n = 30) was matched to 2 other inserts, each retrieved from patients who had not achieved 120° of flexion before revision. We matched based on manufacturer, insert design, insert size, and patient age at index surgery (±8 years). The length of implantation (LOI) was not significantly different between the high and low ROM groups (Mann-Whitney rank sum test, LOI = 28.9 ± 37 months for high ROM vs 19.1 ± 12 months for low ROM; P = .99). Inserts were both HF and traditional PS designs and included 3 manufacturers: 12 Zimmer (Warsaw, IN) NexGen LPS-Flex inserts, 18 Exactech (Gainesville, FL) Optetrak PS inserts (a non-HF design), 18 Optetrak Logic inserts (an HF design), 33 Smith & Nephew (Memphis, TN) Genesis II PS inserts (a non-HF design), and 9 Genesis II HF inserts. The Exactech inserts (Optetrak PS and Optetrak Logic) had been direct compression molded from ultra-high-molecular-weight polyethylene (UHMWPE). While implanted, they were locked into titanium alloy tibial trays with a superior surface roughness of approximately 0.76 μm. Zimmer (NexGen LPS-Flex) and Smith & Nephew (Genesis II PS and Genesis II HF) inserts had been machined from extruded UHMWPE stock material. Zimmer inserts were locked into cobalt-chromium tibial trays that had a superior surface with a blasted finish (surface roughness of approximately 1.73 μm), whereas Smith & Nephew inserts were locked into highly polished cobalt-chromium alloy tibial trays with a superior surface roughness of approximately 0.05-0.08 μm [19].

Other baseline demographics (besides age at index surgery and LOI) collected for the study included body mass index, sex, laterality, reason for revision, and ROM (Table 1). ROM documentation was reviewed for maximal postoperative (pre-revision) ROM with the assumption that this represented the “best” functional state. The demographics were used to ensure a proper match between the high and low ROM patients and to ensure that the nonmatching demographics did not differ between the 2 groups (Table 2).

Inserts were graded by 2 independent observers who were blinded to the clinical information. Inserts were graded according to a modified Hood scoring system for 7 modes of damage (scratching, pitting, burnishing, abrasion, delamination, deformation, and third body debris) under a low-power (10×) light stereomicroscope (WILD Type 355110, Heerbrugg, Switzerland) [20]. Inserts were divided into 14 tibiofemoral zones (zones 0-13, Fig. 1) and 4 backside zones (zones 14-17, Fig. 1), and each damage mode was assigned a grade on a scale from 0 to 3 based on the extent and severity of damage as previously described [7,20]. The total damage score per insert was the sum of the tibiofemoral and the backside damage scores resulting in a maximum possible score of 378 per insert (18 zones × 7 damage modes × maximum score of 3). The