Brief Followup Report

Does High-flexion Total Knee Arthroplasty Allow Deep Flexion Safely in Asian Patients?

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Abstract

Background The long-term survivorship of TKA in Asian countries is comparable to that in Western countries. High-flexion TKA designs were introduced to improve flexion after TKA. However, several studies suggest high-flexion designs are at greater risk of femoral component loosening compared with conventional TKA designs. We previously reported a revision rate of 21% at 11 to 45 months; this report is intended as a followup to that study.

Questions/purposes Do implant survival and function decrease with time and do high-flexion activities increase the risk of premature failure?

Methods We prospectively followed 72 Nexgen LPS-flex fixed TKAs in 47 patients implanted by a single surgeon between March 2003 and September 2004. We determined the probability of survival using revision as an end point and compared survival between those who could and those who could not perform high-flexion activities. Minimum followup was 0.9 years (median, 6.5 years; range, 0.9–8.6 years).

Results Twenty-five patients (33 knees) underwent revision for aseptic loosening of the femoral component at a mean of 4 years (range, 1–8 years). The probability of revision-free survival for aseptic loosening was 67% and 52% at 5 and 8 years, respectively. Eight-year cumulative survivorship was lower in patients capable of squatting, kneeling, or sitting crosslegged (31% compared with 78%). There were no differences in the pre- and postoperative mean Hospital for Special Surgery scores and maximum knee flexion degrees whether or not high-flexion activities could be achieved.

Conclusions Overall midterm high-flexion TKA survival in our Asian cohort was lower than that of conventional and other high-flexion designs. This unusually high rate of femoral component loosening was associated with postoperative high-flexion activities.

Level of Evidence Level IV, prospective study. See the Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

The long-term survivorship of TKA in Asian countries is reportedly comparable to Western countries [12, 15, 19, 23]. However, one of the major problems that remain to be solved in Asian countries is restoring the preoperative high-flexion activities [14, 20, 29].

Numerous factors such as preoperative ROM, body habitus, surgical technique, prosthesis design, and postoperative rehabilitation influence maximal flexion after TKA [3, 20]. Recently, so-called high-flexion TKA designs were developed to safely permit 155° of knee flexion and to accommodate resumption of high-flexion daily activities [1, 38]. To eliminate edge loading of the femoral component on the posterior tibial articular surface, the posterior

femoral condyles were extended. To reduce extensor mechanism impingement in deep flexion, the anterior margin of the tibial articular component was recessed. A modified posterior-stabilized cam/spine mechanism was designed to increase subluxation resistance at high-flexion angles.

Results of these high-flexion TKA designs have been variable: some authors reported improved postoperative ROM compared with the conventional designs [16, 25, 37], whereas others have found no major improvement [18, 27, 33]. Although most studies from Western countries have reported survival rates of 99% to 100% at 2 to 5 years using high-flexion TKA [9, 26, 35], several studies [6, 13] have noted a high rate of aseptic loosening of the femoral component for one specific high-flexion design at short-term followup and frequent use of high-flexion activity enabled by increased maximum flexion is reportedly one of the causes of this high rate of aseptic loosening. Even in normal native knees, high-flexion activities such as prolonged squatting or kneeling are risk factors for tibiofemoral osteoarthritis [7, 11, 30, 41, 44]. Furthermore, removing more bone in posterior femoral condyles and the intercondylar area may result in a weaker bone, and the increased stress imposed on the femoral component during high-flexion activities can lead to loosening [5, 28, 30]. In a cohort of 47 patients, we previously reported a revision rate of 21% at 11 to 45 months [13]. However, given the relatively short followup and high revision rate, we believed it important to follow that cohort.

Therefore, we determined whether implant survival and function decreased with time, whether there were signs of radiographic failure, and whether high-flexion activities increase the risk of premature failure in Asian patients who had undergone high-flexion TKA.

Patients and Methods

Between March 2003 and September 2004, we performed 72 primary cemented NexGen LPS-Flex (Zimmer, Warsaw, IN, USA) fixed-bearing TKAs in 47 patients. All

47 patients were previously reported [20]. At the same period, we performed 157 conventional fixed-bearing primary TKAs in 110 patients. Indications for implanting a high-flexion TKA were severe knee pain and functional loss unresolved with nonoperative treatment modalities, radiographic evidence of advanced osteoarthritic change (Grade 3 or 4 of Kellgren-Lawrence classification), and a strong desire to perform high-flexion activities postoperatively. Contraindications were the presence of active infection or an incompetent extensor mechanism. We did not exclude patients with a preoperative flexion of less than 100°. All 47 patients were available for 5-year survival analysis, but five patients (six knees) died between 5 and 8 years postoperatively. There were 44 women and three men with an average age of 68.3 years (range, 45–79 years) at the time of the surgery. The preoperative diagnosis for all patients in this study was degenerative osteoarthritis. The average body mass index was 26 kg/m² (range, 19–32 kg/m²). No patients were lost to followup. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. Minimum followup excluding the censored patients by revision was 5.0 years (mean, 7.7 years; range, 5.0–8.6 years). Our institutional review board approved the study protocol and all participants provided informed consent.

To determine whether high-flexion activities affected the femoral component loosening and survival rate, we divided the patients into two groups, that is, those who could squat, kneel, or sit crosslegged (Group HF) and those who could not perform these (Group U). The demographic data of two groups showed no difference. However, the mean followup period of patients in Group U was longer than that of Group HF (Table 1).

The tibial component was fully cemented using Simplex P cement (Howmedica, Rutherford, NJ, USA) in a doughy state and pressurizing it digitally into the proximal tibia. For femoral fixation, cement was placed on the cut surface of the bones and only on the inside of the posterior condyles of the component before it was impacted onto the prepared femur.

Table 1. Demographics of the knee cohort for group analysis

Demographic	All	Group HF	Group U	Significance
Number of patients who can do any high-flexion activity	72	39 (54.2%)	33 (45.8%)	
Number of patients who can do each high-flexion activity				
Squatting		20 (27.8%)		
Kneeling		11 (15.3%)		
Sitting crosslegged		34 (47.2%)		
Mean age (years; range)		67.8 (51–79)	68.8 (49–79)	0.579
Mean followup (years; range)		5.1 (0.9–8.6)	6.3 (0.9–8.6)	0.047
Mean body mass index (kg/m ² ; range)		26.7 (19.4–32.0)	25.4 (19.4–30.1)	0.087

Initially, weightbearing high-flexion activities such as squatting, kneeling, or sitting crosslegged were allowed as tolerated after discharge. However, after encountering a high rate of femoral loosening in 2006, we discouraged high-flexion activities in daily life.

We requested all patients to return for postoperative evaluation at 6 weeks, 3 months, 1 year, and annually thereafter, like other TKA series. To maximize patient followup, we contacted by telephone all patients who failed to return for annual followup. We assessed preoperative and postoperative functional performance using the Hospital for Special Surgery (HSS) scores [21]. The passive ROM of the knee was measured by the physician assistant nurse using a goniometer at each followup, and postoperative complications and reoperations were recorded. In addition, patients were asked to squat, kneel, or sit crosslegged at followup visits. AP, lateral, and Merchant's view radiographs were obtained at each followup, and these were analyzed using the Knee Society radiological scoring system to delineate radiolucencies [10]. Prosthetic loosening was defined as the presence of continuous radiolucent lines of 2 mm or more adjacent to the fixation interface of the prosthetic component or the presence of prosthesis migration.

Differences in survival between the two groups were investigated with a log rank test for equality of survival and a Kaplan-Meier curve generated using revision surgery as the end point. We determined differences in patient functional score and maximum flexion degrees between the two groups using the Mann-Whitney test and differences in radiographic loosening between the two groups using the chi square test and Fisher's exact test. Data analysis was performed using SPSS software (SPSS Inc, Chicago, IL, USA).

Results

Thirty-three revision procedures for aseptic loosening were conducted in the 72 knees at a mean of 3.5 years (range, 0.9–7.8 years) postoperatively. The overall revision rate was 46% (33 of 72) with rates of 67% (26 of 39) in Group HF and 21% (seven of 33) in Group U. Kaplan-Meier survival analysis using revision for aseptic loosening as the end point showed a difference ($p = 0.001$) between the two groups (Fig. 1). The cumulative survival rates at 5 and 8 years were 67% and 52% overall, 54% and 31% in Group HF (SE 0.8 and 0.81) and 82% and 78% in Group U (SE 0.67 and 0.73), respectively. With the exception of two cases in which femoral loosening was combined with loosening about the tibial component, the femur only was revised with a LCCK (Zimmer, Warsaw, IN, USA) femoral component, stem, and polyethylene insert.

At last followup before the loosening of the implant was observed, mean pain relief and function improved in all

Fig. 1A–B Kaplan-Meier survival curves for high-flexion TKAs in overall subjects (**A**) and in two groups classified depending on their ability to perform high-flexion activities (**B**) indicate that these activities increase the risk of premature failure in Asian patients.

47 patients compared with preoperatively: the mean preoperative HSS scores improved after the primary TKA from 74 (range, 54–91 points) to 82 points (range, 51–96 points) and the mean preoperative ROM of 121° (range, 80°–145°) increased to a mean of 132° (range, 84°–150°) after high-flexion TKAs. There were no differences in the pre- and postoperative mean HSS scores and maximum knee flexion degrees between the groups except postoperative flexion contracture degrees (Table 2). The patients in Group HF could perform any high-flexion activities at 3 or 6 months postoperatively.

Table 2. Pre- and postoperative clinical results for group analysis

Clinical results	All	Group HF	Group U	Significance
Mean HSS (SD)				
Preoperative	73.9 (9.6)	74.7 (10.1)	72.8 (8.8)	0.514
Postoperative	81.5 (9.0)	82.2 (6.7)	80.5 (11.7)	0.535
Flexion contracture (SD)				
Preoperative	9.1 (11.5)	7.8 (10.4)	8.9 (9.6)	0.639
Postoperative	1.4 (3.7)	2.2 (4.4)	0.2 (0.9)	0.008
Maximum knee flexion (SD)				
Preoperative	129 (16.1)	131 (12.4)	129 (15.3)	0.443
Postoperative	130 (13.1)	131 (12.8)	132 (10.0)	0.715

HSS = Hospital for Special Surgery score.

Progressive radiolucent lines about components and radiologic component loosening or migration were observed in 35 femurs and two tibias (eight of 33 in Group U and 28 of 39 in Group HF). Radiolucent lines were most frequently noted (69% [50 of 72]) in Zone 1 of femoral components (progressive or greater than 2 mm, 35 of 72; nonprogressive and less than 2 mm, 15 of 72). The incidences of radiolucent lines at other areas were 24% (17 of 72), 8% (six of 72), and 21% (15 of 72) at Zones 2, 3, and 4 of femoral components, respectively, and 6% (four of 72) at Zone 1 of tibial components. No knee showed loosening or osteolysis associated with the patellar components.

During followup, there was no deep infection. After revision, there were two cases of deep infection requiring implant removal and a later two-staged reimplantation.

Discussion

We previously reported an unusually high rate of premature failure with femoral component loosening from a high-flexion TKA design in an Asian cohort [13]. However, given the relatively short followup we believed it important to follow that cohort. Therefore, we determined whether implant survival and function decreased with time, whether there were signs of radiographic failure, and whether high-flexion activities increase the risk of premature failure in Asian patients who had undergone high-flexion TKA.

This study presents a few limitations. First, we considered a single type of high-flexion design and have no control groups with a nonhigh-flexion standard design or other types of high-flexion prostheses. Ninety-four percent of the subjects were Asian females who had excellent preoperative motion (approximately a 120° arc). Therefore, the findings may not be applicable to all high-flexion TKA implants and the general population. Second, we only assessed whether patients could perform high-flexion activities at followup. Quantitative evaluation for the high-flexion activities

(ie, how much time they spend in high-flexion positions and how many degrees they flex the knees in daily activities) was not performed.

Many authors have tried to predict and demonstrate the efficacy and safety of the high-flexion TKA (Table 3) [6, 16–18, 32, 40, 42]. However, the reported effects of a high-flexion design on maximal flexion varied considerably between studies, and no study has thus far demonstrated the subjects adapted themselves to activities that demanded squatting in their daily lives [28, 36]. Recently, Cho et al. reported a high incidence of early loosening of the femoral components after high-flexion TKA [6]. They reviewed a group of 166 patients (218 TKAs) implanted with the same fixed-bearing high-flexion TKA at a mean followup of 51 months. They observed progressive radiolucent lines in approximately 14% of the femoral components and 23% of these cases required revision for femoral component loosening. A higher percentage of patients were able to squat in the cohort with progressive radiolucent lines (77%) than in those without progressive femoral component radiolucent lines (20%). Our findings confirm their report.

Deep flexion of the knee in Asian countries is often necessary to perform routine activities such as kneeling, squatting, and sitting with both legs crossed [31, 34]. In our series, the mean preoperative maximum flexion was approximately 130°, and most subjects had been performing high-flexion activities in daily life preoperatively although the activities caused pain. Although the mean postoperative maximum flexion was also 130°, only 54% of the subjects were able to perform any high-flexion activities after TKA, and they showed a substantially higher failure rate of high-flexion TKA. Although the real causes of failures should be multifactorial including technical and prosthetic factors, a high rate of aseptic loosening of the femoral component for this specific high-flexion design could be attributed to certain characteristics of the design and the Asian lifestyle or culture requiring deep knee flexion [26, 28, 30, 35].

Activities of daily living requiring deep flexion after TKA have not been fully investigated. In several studies performed in Western countries, 40% to 75% of the patients had difficulty with squatting, kneeling, and gardening after conventional TKA and even high-flexion TKA [26, 43]. Also, two studies in Asian countries showed similar unsatisfactory results. In one study, none of the patients who are able to squat adapted themselves to activities that demanded squatting in their daily lives [16]. Another study demonstrated that 15% to 43% of the patients could engage in kneeling, Thai polite-style sitting, or crosslegged sitting, but the authors found no difference between high-flexion and conventional TKA [40].

The amount of increase in flexion observed in studies that have reported superior flexion for a high-flexion TKA design is limited (< 10°; weighted mean improvement, 2.5°)

Table 3. Summary data for previous studies using the NexGen LPS-Flex implant

Study	Mean age (years)	Sex (percent male)	Followup (mean years)	Survival rate (%)	Mean preoperative ROM (°)	Mean postoperative ROM (°)	Mean postoperative knee score	Mean postoperative HSS score	Progressive radiolucent lines (%)	Country
Kim et al. [17]	67	7	3.0–4.8	99.6	117.3	135	95	NR	0.4	South Korea
Huang et al. [16]	70	16	2.3	100	110.3	138	96	NR	0	Taiwan
Kim et al. [18]	68	4	2.0–2.2	100	127	139	92	89	0	South Korea
Weeden and Schmidt [42]	63	40	1	100	120	132	92	NR	0	USA
Tanavalee et al. [40]	70	8	6–7.3	98.3	135	135	96	NR	4	Thailand
Ng et al. [32]	68	20	1.7–4.4	100	99	105	NR	NR	NR	China
Cho et al. [6]	64	13	3–6	96.8	109	129	87	NR	14	South Korea
Current study	68	6	0.9–8.6	52	121	132	NR	82	50	South Korea

HSS = Hospital for Special Surgery; NR = no report.

[4, 8, 18, 22, 24, 25, 32, 33]. In a recent systematic literature review analyzing the change in range of knee flexion after conventional and high-flexion TKA, the Western patient group showed a substantial difference in the gain of flexion with both implants. In contrast, no major gain in flexion was observed in the Asian patient group [39]. Therefore, it remains unclear whether superior flexion is reproducibly obtained after implantation of high-flexion TKA designs.

We observed progressive radiolucent lines about femoral components in 35 of 72 knees and most were frequently noted in Zone 1 of femoral components. A recent study with a mobile-bearing high-flexion design reported an incidence of posterior femoral radiolucent lines in Zones 1 and 4 of 6% and 43%, respectively [2].

Overall midterm high-flexion implant survival of our Asian cohort is lower than that of conventional and other high-flexion designs although motion and function of the knees were improved postoperatively and this unusually high rate of femoral component loosening is associated with postoperative high-flexion activities. Closer attention is required and caution is needed when implementing alternative high-flexion TKA designs in patients who have the traditional Asian lifestyle.

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