High-flexion TKA in patients with a minimum of 120 degrees of pre-operative knee flexion: outcomes at six years of follow-up

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Abstract We prospectively evaluated outcomes of high-flexion total knee arthroplasty in 165 patients who had advanced arthritis with a minimum 120-degree pre-operative knee flexion, with a mean follow-up of 77 months. Patients were divided into two groups according to their ability to perform full-range (heel-to-buttock) pre-operative knee flexion (group A) and the inability to do so (group B). The overall clinical rating was “excellent” in 96% of patients and “good” in 4% of patients. Mean maximum knee flexion decreased from 137.9° to 134.8°, with no statistical difference between pre- and post-operative knee flexion. However, patients in group A had significantly decreased knee flexion (146.2° vs. 135.0°, $p < 0.001$), whereas patients in group B exhibited no change in knee flexion (133.7° vs. 134.7°, $p = 0.14$). We found that 14.7%, 36.5% and 43.0% of the studied patients could engage in kneeling, Thai polite style sitting and cross-legged sitting, respectively, with no significant differences between groups A and B. The survival rates for any reoperation and prosthesis-related problem (such as early loosening) at six years were 98.3% and 100%, respectively. At six-year follow-up in patients with well preserved pre-operative knee flexion, the high-flexion knee prosthesis provided a favourable outcome without improving knee flexion.

Introduction

Deep knee flexion is a necessity for the traditional Asian lifestyle, which includes kneeling, squatting, cross-legged sitting and Thai polite style sitting. Zhang et al. [1] reported that 40% of Chinese men and 68% of women squatted for a minimum of one hour per day at a mean age of 25 years. When a total knee arthroplasty (TKA) is indicated for advanced arthritis in Asian patients, the patients’ main expectations were similar to those of Western patients, including pain relief and a return to daily activity [2, 3]. Although Park et al. [3] reported that pre-operatively, issues related to high-flexion activities were of no more concern than other issues among Asian patients, after surgery, dissatisfied patients tended to perceive functional disabilities in high-flexion activities to be more important than those who were satisfied [4].

To increase patient satisfaction, current total knee prostheses have been designed differently to facilitate better knee flexion [5, 6]. Early results and post-operative range of motion (ROM) of the knee following TKA using the high-flexion knee prosthesis showed favourable outcomes [7, 8]. However, some studies [9, 10] reported no difference in outcome between those who underwent TKA using high-flexion or standard total knee prosthesis. In most studies of high-flexion TKA [7–11] mean pre-operative maximum knee flexion ranged from 111–127 degrees. To our knowledge, there has been no study of high flexion TKA focusing on patients who have well-preserved knee ROM at the time of surgery.

The purpose of this study was to evaluate the results of TKA performed in patients with equal or more than 120 degrees of pre-operative knee flexion, using the high-flexion knee prosthesis. In addition, we evaluated outcomes of high-flexion TKA in patients who were able to do a full-

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range (heel-to-buttock) pre-operative knee flexion and those who were unable to do so.

Materials and methods

From November 2002 to March 2004, a consecutive series of 165 patients (189 knees) who had late-stage osteoarthritis with well-preserved knee ROM and were scheduled for TKA, were prospectively evaluated. Inclusion criteria included the following: patient age from 45 to 85 years old, advanced primary osteoarthritis, no previous major knee surgery, a minimum of 120 degrees of knee flexion, less than 20 degrees of knee deformity in the coronal plane, less than 15 degrees of flexion contracture and body mass index (BMI) of less than 30 kg/m². All operations were performed by a single surgeon (AT) using a single surgical approach (mini-midvastus approach), a single knee prosthesis (NexGen Legacy Posterior Stabilised LPS-Flex, Warsaw, IN, USA) and a single rehabilitation protocol.

Pre-operatively, patients were divided in two groups according to the ability to perform non-weight-bearing full-range knee flexion (heel-to-buttock knee flexion). Patients who were able to execute full-range knee flexion were in group A (Fig. 1) and the rest were in group B. The non-weight-bearing passive knee ROM was evaluated by two assessors (AT and SN) pre-operatively and at the latest post-operative follow-up using a goniometer, with the patient in the supine position following the method described by Kim et al. [8]. The mean values of maximum non-weight-bearing extension and flexion measured by both evaluators were recorded. At a minimum follow-up of six years, patients were evaluated for clinical and functional outcomes using the Knee Society (KS) clinical

and function scores [12], the ROM, specific deep knee-bending activities and radiographic results. The change of knee ROM after TKA was compared between patients in group A and patients in group B.

Serial single-limb standing anteroposterior and lateral radiographs taken during the pre-operative period, three- to six-month follow-up and yearly follow-up were performed using 14 by 17-inch cassettes. The radiographic limb alignments, which were evaluated during the pre-operative and the three- to six-month periods, were compared using the mean values measured by two independent observers (ST and AL). Other abnormal radiographic signs were evaluated at the latest radiographic follow-up.

Statistical analysis

Statistical analysis was performed using GraphPad Prism version 5.01 for Windows, GraphPad Software (San Diego, CA, USA). Descriptive statistics (mean, range and percent) were used for the variables evaluated. The Student's *t*-test was used to compare continuous parameters between both groups. The chi-squared test was used for qualitative comparative parameters. The *p*-values of <0.05 were considered as significant. Kaplan-Meier survival analyses were used to analyse the six-year survival rate among patients that underwent reoperation for a prosthesis-related problem.

Results

Among all 165 patients (189 knees), nine patients (11 knees) were lost to follow-up, and thus, there were 156 patients (178 knees) available for evaluation. The average age of patients was 70 years (range, 48–83 years), and the average body mass index (BMI) was 26.2 kg/m² (range, 21.9–31.8 kg/m²). Comparative pre-operative parameters for both groups are shown in Table 1. Notably, the male/female ratio differed between the groups.

At a mean follow-up of 77 months (range, 72–88 months) in the study group (the entire patient cohort who were available for follow-up), there were significant differences in KS clinical score ($p<0.001$) and function score ($p<0.001$) between pre- and post-operative evaluation. The overall KS clinical rating was “excellent” among 96% of patients and “good” among 4% of patients, with no significant differences between groups with regard to post-operative variables (Table 1). The maximum knee extension improved from 2.5 degrees (range, −15 to 15 degrees) to −0.2 degrees (range, −10 to 5 degrees), and the maximum knee flexion decreased from 137.9 degrees (range, 120–150 degrees) to 134.8 degrees (range, 110–145 degrees). However, there was no significant change in ROM between the pre-operative and post-operative periods ($p>0.05$).

Fig. 1 A patient from group A demonstrating the ability to perform pre-operative full-range (heel-to-buttock) knee flexion

Table 1 Demographic data and follow-up & clinical variables

Parameters	Studied group	Group A	Group B	<i>p</i> value
Number of patients/ knees	156/178	51/60	105/118	
Mean age (years)	70	70.5	69.8	>0.05
Number of male/female	12/144	8/43	4/101	0.02*
Number of left/right side	90/88	32/28	58/60	>0.05
Mean BMI	26.2	25.7	26.4	>0.05
Preop knee deformity (degrees)	5 (Anat varus)	4.7 (Anat varus)	5.1 (Anat varus)	>0.05
Mean follow-up (months)	77	76.6	77.2	>0.05
Mean preop KS clinical score (points)	37.3	37.7	37.1	>0.05
Mean postop KS clinical score (points)	96.2	96.5	96.0	>0.05
Mean preop KS function score (points)	31.1	31.5	30.9	>0.05
Mean postop KS function score (points)	87.8	87.9	87.7	>0.05

Anat varus Anatomical varus, *BMI* body mass index, *KS* Knee Society, *preop* preoperative, *postop* postoperative

Concerning the change in ROM observed in each group, patients in group A exhibited an average loss of flexion of 11.2 degrees after surgery, with significant differences between the pre- and post-operative periods. In contrast, patients in group B displayed an average one degree increase of ROM (Table 2). This trend was not significant. Regarding specific post-operative deep knee flexion activities the overall percentages of patients who were able to kneel, sit in the Thai polite style (Fig. 2) and sit in a cross-legged position were 14.7% (15.7% in group A and 14.3% in group B, $p=0.81$), 36.5% (37.3% in group A and 36.2% in group B, $p=1.0$) and 43.0% (43.1% in group A and 42.9% in group B, $p=1.0$), respectively. There were no significant differences between groups A and B with regard to the percentages of patients able to perform these specific deep knee flexion activities.

Complications included one patient with deep infection at 14 months after surgery and two patients with early knee instability at 15 and 24 months after surgery. This instability was related to complete subperiosteal release of the medial collateral ligament at the time of surgery. All three patients were doing well at the latest

follow-up after two-stage revision TKA for infected knee or thicker polyethylene exchanges for unstable knees. There was no clinical complication related to the high flexion prosthesis (e.g. painful femoral loosening as described by Han and associates [13]). The survival rates at six years for patients who underwent reoperation for any reason and for prosthesis-related problem were 98.3% and 100%, respectively.

Radiographic results

Of the 189 knees evaluated, 131 knees that had adequate true anteroposterior and lateral radiographs were included for evaluation. The mean pre-operative alignment was 5.0 degrees of anatomical varus (range, 0–18 degrees), and the mean post-operative alignment was 5.1 degrees of anatomical valgus (range, 1–7 degrees). There were 25 knees with 1-mm non-progressive radiolucent lines in zone 1 of the femoral component and seven knees with 1-mm non-progressive radiolucent lines in zone 1 of the tibial component, as described by the criteria used for Knee Society radiographic evaluation [12]. There was no definite radiographic loosening of the implant.

Table 2 Comparing the mean and range of range of motion (ROM) between preoperative period and latest follow-up

Group and parameters	Maximum extension		Maximum flexion		<i>p</i> value
	Degrees	Range	Degrees	Range	
Group A (60 knees)					
Preoperative measured value	0.9	(−)15–15	146.2	145–150	<0.001
Postoperative measured value	−1.6	(−)10–5	135.0	125–145	
Group B (118 knees)					
Preoperative measured value	3.4	(−)10–15	133.7	120–140	0.14
Postoperative measured value	0.5	(−)5–5	134.7	110–145	

Fig. 2 A patient sitting in Thai polite style. Patients who underwent unilateral TKA (white arrow) typically preferred placing the foot of the operated limb underneath the unaffected knee

Discussion

Several studies [7–10, 14] have reported satisfactory short- to mid-term clinical results of high-flexion total knee systems in terms of improved range of knee movement and functional performance. Regarding the effect of cruciate-preserving design on high-flexion knee prosthesis, the randomised study of Kim et al. [11] reported no short-term difference in knee ROM, clinical and radiographic results between high-flexion posterior cruciate-retaining TKA and high-flexion posterior cruciate-substituting TKA. According to an in vivo knee kinematics study by Moynihan et al. [15], when the knee was flexed beyond 90 degrees to deep knee flexion, the posterior femoral translation and internal tibial rotation increased steadily. Thus, the mobile bearing design provides tibial rotation during flexion and theoretically facilitates better knee motion while minimising stress at the tibial bone–prosthesis interface. In contrast, the randomised controlled study on a single modern TKA system with different bearings (fixed or mobile bearing design) of Hamusch et al. [16] demonstrated

no short-term difference in knee ROM and functional outcome. However, the study comparing a single mobile bearing total knee prosthesis between the high-flexion design and the standard design reported similar results to several studies of fixed bearing design in terms of significantly improved short-term knee ROM and outcome [17].

Although several high-flexion designs of total knee prosthesis, regardless of issue on posterior cruciate ligament or motion of bearing unit, have shown better postoperative knee ROM than those with standard knee designs, a systematic review on results of high-flexion TKA [18] concluded that there was insufficient evidence to support advantages of high-flexion TKA, as many studies had inadequate methodological rigour, such as inadequate blinding, flawed participant selection, short follow-up periods and functional outcomes which lacked sensitivity.

In this series, at the latest follow-up, clinical outcome following TKA using a single design of high flexion prosthesis was in line with that obtained in previous studies [7–10], with a similar significant improvement after surgery

Table 3 Comparing clinical outcomes and knee flexion among studies on high-flexion TKA

Authors	KS clinical score (point)		KS function score (point)		Preop maximum flexion (degrees)	Postop maximum flexion (degrees)	Specific knee flexion activities (percent)		
	Preop	Postop	Preop	Postop			Kneeling	Cross-legged sitting	Thai polite style sitting
Kim TH et al. [8]	30.9	95	44.9	81.3	117.3	135	NA	64.1	NA
Nutton et al. [10]	NA	NA	50.7	76.9	119	127	NA	NA	NA
Huang et al. [7]	42	96	45	88	110	138	80	NA	NA
Seon et al. [14]	NA	NA	NA	NA	124.1	135.3	46	76	NA
Kim YH et al. [11]	27	95	53.9	83.7	123	135	NA	NA	NA
Our study	37.3	96.2	31.1	87.7	137.9	134.8	14.7	43	36.5

KS Knee Society score, *preop* preoperative, *postop* postoperative, *NA* not available

(Table 3). In studies resulting in favourable post-operative ROM following fixed bearing high-flexion TKA, a common criterion used for patient selection was a minimum of 90 degrees of knee flexion [8–10, 14]. According to these reports, the mean pre-operative maximum knee flexion ranged from 111 to 127 degrees, and the mean increased post-operative ROM ranged from 8 to 15 degrees.

Although the mean post-operative maximum knee flexion in our study was similar to the values obtained in the reports mentioned, the selection criterion for knee ROM was much greater in our study as compared to others. With a mean pre-operative maximum flexion of 137.9 degrees and 3.1-degree loss of flexion after surgery, our study could not demonstrate increased knee flexion following the use of high-flexion knee prosthesis in patients who had very good pre-operative knee flexion.

Remarkably, we found that the post-operative knee flexion of patients in group A was significantly decreased by 11.2 degrees from levels observed during pre-operative evaluation, whereas patients in group B exhibited similar maximum knee flexion pre- and post-operatively. As full-range passive knee flexion is not uncommon in the advanced stage of knee arthritis in Asians, TKA in knees with advanced arthritic and well-preserved ROM may result in decreased ROM after surgery.

Furthermore, while our study found post-operative knee ROM similar to those reported in the studies by Kim et al. [9] and Seon et al. [14], less than 50% of our patients were able to kneel or sit in a cross-legged position. These values are much lower than those reported by previous studies. Huddleston et al. [19] evaluated post-operative knee flexion in 20 patients with high-flex TKA. The authors found that patients could flex the operated knee more than 90 degrees and 120 degrees for only 0.5% and 0.1% of a total 35.7-hour testing time, respectively. Therefore, in addition to appropriate patient selection criteria for high-flexion TKA, patient awareness (including concern of family members in the cases of dependent patients) affected post-operative deep knee flexion activities. In our study, the reduced ability to perform specific knee flexion activities after surgery may have resulted from the level of patient awareness, the reduced time devoted to individualised daily activity due to the compound family structure in Thailand, and the individual patient's personal beliefs.

In contrast to the study by Han et al. [13], who reported a high incidence of early femoral component loosening in high-flexion TKA, our study mirrors several studies [7–9] reporting no or very limited symptomatic component loosening. The extensive reduction in deep knee flexion activities observed herein but not in any other reported study with long-term follow-up may result from the lack of any component loosening. Although deep knee bending activities seem to be necessary for Asian cultures, there are

concerns related to the delayed effects on the durability of TKA post-operatively. It is recommended that these patients engage in such activities only when it is necessary to avoid repetitive joint overload, which may result in early component failure [13].

In conclusion, TKA using the high-flexion prosthesis (NexGen LPS-Flex) provided a favourable outcome at six-year follow-up, without complications related to the prosthesis. However, the high-flexion knee prosthesis did not improve knee flexion when pre-operative knee flexion was a minimum of 120 degrees. Furthermore, post-operative knee flexion was significantly decreased in patients who had full-range pre-operative knee flexion. Although most patients expected improved deep knee flexion, less than 50% of patients were able to engage in such activities comfortably following the operation.

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