Range of Motion of Standard and High-Flexion Posterior Stabilized Total Knee Prostheses

A Prospective, Randomized Study

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Background: The restoration of posterior femoral translation has been shown to be an important factor in enhancing knee flexion after total knee arthroplasty. The purpose of this study was to compare the ranges of motion associated with standard and high-flexion posterior stabilized total knee prostheses in patients managed with simultaneous bilateral total knee arthroplasty.

Methods: Fifty patients (mean age, sixty-eight years) received a standard fixed-bearing knee prosthesis in one knee and a high-flexion fixed-bearing knee prosthesis in the contralateral knee. Two patients were men, and forty-eight were women. At a mean of 2.1 years postoperatively, the patients were assessed clinically and radiographically with use of the knee-rating systems of the Knee Society and The Hospital for Special Surgery.

Results: The mean postoperative Hospital for Special Surgery knee score was 90 points for the knees treated with the standard fixed-bearing prosthesis and 89.4 points for those treated with the high-flexion prosthesis. At the time of the final follow-up, the knees with the standard prosthesis had a mean range of motion of 135.8° (range, 105° to 150°) and those with a high-flexion prosthesis had a mean range of motion of 138.6° (range, 105° to 150°) ($p = 0.41$). No knee had aseptic loosening, revision, or osteolysis.

Conclusions: After a minimum duration of follow-up of two years, we found no significant differences between the groups with regard to range of motion or clinical and radiographic parameters, except for posterior femoral condylar offset.

Level of Evidence: Therapeutic Level II. See Instructions to Authors for a complete description of levels of evidence.

The range of motion after total knee arthroplasty is an important component of a patient's overall functional outcome[1]. However, patients rarely flex the knees beyond 120° following total knee arthroplasty[2-5]. Although the mechanisms that hinder more flexion are unclear, the ability to restore posterior femoral translation has been shown to be an important factor in enhancing knee flexion after total knee arthroplasty[4-7]. A reduction in posterior femoral translation has been found to cause impingement of the posterior edge of the tibial component on the femoral shaft, thus preventing a high degree of flexion of the knee[5,6].

The NexGen LPS-Flex total knee system (Zimmer, Warsaw, Indiana) was introduced to enhance knee flexion after total knee arthroplasty. Compared with the NexGen LPS prosthesis, the NexGen LPS-Flex system includes an extension of the posterior condyle of the femoral component by 2 mm, a modification of the cam and tibial spine, and a reduction of patellar impingement. The purpose of the extended posterior condyle of the femoral component is to extend the surface of the femoral component posteriorly to increase the articular contact area at high flexion angles and thereby increase posterior femoral translation and the range of flexion. The shape of the femoral cam was modified to improve stability of the femoral component on the articular surface and to reduce the bending moment applied to the articular surface of the spine. The femoral cam design increases the subluxation resistance and increases the contact surface between the cam and the tibial spine beyond that of the standard design at flexion angles of >130°. To decrease stresses on the quadriceps mechanism and to reduce the potential for patellar impingement during high degrees of flexion, material was removed from the anterior face of the polyethylene tibial bearing.

We performed a prospective, randomized study to compare the ranges of motion of the NexGen LPS and NexGen LPS-Flex total knee replacements in patients who were managed with simultaneous bilateral total knee arthroplasty.

Materials and Methods

Between July and September 2002, the senior author (Y.-H.K.) performed fifty consecutive primary bilateral total

knee arthroplasties in fifty patients (100 knees). All fifty patients were enrolled in the present study. The bilateral total knee arthroplasties were performed during the same anesthesia session, with one side treated immediately after the other. No patient was lost to follow-up. The study was approved by our institutional review board, and all patients provided informed consent.

Randomization of the use of a NexGen LPS or a NexGen LPS-Flex prosthesis was determined from a sequential pool on the basis of a table of random numbers. Each of the fifty patients received a NexGen LPS total knee component on one side and a NexGen LPS-Flex total knee component on the contralateral side. The order of insertion of the two prostheses was assigned alternately to each side. Two patients were men, and forty-eight were women. The mean age at the time of the index operation was sixty-eight years (range, fifty-three to eighty-one years). The diagnosis was osteoarthritis for forty-nine patients and rheumatoid arthritis for one. No patient had had a previous knee operation.

All procedures were performed through a midline skin incision measuring 9 to 12 cm in length, with a subvastus approach into the joint. The anterior and posterior cruciate ligaments were excised in all patients in both groups.

Ligamentous balancing was done, and an attempt was made to resect 10 mm of tibial bone distally from what was considered to be the intact articular surface in order to achieve a surface that was perpendicular to the shaft of the tibia in the coronal plane with a 7° posterior slope in the sagittal plane. The distal and posterior femoral condylar resection was done with an attempt to remove a length of bone that was equal to the thickness of the femoral component to be inserted. The valgus angle of distal femoral resection, made with use of an anterior referencing system, was the same in the two groups. The amount of bone resected from the posterior femoral condyle was 2 mm greater in the knees to be treated with the NexGen LPS-Flex prosthesis than it was in the knees to be treated with the standard NexGen LPS prosthesis. The patellar thickness was measured before the resection, and an attempt was made to remove a segment of bone that was equal to or slightly thicker than the component to be inserted. After pulsed lavage, all implants were inserted with cement, which was pressurized.

A splint was applied with the knee in 15° of flexion, and it was worn for the first twenty-four hours after the operation. The knee was placed in a continuous-passive-motion machine after the splint was removed. All patients began walking with crutches or a walker and started active and passive range-of-motion exercise on the second day after the operation. The patients used crutches or a walker, with full weight-bearing, for six weeks and then used a cane for six weeks.

Clinical and radiographic evaluations were done at three months after the operation, at one year, and then yearly thereafter. The mean duration of follow-up was 2.1 years (range, 2.0 to 2.2 years). Each knee was rated preoperatively and postoperatively according to the systems of the Knee Society[8] and The Hospital for Special Surgery[9]. In addition, each patient completed the Short Form-36 (SF-36) questionnaire[10], which is self-administered. The SF-36 consists of a visual analog scale for the assessment of the severity, location, and frequency of pain as well as a series of questions regarding the achievement of functional benchmarks (the ability to climb stairs, to walk a certain distance, and to participate in specific sports), the overall sense of well-being, and the level of satisfaction with the operative result.

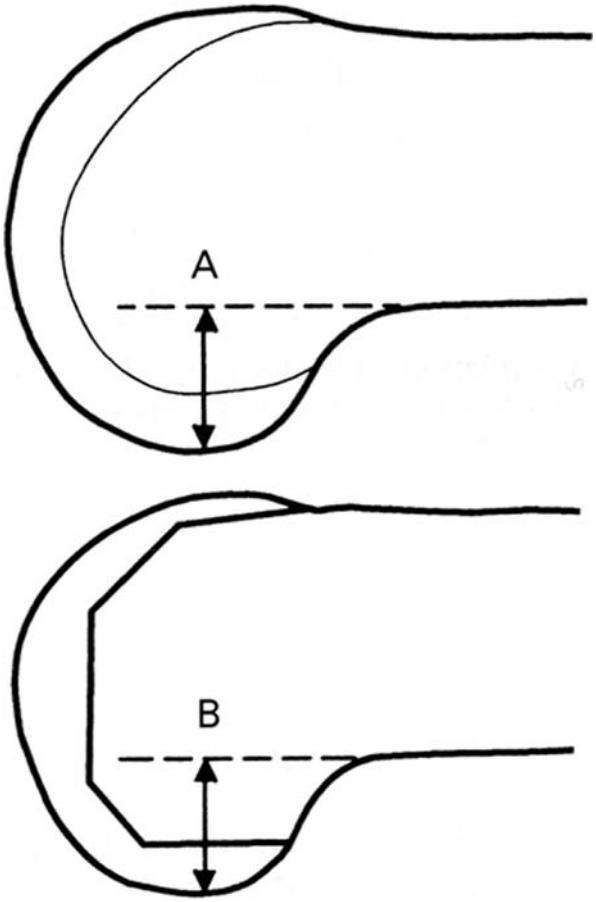

Fig. 1
Diagram showing the measurement of posterior femoral condylar offset before (A) and after (B) the operation.

The active range of motion was determined with use of a standard (60-cm) clinical goniometer before the operation and at the time of the review. The patients were told to bend their knees as much as they could while lying in a supine position. The range of motion was measured for all patients, on two occasions, by one of the authors (Y.-H.K.) as well as by another author (K.-S.S.) who was blinded to the type of implanted prosthesis. The range of motion was considered to be the arc of motion instead of the flexion angle.

Anteroposterior radiographs with the patient both standing and lying supine, lateral radiographs, and skyline patellar radiographs were made preoperatively and postoperatively and were assessed for the alignment of the limb (tibiofemoral angle), the position of the components, and the presence and location of radiolucent lines at the bone-cement interface according to the recommendation of the Knee Society[8].

TABLE I Clinical Results

	Knee Society Scoring System					
	Preoperative			Final Follow-up		
Parameters	NexGen LPS	NexGen LPS-Flex	P Value*	NexGen LPS	NexGen LPS-Flex	P Value*
Total knee score *(points)*	28	36	0.8583	93	92	0.3356
Pain score *(points)*	0	0	0	43	43	0.2241
Degree of pain *(no. [%] of knees)*						
None	—	—	—	—	—	—
Mild	—	—	—	—	—	—
Moderate	—	—	—	—	—	—
Severe	—	—	—	—	—	—

*The p values pertain to the comparison between the NexGen LPS group and the NexGen LPS-Flex group with use of the Student t test.

Posterior femoral condylar offset was evaluated on preoperative and postoperative lateral radiographs by measuring the maximum thickness of the posterior condyle projected posteriorly to the tangent of the posterior cortex of the femoral shaft (Fig. 1). The preoperative and postoperative measurements were then compared, after correction for magnification, with use of the diameter of the femoral shaft 10 cm proximal to the femoral articular surface as a reference measurement.

The level of the joint line was determined on anteroposterior radiographs, made with the patient lying supine, before and after surgery. This was done by measuring the distance between the tip of the fibular head and the distal margin of the lateral part of the femoral condyle preoperatively and the distance between the tip of the fibular head and the distal margin of the lateral femoral component postoperatively. Skyline patellar radiographs were examined for patellar tilt, subluxation, or dislocation.

Statistical comparison of the clinical and radiographic

Fig. 2-A

Figs. 2-A and 2-B Radiographs of both knees of a sixty-four-year-old woman with osteoarthritis. **Fig. 2-A** Anteroposterior radiographs, made two years after surgery, showing the NexGen LPS-Flex fixed-bearing prosthesis (left side of image) and the NexGen LPS fixed-bearing prosthesis (right side of image) to be solidly fixed in a satisfactory position. There are no radiolucent lines or other signs of osteolysis around the tibial components.

TABLE I *(continued)*

The Hospital for Special Surgery Scoring System					
Preoperative			Final Follow-up		
NexGen LPS	NexGen LPS-Flex	P Value*	NexGen LPS	NexGen LPS-Flex	P Value*
62	61	0.9246	90	89	0.7108
7	7	0.9658	28	27	0.3825
0 (0%)	0 (0%)	—	38 (76%)	36 (72%)	—
0 (0%)	0 (0%)	—	12 (24%)	13 (26%)	—
6 (12%)	5 (10%)	—	0 (0%)	1 (2%)	—
44 (88%)	45 (90%)	—	0 (0%)	0 (0%)	—

results associated with the two groups was done with analysis of variance, chi-square analysis, Pearson regression analysis, the independent unpaired Student t test, and the two-tailed Student t test.

Twenty patients were required to determine whether there was a significant difference (power = 0.8 and $p < 0.05$) in the knee scores between the NexGen LPS and NexGen LPS-Flex groups. Thirty-six patients were required to determine whether there was a significant difference (power = 0.8 and $p < 0.05$) between the two groups with regard to the radiographic parameters, including the tibiofemoral angle, position of the components, presence of radiolucent lines, posterior femoral condylar offset, and level of the joint line. Forty-two patients were required to determine whether there was a significant difference between the two groups (power = 0.8 and $p < 0.05$) with regard to the range of motion of the knees.

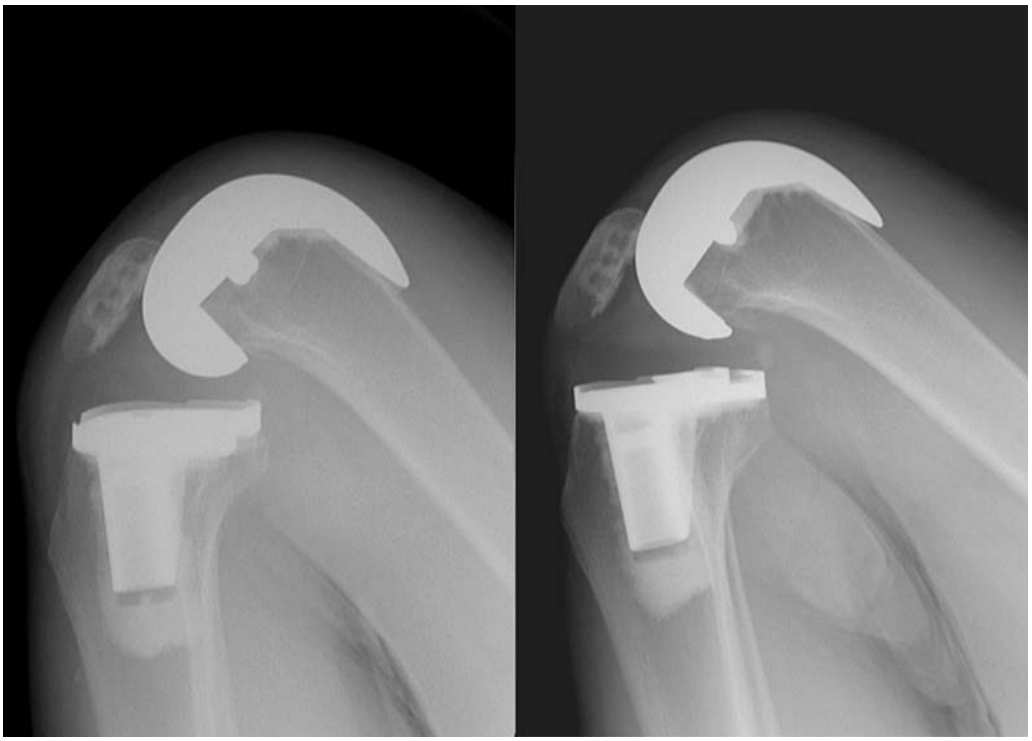

Fig. 2-B

Lateral radiographs, made two years after surgery, showing both the NexGen LPS-Flex fixed-bearing prosthesis (left side of image) and the NexGen LPS fixed-bearing prosthesis (right side of image) to have a satisfactory range of motion (145° of flexion). There are no radiolucent lines or other signs of osteolysis around the femoral, tibial, or patellar component. The NexGen LPS-Flex prosthesis appears to provide greater contact area between the femoral and tibial components.

Results

Clinical Results

Knee Score

The preoperative and postoperative knee and pain scores are summarized in Table I. The Knee Society and The Hospital for Special Surgery knee scores did not differ significantly between the two groups either preoperatively ($p = 0.8583$ and $p = 0.9246$, respectively) or postoperatively ($p = 0.3356$ and $p = 0.7108$, respectively). In the NexGen LPS group, the mean postoperative knee score was 92.5 points (range, 82 to 100 points) according to the system of the Knee Society and 90 points (range, 75 to 100 points) according to the system of The Hospital for Special Surgery. In the NexGen LPS-Flex group, the mean postoperative knee score was 91.6 points (range, 70 to 100 points) according to the system of the Knee Society and 89.4 points (range, 70 to 100 points) according to the system of The Hospital for Special Surgery.

Pain

The postoperative pain scores, according to both knee-scoring systems, did not differ significantly between the groups ($p = 0.2241$ and $p = 0.3825$). Of the fifty knees treated with the NexGen LPS implant, thirty-eight (76%) were not painful at the time of the latest follow-up, twelve (24%) were mildly painful, and none were moderately or severely painful. Of the fifty knees treated with the NexGen LPS-Flex prosthesis, thirty-six (72%) were not painful, thirteen (26%) were mildly painful, one (2%) was moderately painful, and none were severely painful.

Range of Motion (Table II)

Preoperatively, the mean knee flexion contracture was 6° (range, 0° to 50°) in the NexGen LPS group and 5° (range, 0° to 50°) in the NexGen LPS-Flex group. At three months, no knee had a measurable flexion contracture. The mean range of flexion preoperatively, at three months postoperatively, at one year, and at two years did not differ significantly between the two groups ($p = 0.41$ at two years) (Figs. 2-A and 2-B).

Satisfaction

Thirty-eight patients (76%) were fully satisfied with the outcome of the operation with the NexGen LPS prosthesis, and twelve patients (24%) were satisfied. Thirty-six patients (72%) were fully satisfied with the result of the operation with the NexGen LPS-Flex prosthesis, thirteen patients (26%) were satisfied, and one patient (2%) was dissatisfied because of constant moderate pain.

Radiographic Results

There were no significant differences between the groups with regard to the position of the femoral and tibial components in the coronal and sagittal planes, the alignment of the knee, the patellar angle (the angle between a line along the patellar cut surface and a line joining the most proximal margins of the femoral condyles of the component on the skyline radiograph), the amount of the tibial surface area covered by the implants (tibial capping), or the mean level of the joint line (all $p > 0.05$). The alignment of the knee was a mean of 5.4° of valgus in the NexGen LPS group and 7° of valgus in the NexGen LPS-Flex group. There were no radiolucent lines in either group. The preoperative posterior femoral condylar offset was approximately the same (26.6 and 26.5 mm) in the two groups. However, the postoperative posterior femoral condylar offset was significantly greater ($p = 0.0012$) in the NexGen LPS-Flex group (27.3 mm) than in the NexGen LPS group (25.3 mm). On the lateral radiographs of the knees in full flexion, the NexGen LPS-Flex prosthesis appeared to provide a greater contact area between the femoral and tibial components (Figs. 2-A and 2-B). No knee had loosening of the femoral, tibial, or patellar component, and no knee had subluxation or dislocation of the tibiofemoral joint or a patellar dislocation.

Discussion

It has been claimed that the anterior-posterior dimensions of the tibial articular surface on the medial and lateral sides of an intact knee are greater than the comparable dimensions of the tibial polyethylene of a NexGen LPS total knee prosthesis. As a consequence, posterior femoral translation results in contact with the posterior portion of the tibial articular surface of the NexGen LPS system. This might result in edge-loading of the posterior tibiofemoral joint and inhibit further posterior femoral translation. In the NexGen LPS-Flex prosthesis, the posterior femoral condyles are elongated by 2 mm to provide a greater contact area between the femoral and tibial components during high degrees of flexion. Therefore, the tibial component is placed more posteriorly on the plateau, which may enhance posterior femoral translation and the range of flexion. Also, the cam-spine mechanism of the NexGen LPS-Flex prosthesis is designed to facilitate posterior femoral translation, thus improving knee flexion[11].

In our study, the average range of postoperative motion was approximately the same in the two groups. A high degree of flexion was achieved with both types of prosthesis, which may have clouded the possible advantage of the NexGen LPS-

TABLE II Range of Motion

Type of Prosthesis	Mean Range of Motion			
	Preoperative	3 Months	1 Year	2 Years
NexGen LPS	126° (range, 55° to 150°)	133° (range, 100° to 150°)	136° (range, 105° to 150°)	136° (range, 105° to 150°)
NexGen LPS-Flex	127° (range, 55° to 150°)	135° (range, 105° to 150°)	139° (range, 115° to 150°)	139° (range, 105° to 150°)
P value	0.8164	0.2327	0.5058	0.41

Flex knee. Several factors may have played an important role in the achievement of this high degree of flexion, including the preponderance of women, the low body mass index of the patients, the use of the subvastus approach, the relatively good preoperative range of motion, and the effective restoration of the joint line[12,13]. Postoperatively, the posterior femoral condylar offset was significantly better ($p = 0.0012$) in the NexGen LPS-Flex group than it was in the NexGen LPS group. This finding, however, did not appear to be clinically relevant because it was not associated with a better range of motion.

Although the NexGen LPS-Flex group did not have a better range of motion than the NexGen LPS group, lateral radiographs of the knees in full flexion demonstrated that the NexGen LPS-Flex prosthesis provided a greater contact area between the femoral and tibial components. Increased contact area can reduce the peak stresses in the polyethylene tibial bearing and reduce wear of the polyethylene. Consequently, the long-term risk of osteolysis may be reduced.

Bellemans et al. showed that, in patients treated with cruciate-retaining total knee arthroplasty, posterior femoral condylar offset correlated with the range of flexion of the knee[2]. They claimed that restoration of posterior femoral condylar offset is important because it allows a greater degree of flexion before impingement occurs. In the current series, posterior femoral condylar offset was well restored compared with the preoperative value in the NexGen LPS-Flex group but not in the NexGen LPS group, in which the postoperative offset was decreased by a mean of 1.2 mm compared with the preoperative value. In the NexGen LPS-Flex group, an additional 2 mm of the posterior femoral condyle was resected, but this additional resection was compensated for by a 2-mm extension of the posterior condyle of the femoral component. Therefore, theoretically, the posterior femoral condylar offset should have been the same in the two groups. The reason why the NexGen LPS group had a 2.0-mm decrease in the offset compared with the NexGen LPS-Flex group is not known. Although we attempted to remove more posterior femoral condylar bone (2 mm) and the posterior femoral condyle was elongated by 2 mm in the NexGen LPS-Flex group, the posterior femoral condyle appeared to be resected more in the NexGen LPS group than in the NexGen LPS-Flex group, possibly because of a technical error. Despite the fact that the posterior femoral condylar offset was well restored in the NexGen LPS-Flex group, the range of flexion was approximately the same as that in the NexGen LPS group. This finding suggests that restoration of the posterior condylar offset in a knee with a posterior stabilized total knee prosthesis may not be as crucial for allowing a greater degree of flexion before impingement as it is in a knee with a posterior cruciate-retaining total knee prosthesis.

The present study demonstrated gratifying results in association with both devices, with no differences between them in terms of clinical and radiographic findings, except for posterior femoral condylar offset. We believe that several factors were responsible for our superior results: better cementing technique and design of the component, small and light patients, and a relatively short duration of follow-up.

The NexGen LPS-Flex prosthesis did not demonstrate its theoretical advantage of providing a better range of motion of the knee. Other factors such as a good preoperative range of motion, flexion-space balancing, posterior tibiofemoral articular contact stability, limb characteristics (long and slender versus short and thick), and the patients' motivation may have affected the clinical results and the range of motion. ■

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