

# Range of Motion In High Flexion Total Knee Arthroplasty vs. Standard Posterior Stabilized Total Knee Arthroplasty A Prospective, Randomized Study

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## Abstract:

Range of motion after knee replacement is an important factor in overall outcome. The purpose was to compare motion in patients receiving high flexion prosthesis vs. standard prosthesis. 24 high flexion and standard knee prostheses were used. Patients were followed for two years and evaluated prospectively. The mean HSS was 80.4 for the standard group and 80.7 for the flexion group. At two year follow up the standard prosthesis group had mean flexion of 113°. The high flexion prosthesis group had mean flexion 106°. No knee had aseptic loosening, infection, or osteolysis. At two year follow up, there were no significant differences between groups with regard to range of motion, clinical outcome, or radiographic evaluation. Keywords: total knee arthroplasty, high flexion, range of motion

## Introduction

Range of motion in total knee arthroplasty is a key determining factor in a patient's overall functional outcome.<sup>1</sup> The fact that most knees do not flex more than 120° after surgery has been studied extensively, but no one theory sufficiently explains this phenomenon.<sup>2,3,4,5</sup> To address deep flexion issues after total knee arthroplasty high flexion designs have been developed in the last decade.

The Nexgen LPS-Flex Total Knee system (Zimmer, Warsaw, Indiana) has three principle design modifications compared to the LPS standard system. First, to address potential point loading of the posterior femoral condyle on the polyethylene liner at flexion angles of up to 155°, the posterior femoral condyles have been extended by 2mm. The radius of the posterior femoral condyles has been extended to provide larger tibio-femoral contact area in high flexion (fig. 1). The outside A/P dimension of the component does not change as a result of these modifications. The second modification is an increase in cam height. This greater jump height is to prevent tibio-femoral disassociation

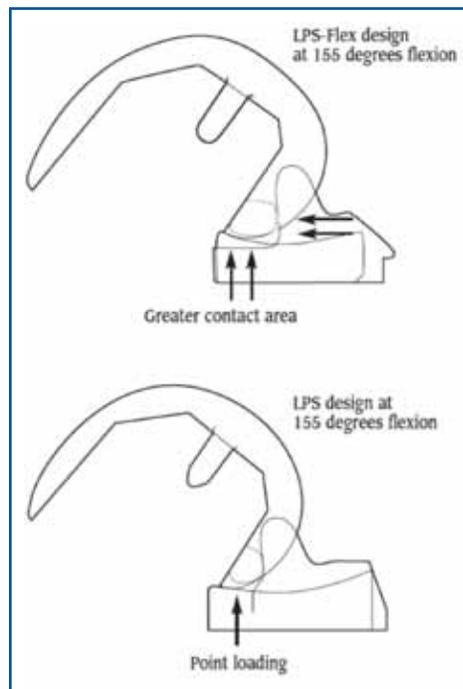


Figure 1: Diagram of a cruciate retaining standard total knee arthroplasty compared to high flexion total knee arthroplasty design at 155° of flexion this figure is reproduced with permission from Zimmer (Warsaw, Indiana)

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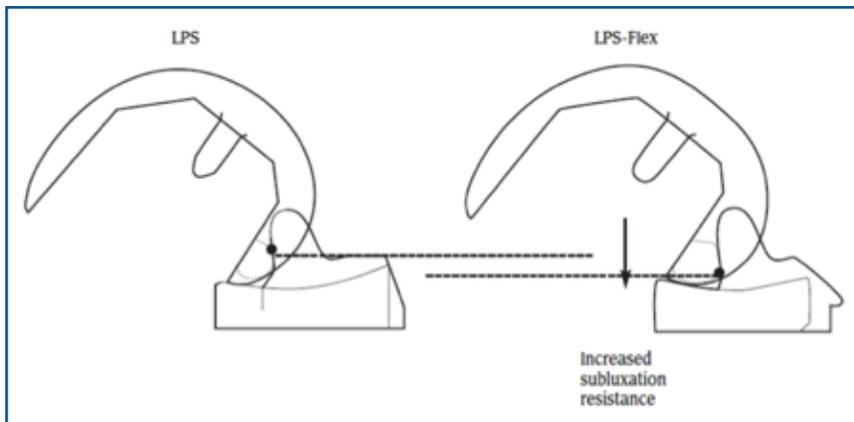


Figure 2: Diagram of difference in cam height and theoretical increased jump distance in standard total knee prosthesis vs. high flexion prosthesis this figure is reproduced from Zimmer (Warsaw, Indiana)

during flexion from 120° to 155° (fig. 2) In some posterior stabilized knees, as the knee goes into deeper flexion, the cam on the femoral component begins to move superiorly on the spine of the tibial articular surface. To address this, the shape of the cam on the LPS-Flex Femoral Component has been modified to contact the spine more inferiorly and thereby provide a greater jump height at flexion angles greater than 130°. The third modification is that the anterior flange of the femoral component has a larger deeper cutout to provide increased conformity for patella-femoral tracking and the anterior lip of the polyethylene has a cut out for the patellar tendon.

Theoretically these design modifications may lead to better postoperative range of motion. Several studies have shown a difference between standard and high flexion prostheses, but other studies have shown no difference. A previous meta-analysis including six studies did show a significant difference in favor of the high flexion design but, only two of those studies were randomized controlled trials.<sup>6</sup> In another systematic review no difference was found between the prostheses but, data synthesis and quantitative analysis were not performed.<sup>7</sup> Consequently, controversy remains over designs with high flexion modifications. Thus, we performed a prospective randomized trial to assess differences in pain, functioning, and range of motion in the Nexgen LPS and Nexgen LPS-Flex total knee systems.

## Materials and Methods

Between 2004 and 2006 the senior Author (S.L.) performed 24 consecutive primary total knee arthroplasties in 23 patients at the Atlanta VAMC. No patient was lost to follow up. One patient was eliminated from the study due to early (< 6 months) aseptic loosening of the tibial component requiring revision. The study was approved by the institutional review board and informed consent was obtained. Randomization of the total knee prosthesis, NexGen LPS standard or

High Flexion, was determined on a sequential pool on the basis of a table of random numbers. The mean age of the patients at the time of operation was 60.5 years (range 45-74) and all were veterans. 23 patients were men and 2 were women. 13 patients had previous knee surgery (9 open meniscectomy, 3 arthroscopic chondroplasty, 1 arthroscopic loose body removal) The preoperative diagnosis for 18 patients was osteoarthritis, 3 had post-traumatic arthritis, and 2 had rheumatoid arthritis. Pre-operative tibio-femoral angle was measured in all patients and there were no valgus knees.

The surgical technique for all procedures was a midline skin incision approximately ten centimeters with a median parapatellar arthrotomy. The cruciate ligaments were sacrificed in all patients. The magnitude and angles of the bony resections were standardized across treatment groups. The distal femoral resection was made with an intramedullary guide to resect 10 mm of bone from the most prominent femoral condyle at an angle of 5° of valgus. The tibial resection was made using an extramedullary guide with the goal of producing a neutral cut in the coronal plane and 7° of posterior slope in the sagittal plane. The anterior, posterior, and Chamfer cuts were made with a posterior femoral condylar referencing guide in 3 degrees of external rotation. In the NexGen High Flexion group, 2 additional mm of posterior femoral condylar bone was resected compared to the NexGen LPS Standard group. Posterior condylar osteophytes were resected in all patients. Ligament balancing was aided with the use of spacer blocks

with the goal of creating symmetric gaps of equal magnitude in flexion and extension. Superficial MCL release was required in 7 patients including four in the high flexion group and three in standard group. The amount of bone removed during patellar resection was equal to or slightly greater than the thickness of the patellar component. All implants were cemented. The capsule was closed in 30 degrees of flexion in all patients.

All patients had patient controlled analgesia immediate post-operatively and CPM machine's applied postoperative day 0 for at least 6 hours per day. Patients were allowed weight bearing as tolerated and worked with physical therapy beginning post operative day 1.

Clinical and radiographic evaluations were taken 6 weeks post-operatively, 6 months, one year, and two years. Each knee was rated pre and post operatively to the systems of the knee society and the Hospital for Special Surgery. Patients also completed the Short Form 36 (SF-36) questionnaire.

Active range of motion was determined preoperatively and post-operatively with a 12 inch

goniometer at 6 weeks, 6 months, 1 year, and two years. Clinicians were blinded with regard to which total knee prosthesis was implanted.

Radiographic evaluations were made pre-operatively and post-operatively by obtaining AP, Lateral, and skyline views. Evaluations were made at 6 weeks, 6 months, 1 year, and 2 years. Assessments were made based on limb alignment and component position. Radiolucencies and bone loss were also noted on AP, Lateral, and sunrise views. Skyline views were also examined for patellar tilt, subluxation, and dislocation.

## Results

### Clinical Outcomes

#### Knee Score

The pre-operative and post-operative knee scores are summarized in Table I. The Hospital for Special Surgery (HSS) and Knee Society scores (KSS) did not differ significantly between the two groups pre-operatively (P= 1.00000 and p= 0.7404, respectively) or post-operatively (p = 0.9177 and

*Table 1: Knee Outcome Scores*

Variable	Group	Preop		6 week		6 month		1 year		2 year	
		mean±sd	p-value								
HSS	STD	55.00	1.0000	63.30	0.9759	71.45	1.0000	75.82	0.4134	80.42	0.9177
		±12.38		±12.85		±11.41		±14.08		±10.48	
	Flex	56.95		64.09		72.4		71.22		80.76	
		±8.69		±9.63		±9.25		±12.14		±9.24	
KSS	STD	47.92	0.7404	58.64	0.5337	69.17	0.5206	71.67	0.2264	78.64	0.2313
		±14.99		±16.90		±18.44		±14.29		±19.12	
	Flex	49.17		52.5		63.75		57.73		69.09	
		±11.45		±24.07		±16.11		±25.24		±18.55	

KSS: knee society score; Hospital Special Surgery; STD: indicated Conventional Prostheses; Flex: indicates high flexion prostheses; sd: indicates standard deviation

*Table 2: Mean Range of Motion*

	group	Pre-operative		6 weeks		6 months		1 year		2 year	
		Mean+/- sd	p-value	Mean+/- sd	p-value	Mean+/- sd	p-value	Mean+/- sd	p-value	Mean+/- sd	p-value
Flexion	STD	113.00±15.67	0.0895	107.45±14.31	0.0814	112.25±13.71	0.3089	115.08±16.98	0.0376	113.00±10.09	0.1853
	Flex	101.83±11.34		92.42±24.77		105.42±9.63		104.73±11.47		106.27±12.17	
Extension	STD	7.58±8.22	0.8735	11.55±7.35	0.3693	6.67±2.96	0.7659	4.17±2.62	0.7711	1.27±3.20	0.6933
	Flex	7.33±7.60		9.42±9.34		4.58±9.09		2.45±8.50		0.64±7.78	

STD: standard prosthesis; Flex: high flexion prosthesis; SD: standard deviation

$p = 0.2313$ , respectively). The mean pre-operative HSS score for the standard knee prosthesis group was 55 (mean sd $\pm$  12.38) and 56.95 (mean sd $\pm$  8.69) in the high-flexion group. In the NexGen LPS group, the mean postoperative knee score was 80.4 (mean  $\pm$  sd 10.48) for the Hospital for Special Surgery Score and 78.6 (mean  $\pm$  sd 19.12) for the Knee Society Score. In the NexGen LPS Flex Group, the mean postoperative knee score was 80.7 (mean  $\pm$  sd 9.24) for the Hospital for Special Surgery Score and 69.1 (mean  $\pm$  sd 18.55) for the Knee Society Score.

*Range of Motion*

The mean pre-operative and post-operative range of motion is summarized in Table 2. Preoperatively, the mean flexion contracture was 8° (mean  $\pm$  sd 8.22°) for the NexGen LPS Group and 8° (mean  $\pm$  sd 7.60°) in the NexGen LPS Flex Group. At two years the mean flexion contracture in the LPS group was 1.2° (mean  $\pm$  sd 3.2°) and 0.6° (mean  $\pm$  sd 7.78°) in the NexGen LPS Flex Group. The flexion preoperatively in the Nexgen LPS Group was 113° (mean  $\pm$  sd 15.67°) and 102° (mean  $\pm$  sd 11.34°) in the Nexgen LPS Flex Group. At two year follow up, the mean post-operative flexion in the standard group was 113° (mean sd $\pm$  10.09) and 106.2° (mean sd $\pm$  12.17°) in the high flexion group. There was no significant difference between the two groups with regard to preoperative flexion contracture ( $p = 0.8735$ ) nor at the two year follow up ( $p = 0.6933$ ). There was also no significant difference with regard to flexion between the two groups preoperatively ( $p = 0.0895$ ) and at the two year follow up ( $p = 0.1853$ ).

*Quality of Life Outcomes*

In the NexGen LPS Group the SF-36 Physical Scores were 30.29 (mean  $\pm$  sd 6.11) preoperatively and were 39.14 (mean  $\pm$  sd 6.66) at the two year follow up. The Nexgen LPS Flex Group had SF-36 Physical Scores of 30.39 (mean  $\pm$  sd 10.89) preoperatively and 43.72 (mean  $\pm$  sd 11.14) at the two year follow up. There was no significant between the SF-36 Physical Scores between the two groups preoperatively ( $p = 0.5508$ ) or at the two year follow up ( $p = 0.3653$ ).

In the NexGen LPS Group the SF-36 Mental Score was 46.70 (mean  $\pm$  sd 10.70) preoperatively and 50.16 (mean  $\pm$  sd 9.87) at the two year follow up. In the NexGen LPs Flex group the SF-36 Mental Score was 49.15 (mean  $\pm$  sd 14.77) preoperatively and 47.19 (mean  $\pm$  sd 14.15) at the two year follow up visit. There was no significant difference between the two groups SF-36 Mental Scores preoperatively ( $p = 0.5041$ ) or at the two year follow up ( $p = 0.7427$ ).

*Radiographic Evaluation*

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 or varus and valgus alignment of the knee. There was also no significant differences between the patella angle (the angle between a line along the patellar cut surface and a line joining the most proximal margins of the femoral condyle of the component on the skyline radiographs), the amount of tibial surface area covered by the implants, or the mean level of the joint line (figs. 3 and 4). In the NexGen LPS Group one patient had patellar bone loss on the skyline view at the two year follow up. One patient in the NexGen LPS Flex Group had tibial bone loss at two year follow up. There were no other findings of radiolucency or bone loss on



Figure 3: Anteroposterior radiograph of fixed bearing posterior stabilized high flexion prosthesis



Figure 4: Lateral radiograph showing posterior stabilized fixed bearing high flexion total knee arthroplasty

AP, lateral, or skyline views at the two year follow up in either group.

### Complication Report

Of the 24 arthroplasties performed, one patient in the NexGen LPS Flex Group developed arthrofibrosis requiring manipulation under anesthesia ten weeks after the index procedure. Afterwards with aggressive PT the patient achieved a functional range of motion. Another patient was excluded from the study secondary to early aseptic loosening of the tibial component requiring revision total knee arthroplasty.

### Discussion

Despite advancements in surgical technique, implant design, and postoperative management, limitation of postoperative range of motion continues to be a relatively common complication.<sup>8</sup> Although early studies reported stiffness in >50% of patients with TKA<sup>9</sup>, the true incidence appears to be 8% to 12%.<sup>8,10,11</sup> Biomechanical studies and gait analysis have shown that patients require 67° of knee flexion during the swing phase of gait, 83° to ascend stairs, 90° to 100° to descend stairs, 93° to rise from a standard chair, and up to 105° to rise from a low chair.<sup>12,13</sup> Active patient populations require range of motion for quality of life.

Variables affecting post-operative outcomes from total knee arthroplasty have been extensively studied and can be categorized as pre-operative, intraoperative, and postoperative factors. Preoperative ROM is an important predictor of ultimate ROM after TKA. Ritter and Stringer<sup>14</sup> found that the amount of achieved postoperative flexion correlated with the amount of preoperative flexion. In their study, 8 patients with mean preoperative flexion < 75° achieved mean flexion of 85.6° at 1 year after surgery, whereas 43 patients with mean preoperative flexion of 76° to 95° had mean postoperative flexion of 95.1°. An interesting trend observed in studies of patients with poor preoperative flexion (<90°) is that they tend to gain flexion postoperatively; patients with a mean preoperative flexion >105° tend to experience a net loss in flexion, despite retaining greater mean ROM overall.

Ritter and Harty<sup>15</sup> investigated predictors of post-operative range of motion in total knee arthroplasty and reported those requiring a release of the deep and superficial medial collateral ligament had decreased post-operative flexion due to the high degree of pre-operative varus deformity. Furthermore, valgus knees that lacked intra-operative extension contributed to decreased post-operative range of motion.

Intraoperative technical factors may lead to postoperative limitations in flexion, extension, or both. Limitations in flexion or flexion contractures can result from improper flexion-extension gap balancing, malpositioning or oversizing of components, inadequate femoral or tibial resection, excessive joint line elevation, creation of an anterior tibial slope, or incomplete resection of posterior condylar osteophytes (figure 5). Ritter et al<sup>15</sup>

reported that removal of posterior osteophytes consistently improved post-operative flexion especially in patients whose pre-operative flexion was >105°. Inadequate distal femoral cut with a pre-operative posterior capsular tightness can lead to a tight extension gap and contribute

to a post-operative flexion contracture. Tightness in both flexion and extension usually occurs because of technical errors on the tibial side. Failure to resect enough tibial bone or inserting a polyethylene component that is too thick can lead to flexion and extension gap tightness. Overstuffing of the patellofemoral joint can also contribute to a tight extensor mechanism and decreased motion after TKA. This occurs with inadequate resection of the patella or anterior placement of the femoral component.

Postoperative factors that can lead to inadequate knee ROM include poor patient motivation and



Figure 5: Lateral radiograph of a cemented fixed bearing cruciate retaining total knee arthroplasty with significant unresected posterior osteophytes impinging on the polyethylene insert preventing flexion

compliance, deep infection, arthrofibrosis, patellar complications, complex regional pain syndrome (CRPS), and heterotopic ossification (HO).

Multiple investigations with outcome measures evaluating the effectiveness of high flexion total knee arthroplasty designs have not shown significant difference to its standard flexion counterparts. Kim et al<sup>16</sup> published a prospective randomized trial on bilateral total knee arthroplasty in which high flexion designs were compared to standard posterior stabilized designs. 250 patients with bilateral total knee arthroplasty one being high flexion and one being standard were compared using questionnaires, knee scoring systems, clinical, and radiographic examinations. The authors found no significant clinical differences between groups showing no advantage to the high flexion design. Seon et al<sup>17</sup>, provided a study of 50 knees randomized to high flexion or standard design. These cruciate retaining high flexion implants had femoral alterations with 2 mm of extended femoral condyle as well as polyethylene modifications. The patients were followed prospectively for two years and had similar range of motion, function, and knee ratings. They suggested that high flexion design alone did not improve clinical outcome after total knee arthroplasty. McCalden et al<sup>18</sup>, compared high flexion total knee arthroplasty design to standard design in a study of 100 patients. 50 patients received a high flexion polyethylene design and the group received standard polyethylene insert. After 2.7 years there was no difference of range of motion between implant designs.

Conversely, Minoda et al<sup>19</sup>, prospectively randomized 171 patients with 181 cruciate retaining total knee arthroplasties. There were high flexion groups as well as standard groups followed prospectively for one year. There were no significant differences between groups with regard to range of motion, knee scores, clinical and radiographic data. However, the high flexion group had a higher average range of motion. Gupta et al<sup>20</sup>, demonstrated a greater range of motion post operatively with use of a high flexion rotating platform. Bin et al<sup>21</sup>, showed significantly greater average knee range of motion at one year in those receiving high flexion prosthesis vs. standard prosthesis. This was particularly true in patients with a preoperative range of motion of less than 90.

The current study attempts to standardize pre-operative and post-operative factors between standard and high flexion groups in order to analyze the effect of an intraoperative factor; specifically whether modifications to the NexGen LPS alone would influence post-operative range of motion and outcome measures. In this study there was no difference between the two groups with regard to range of motion, knee scores, clinical or radiographic data. These findings support other previous literature that high flexion total knee arthroplasty, as an independent variable, does not correlate with improved clinical outcomes including increased postoperative range of motion. Furthermore a potential drawback of the use of high flexion knee designs with additional 2 mm of posterior femoral condylar resection may present a problem in revision cases with respect to bone stock and flexion gap balancing. These findings underscore the importance of addressing all factors that may potentially influence post-operative range of motion as these design modifications alone did not affect post-operative range of motion.

The present study had some limitations. There were no interobserver comparisons which can lead to bias in interpreting radiographs. Also the small sample size may be underpowered to detect a true difference between the high flexion group and the standard arthroplasty group with regard to range of motion, knee scores, clinical and radiographic data. Other problems with small sample size include larger standard deviations in outcome measures and range of motion measurements. Furthermore, this study contains 21 men and two women which is not an accurate representation of gender makeup of the general population. This study was performed at a Veterans Affairs Hospital which accounts for the gender disparity.

From the current study, high-flexion implant designs do not provide a significant improvement over conventional total knee arthroplasty. Further investigation is required in the future to determine if there are differences in implant survival secondary to different contact stresses between designs. Furthermore, continued study of revision of these implants is imperative as it may affect bone stock and gap balancing in revision situations.

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