

Does Greater Knee Flexion Increase Patient Function and Satisfaction After Total Knee Arthroplasty?

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Abstract: The purpose of this study was to determine whether high flexion leads to improved benefits in patient satisfaction, perception, and function after total knee arthroplasty (TKA). Data were collected on 122 primary TKAs. Patients completed a Total Knee Function Questionnaire. Knees were classified as low ($\leq 110^\circ$), mid (111° - 130°), or high flexion ($>130^\circ$). Correlation between knee flexion and satisfaction was not statistically significant. Increased knee flexion had a significant positive association with achievement of expectations, restoration of a "normal" knee, and functional improvement. In conclusion, although the degree of postoperative knee flexion did not affect patient satisfaction, it did influence fulfillment of expectations, functional ability, and knee perception. This suggests that increased knee flexion, particularly more than 130° , may lead to improved outcomes after TKA. **Keywords:** total knee arthroplasty, patient-derived outcomes, patient satisfaction, high flexion, function.
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In the early years of joint arthroplasty, relief of the crippling pain of arthritic disease was the primary goal of these procedures, and in this respect, arthroplasty has been overwhelmingly successful. However, in addition to the resolution of pain symptoms, studies have shown that restoration of knee function is also an important factor in determining the success and outcome after total knee arthroplasty (TKA) [1,2]. In a study comparing arthroplasty patients with age-matched and sex-matched subjects without knee disorders, Noble et al [3] found that control subjects had significantly higher knee function scores in a variety of activities including kneeling, squatting, moving laterally, turning and cutting, carrying loads, stretching, leg strengthening, tennis, dancing, gardening, and sexual activity. In addition, they found that control subjects were approximately one third more likely to kneel and/or squat and were 4 times more likely to be symptom-free while doing so compared to TKA patients. These findings indicate that certain activities that demand higher

degrees of flexion and/or greater biomechanical demands from the knee arthroplasty may result in functional impairment after TKA. In response to this demand for higher function, there has been a push toward "prehabilitation" programs that focus on the development of strength and range of motion (ROM) before surgery and more aggressive postoperative therapy regimens [4]. These advances have been matched by the development of earlier and less invasive surgical interventions and renewed emphasis on designing implants to facilitate higher degrees of flexion, culminating most recently in prostheses labeled as "high flexion" [5-9].

Maximum knee flexion is widely used as an outcome measure after knee arthroplasty and is a major component of many scoring systems [10,11]. However, for the past several years, increasing emphasis has been given to patient-derived outcomes, generally measured in the real and perceived success of medical procedures in achieving pretreatment goals. Previous studies have demonstrated that, to a significant extent, the expectations and perceptions of individual patients may define whether the outcome of knee arthroplasty is successful, whether some degree of residual deficit is disabling, and whether, at some point in the future, symptoms related to knee function will cause the patient to seek additional treatment [12-14]. The growing attention given to patient-reported outcomes after operative procedures has led to increasing interest in the

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quantification and analysis of patient satisfaction after TKA and the extent to which surgical interventions meet patient expectations as well as restoring normal musculoskeletal function.

The normal knee in healthy, nonobese individuals is capable of flexion up to 160°. However, most current reports reveal that on average, patients rarely flex beyond 120° after TKA [11,15-25]. This discrepancy brings about 2 questions. First, what is the minimum degree of flexion necessary for satisfactory function in day-to-day activities? Second, does obtaining higher postoperative flexion beyond the average range lead to significant improvements in patient satisfaction and function? The first question has been addressed by previous studies, which have shown that most activities of daily living, such as sitting and rising from a chair, ascending and descending stairs, and walking normally on both flat and inclined surfaces can be performed normally with a knee that flexes to 110° [26,27].

However, up to 140° of flexion is needed for activities performed in a kneeling or squatting position and for getting up and down from the floor [28]. Thus, about the second question, this suggests that obtaining higher degrees of flexion may lead to improved functional outcomes. Yet, few studies have examined whether postoperative flexion is correlated with patients' perceptions of the success of the procedure. Those studies that have examined possible correlations between flexion, functional outcomes, and quality of life have been mixed. Although some of these accounts have reported subjective improvements in function and quality of life in association with greater knee flexion after TKA [1,2,8,29,30], others have found no relationship [1,8,31]. No studies to date have found a significant correlation between postoperative flexion and overall patient satisfaction after TKA [1]. Thus, the question remains as to whether the increasing cost and effort attributed to obtaining high postoperative flexion translates into greater functional improvement and success from the patient's perspective. The purpose of this study was to determine whether high flexion leads to improved benefits in patient satisfaction, perception, and function after TKA. We hypothesized that there would be a positive correlation with all variables tested.

Methods

After institutional review board approval, data were collected on 122 knees from 111 patients who had undergone primary TKA at least 1 year before participation in the study (mean, 4 years; SD, 2.7 years). Patients were selected from those visiting the senior investigator (BSP) during the 1-year study period. During this period, 297 patients (339 knees) were evaluated about TKA. Patients were excluded from the study if they had not undergone TKA (preoperative), were less than 1 year out from their surgery, or if they had revision surgery. Of the

patients who met criteria, 93 (76%) were women and 29 (24%) were men with a combined average age of 69 years (range, 44-94 years). All procedures were performed by the senior author (BSP) using posterior-stabilized prostheses of a standard design (not high-flexion), primarily P.F.C. Sigma (Depuy Orthopaedics, Warsaw, Ind). The primary etiologies of joint degeneration before arthroplasty were osteoarthritis (80%), rheumatoid arthritis (8%), and prior trauma (3%).

At a minimum of 1 year postoperatively, each patient completed a Total Knee Function Questionnaire (TKFQ), a validated self-administered survey instrument consisting of 55 multiple choice questions relating to symptoms and functional abilities involving the knee [28]. This instrument was developed to assess the frequency with which patients performed a wide spectrum of activities involving the knee and consists of 42 questions that query the personal importance, frequency, and difficulty of performing 3 types of functional activities: (1) baseline activities (17 questions), defined as fundamental activities of daily living, including walking, stair-climbing, sitting, foot care, bathing, and car travel; (2) advanced activities (9 questions), which required greater strength, control, and ROM, including kneeling, squatting, moving laterally, turning and cutting, and carrying loads; and (3) recreational activities and exercises (16 questions), which consisted of 12 activities (stretching, stationary biking, leg strengthening, swimming, golfing, tennis, cross-country skiing, downhill skiing, dancing, gardening, sexual activity, and running). In considering each activity, patients were asked to assess the frequency with which they performed each activity, its personal importance, and the extent to which the function of their replaced knee hindered their participation.

An additional 13 questions evaluated patient satisfaction, activity level, pain, stiffness, and swelling. Each patient was asked to assess their level of overall satisfaction with their knee arthroplasty on a 5-level scale ranging from very satisfied to very dissatisfied. To explore factors associated with satisfaction, a univariate logistic model was developed in which satisfaction was expressed dichotomously by coding patient responses of "satisfied" and "very satisfied" equal to 2, "neutral" equal to 1, and "dissatisfied" and "very dissatisfied" equal to 0. Patients were also asked the following questions:

- (1) Does your TKA keep you from doing anything you would like to do? (Y/N)
- (2) Are you more or less active now than you were before your surgery? (more/less/same)
- (3) Are you as active now as you expected you would be? (Y/N)

Each patient was also asked to report symptoms experienced in their operated knee by answering the questions:

Table 1. Intergroup Patient Demographics and Variables

	High Flexion (20)	Midflexion (81)	Low Flexion (21)	<i>P</i>
Age	70.5 ± 12.0 y	69.8 ± 10.8 y	72.6 ± 9.3 y	.60×
Sex	61% female 39% male	76% female 24% male	90% female 10% male	.10×
Body mass index (kg/m ²)	26.8 ± 4.0	30.7 ± 6.1	35.2 ± 6.6	.004
Primary diagnosis	16 osteoarthritis 4 other	65 osteoarthritis 8 rheumatoid arthritis 3 trauma 5 other	16 osteoarthritis 2 rheumatoid arthritis 1 trauma 2 other	.60×
Pain*	27%	20%	20%	.37×
Swelling [†]	13%	25%	33%	.10×
Stiffness [‡]	14%	22%	57%	.02
Preoperative flexion	125.8 ± 9.2°	110.8 ± 18.0°	100.4 ± 18.8°	<.001
Postoperative flexion	134.8 ± 2.9°	121.0 ± 5.5°	102.1 ± 8.1°	<.0001
Δ Flexion	8.8 ± 11.1°	10.4 ± 17.0°	3.9 ± 20.1°	.37×

* Percentage of patients requiring daily pain medication.

† Percentage of patients with weekly knee swelling.

‡ Percentage of patients with knee stiffness at least 75% of the time.

- (1) Do you ever experience swelling or tightness in your knee? (never to more than once per week, 5 levels)
- (2) What percentage of time is your knee stiff? (never to always [75%-100%], 5 levels)
- (3) How often do you take medication because of pain in your replaced knee? (never to more than once per day, 5 levels)
- (4) Does your operated knee feel "normal"? (Y/N)

Finally, a total composite score for patient satisfaction and fulfillment of expectations concerning knee function was created from all relevant responses. Satisfaction was again coded as 2, 1, and 0, and assigned a weighting factor of 1.5. Each additional variable was also expressed dichotomously with patient answers to "are you as active now as you expected you would be" coded as 1 for "yes" and 0 for "no"; answers to "does your TKA keep you from doing anything you would like to do" coded as 1 for "no" and 0 for "yes"; answers to "are you more or less active now than you were before your surgery" coded as 2 for "more," 1 for "same," and 0 for "less"; and answers to "does your operated knee feel 'normal'" coded as 1 for "yes" and 0 for "no." The subscores were then summed to generate a composite score ranging from 0 (worst) to 8 (best).

Both preoperatively, and at a minimum of 1-year follow-up, the senior investigator measured and recorded the maximum passive flexion of each knee with the patient lying supine on an examination table (nonweight bearing) (Table 1). All knee measurements were performed with a full-sized goniometer for increased accuracy. Knee Society scores were also completed [11]. To facilitate subsequent analysis, all 122 knees were classified into 3 groups according to the recorded value of maximum knee flexion: low flexion ($\leq 110^\circ$; $n = 21$), midflexion (111° - 130° ; $n = 81$), or high flexion ($>130^\circ$; $n = 20$). The low-flexion grouping was

based on previous research indicating that 110° of knee flexion is required to complete most activities of daily living [26,27]. High flexion was defined as more than 130° that is approximately 2 standard deviations higher than the average of the entire population sampled. In addition, this grouping ensured that the average postoperative flexion (120°) was also the median value of the distribution.

The χ^2 test and an analysis of variance test were used to examine the statistical relationship between the independent variables describing the 3 flexion groups, including patient demographics (sex, age, body mass index, and diagnosis), pain (percentage of patients requiring analgesic medication weekly), and frequency of knee symptoms at follow-up including swelling (percentage of patients with weekly swelling) and stiffness (percentage of patients with swelling at least 75% of the time) (Table 1). χ^2 and analysis of variance tests were also used to analyze the relationships between the 3 flexion groups and the Knee Society score, patient satisfaction, the extent to which TKA fulfilled the patient's preoperative expectations, the patient's level of postoperative activity, the presence of functional limitations, the patient's perception of the involved knee, and the total composite score. Significant differences were defined as having a *P* value less than .05. If a statistically significant relationship was found to exist between the flexion groups and a nominal dependent variable, post hoc tests were then conducted among each group pairing to determine where the significant effect actually existed. Statistical analysis was performed using SAS System 5.0.1 (SAS, Cary, NC).

Results

Only patients who had undergone primary TKA with a minimum of 1-year follow-up were included in the study. Maximum passive knee flexion averaged 111° preoperatively (range, 29° - 145°) and improved to an

Table 2. Results Summary

	High Flexion	Midflexion	Low Flexion	<i>P</i>
Knee Society score	93.1 ± 6.5	91.4 ± 12.4	87.7 ± 12.0	.54×
Positive satisfaction	93%	73%	74%	.24×
Expectations achieved	94%	68%	53%	.03
No functional limitations	93%	51%	52%	.009
Knee feels normal	87%	70%	43%	.01
More active	81%	55%	29%	.016

average of 120° postoperatively (range, 85°-143°), with a positive correlation found between preoperative and postoperative flexion ($r = 0.43$; $P < .0001$). Of the 122 knees assessed, 21 (17%) were classified as low flexion ($\leq 110^\circ$), 81 (66%) as midflexion (111° - 130°), and 20 (16%) as high flexion ($> 130^\circ$). There were no significant differences between the 3 flexion groups about age, sex, preoperative diagnosis, pain, swelling, or the degree of change from preoperative to postoperative flexion (Table 1). Thus, ruling out these potential confounding variables as possible explanations for some the observed results. A summary of the results is shown in Table 2.

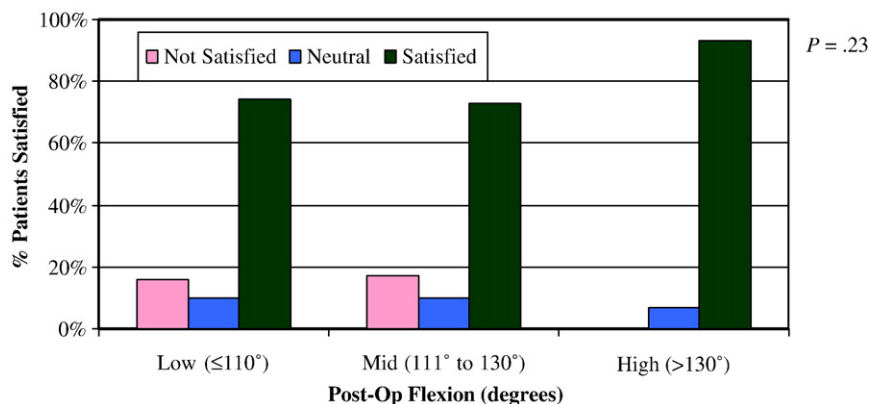
There was no correlation between maximum knee flexion and the Knee Society score (high flexion, 93.2; midflexion, 91.9; low flexion, 90.8; $P = .84$). Overall, 76% of the patients surveyed reported that they were either “satisfied” or “very satisfied” with their TKA, whereas 14% were dissatisfied. Within the high-flexion group, 93% of patients reported feeling satisfied, whereas the midflexion and low-flexion groups obtained satisfaction rates of 73% and 74%, respectively ($P = .24$) (Fig. 1). Thus, although the greatest satisfaction rates were observed in patients with flexion higher than 130°, the overall correlation between knee flexion and satisfaction was not statistically significant. However, there were no patients in the high-flexion group who were dissatisfied, whereas 17% of the midflexion and 16% of the low-flexion patients were dissatisfied ($P = .23$) (Fig. 1).

Statistically significant correlations were found between patient's degree of flexion and the remaining 4 variables tested. When surveyed, 94% of patients within the high-flexion group reported having achieved their expectations, 68% of midflexion patients indicated the same, and only 53% of patients in the low-flexion group reported that their expectations had in fact been met ($P = .03$). When group-to-group comparisons were made, about patients in the high-flexion group were significantly more likely to have met their preoperative expectations compared to patients in the midflexion ($P = .039$) and low-flexion ($P = .007$) groups, but there was no significant difference between the midflexion and low-flexion groups themselves ($P = .19$) (Fig. 2).

Increased knee flexion was also significantly associated with restoration of a knee that “felt normal,” as 87% of high-flexion, 70% of midflexion, and 43% of low-flexion patients reported perceiving their knee as normal ($P = .01$). Intergroup comparisons revealed that both high-flexion ($P = .008$) and midflexion ($P = .02$) patients experienced more normal perception compared to the low-flexion patients, whereas there was no significant difference between the top 2 groups ($P = .19$) (Fig. 3).

When asked whether they had any remaining functional limitations associated with their affected knee, 93% of high-flexion patient's reported that they were without limitations, whereas only 51% and 52% of midflexion and low-flexion patients, respectively, reported experiencing no limitations with the involved knee ($P = .009$). The high knee flexion group exhibited a significant reduction in functional restrictions compared to both midflexion ($P = .002$) and low-flexion ($P = .009$) groups, whereas there was no significant difference between the midflexion and low-flexion groups ($P = .89$) (Fig. 4).

Finally, about postoperative activity level, the results showed that again, the degree of postoperative flexion showed a significant positive association with patient activity level ($P = .016$). Within the high-flexion group,

**Fig. 1.** Patient satisfaction among the 3 postoperative flexion groups.

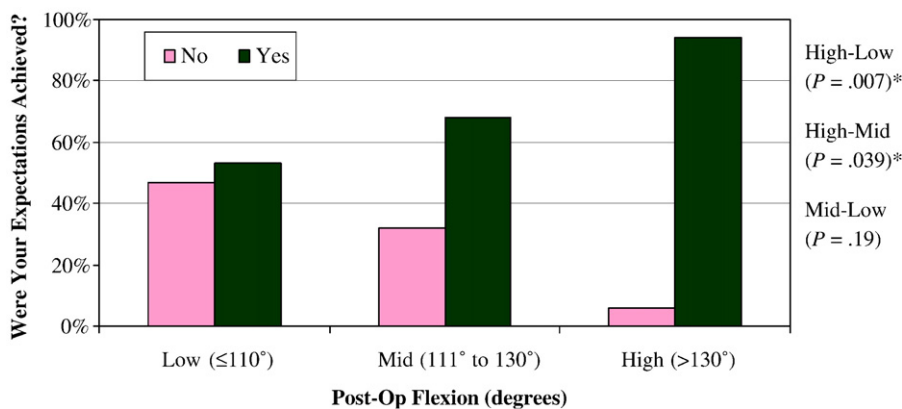


Fig. 2. Percentage of patients achieving preoperative expectations within the 3 postoperative flexion groups.

81% of patients were currently more active than they were before TKA and none reported that they were less active. More than half of the patients in the midflexion group (55%) stated that they were more active, whereas 26% reported that they were currently less active than before the surgery. Only 29% of patients in the low-flexion group were more active than before TKA, whereas more than one third (39%) were currently less active. When group-to-group comparisons were made about whether patients were more active than before, the data revealed that patients in both the high-flexion (0.002) and midflexion (0.03) groups showed significant improvement compared to the low-flexion group, whereas the difference between the high and mid groups was just outside significance ($P = .06$) (Fig. 5).

The average total composite score for satisfaction and fulfillment of functional expectations was 5.79, ranging from 0 (worst) to 8 (best). The composite score was also found to be significantly correlated with postoperative flexion, as patients with higher flexion had better total scores ($r = 0.27$; $P = .009$) (Fig. 6).

Discussion

The purpose of this study was to determine whether high flexion leads to improved benefits in patient satisfaction, perception, and function after TKA. Similar

to previous studies [8,31], we found that the conventional Knee Society scoring system failed to detect any change in patient's functional outcome with the achievement of high knee flexion. However, using the TKFQ, a higher sensitivity testing tool, demonstrated that high knee flexion was significantly associated with achievement of preoperative expectations and elimination of functional limitations. In addition, patients with higher degrees of flexion were significantly more likely to report more normal perception of their involved knee and that they were now more active than they were before surgery. For these outcome measures, the greatest positive results were found in patients who achieved greater than 130° of knee flexion during passive ROM on follow-up examination. Although the degree of postoperative knee flexion did not affect the overall level of patient satisfaction, none of the patients in the high-flexion group ($>130^\circ$) were dissatisfied with the outcome of their TKA, and they also expressed the highest rate of satisfaction. About whether a minimum threshold is present for satisfactory function from the patient's perspective, the results show that the low-flexion group did not exhibit significant improvement compared to the midflexion or high-flexion groups on any of the outcome measures. Furthermore, only the midflexion and high-flexion groups had greater than a 50% success

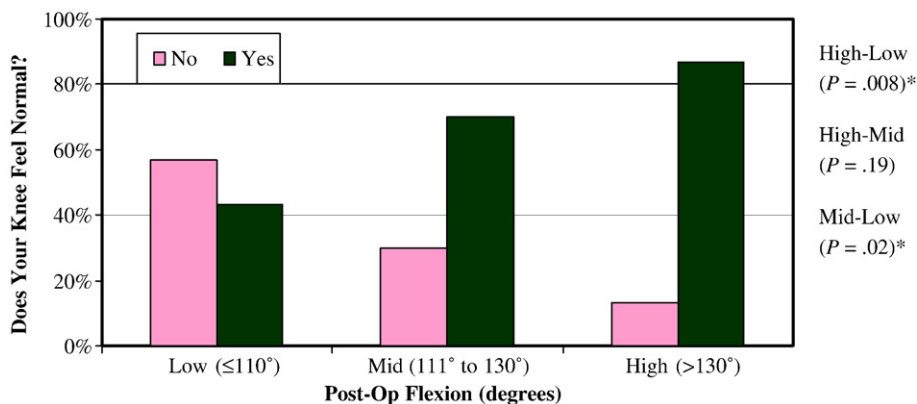


Fig. 3. Percentage of patients with normal knee perception within the 3 postoperative flexion groups.

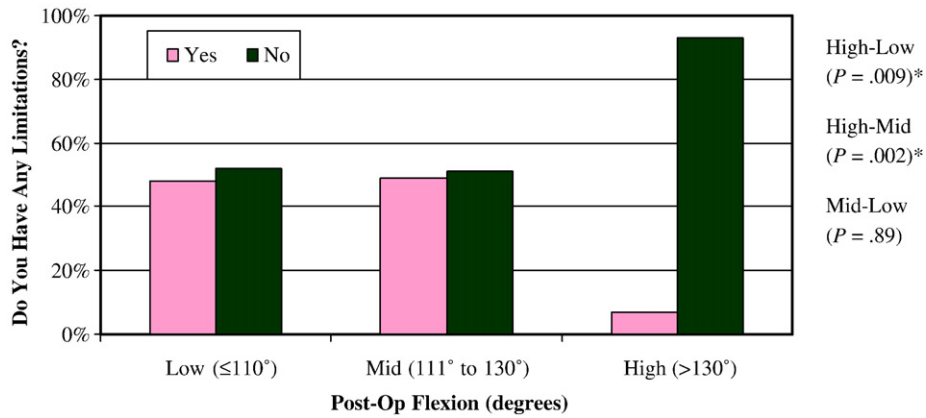


Fig. 4. Percentage of patients without limitations within the 3 postoperative flexion groups.

rate on all subjective variables tested. Thus, it appears that at minimum, more than 110° of knee flexion is required to achieve positive results most of the time.

Previous studies designed to assess the relationship between knee flexion after TKA and functional outcomes, quality of life, and patient satisfaction have provided mixed results. For example, several studies have found that functional outcomes such as the Hospital for Special Surgery scores, stair-climbing scores, walking ability scores, and Western Ontario and McMaster Universities Osteoarthritis index (WOMAC) function scores were all significantly improved by obtaining higher postoperative function [1,2,8]. However, other studies such as that of Meneghini et al [31] found that there was no significant difference in knee function scores of patients who had achieved high flexion at more than 2 years postoperatively. About quality of life, both Pauda et al [29] and Rowe et al [30] found that ROM was positively correlated with improved physical quality of life as measured by the Short Form-36 (SF-36). In contrast, additional studies have found no significant difference in the SF-36 scores between high-flexion and low-flexion groups, suggesting that maximum flexion beyond a certain range may not make a significant difference in a patient's subjective rating of outcome

[1,8]. To the best of our knowledge, only one other study to date has evaluated the relationship between postoperative flexion after TKA and direct patient reported satisfaction. In this study, Miner et al [1] found that there was no significant difference in satisfaction in patients who obtained greater than 95° of flexion after TKA compared to those exhibiting less than 95° flexion at 12-month follow-up. Similarly, we found that although patients in the high-flexion group expressed the highest rate of satisfaction, the overall correlation between knee flexion and satisfaction was not statistically significant.

One reason for the discrepancy among previous studies, including our own, about the relationship between flexion and patient reported outcomes is that there has not been a consistent delineation between what constitutes high, medium, or low flexion postoperatively. The high-flexion groups for some studies would be in the low-flexion group of others and vice versa. This makes it difficult to compare outcomes across studies. In addition, differences in the results of our present report and previous studies may be attributable to differences in the method used to assess subjective patient outcomes. Whereas previous authors have often used joint-specific scoring systems such as the Knee Society score [11,32], other studies have been based on

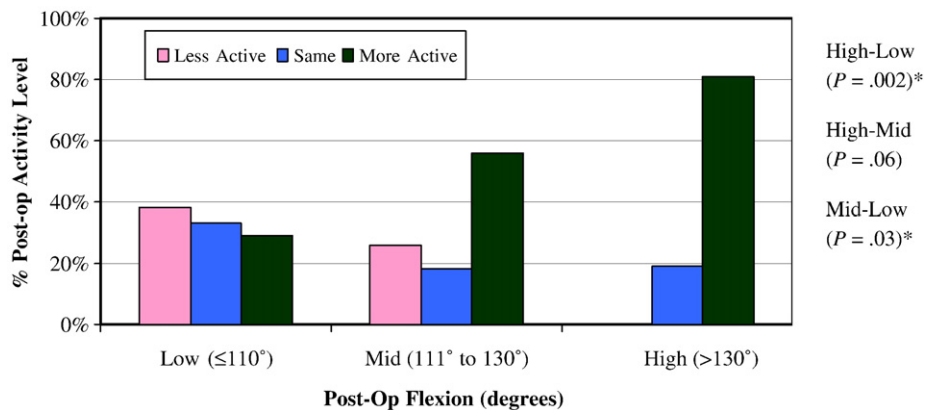


Fig. 5. Patient activity level after TKA among the 3 postoperative flexion groups.

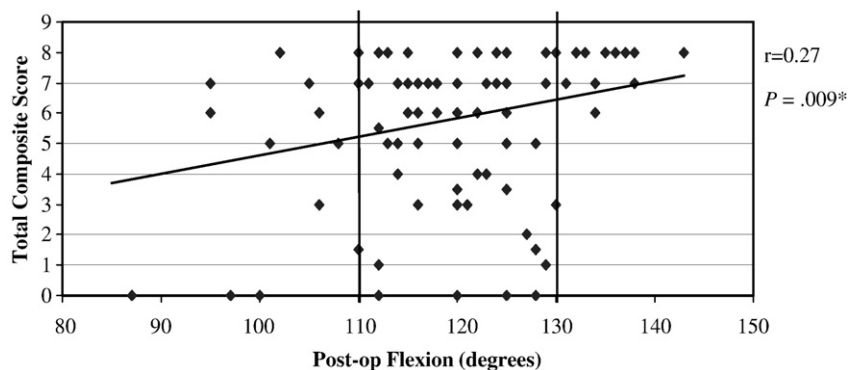


Fig. 6. Correlation between total composite score and degree of postoperative knee flexion.

disease-specific measures such as the WOMAC and general health status measures such as the SF-36, and so, report a more global picture of outcome [33,34]. Conversely, we used a TKFQ that is self-administered and specifically queries activities that each patient considers important. The TKFQ does not attempt to evaluate a patient's overall quality of life but rather the dimensions of the knee function that affect lifestyle, weighted by the importance of each dimension to the patient. This approach has a number of distinct benefits as it reduces the impact of comorbidities and generalized inquiries concerning function having little to do directly with the knee, which are common deficiencies of the SF-36. The WOMAC index is limited by that it only assesses patient reported function without addressing the effect that this has on the patient's overall satisfaction, perception, and achieved expectations. However, the TKFQ evaluates all of these variables along with patient function related directly to the involved knee. Thus, the TKFQ may be better suited to assess the relationship between objective outcomes and patient-centered outcomes including function, perception, and satisfaction.

It is unclear why there was not a statistically significant difference in patient satisfaction between patients in low-flexion and high-flexion groups, despite that knee flexion has been positively associated with patient function, perception, and quality of life in our study and others as well. It may be that pain relief alone is enough for some patients to feel satisfied. Another probable explanation is that the factors contributing to satisfaction vary from patient to patient so that one individual factor, such as postoperative flexion, is unlikely to completely explain variances in satisfaction among a large group of patients. Future studies are needed to assess what particular variables directly influence patient satisfaction. In addition, there is a distinction between having high flexion available, and actually using it, as many high-flexion activities place large biomechanical demands on the knee in muscle force. These demands may be beyond the limits of many patients undergoing TKA such as those whom are overweight, deconditioned, or elderly. Similarly,

use of flexion will depend upon the individual's lifestyle as well as their degree of thigh-calf contact, which will restrict flexion depending on the patient's body habitus. Thus, even if patients are awarded high degrees of flexion postoperatively, they may not be able to appreciate all of the presumed benefits due to these confounding variables.

About external validity, we believe our results can be applied to a wide variety of heterogeneous patient populations. Our patient population was represented by both male and female participants, over a wide age group (44-94 years), with evenly dispersed body mass indexes (20-25, 22%; >25-30, 25%; >30-35, 31%; >35-40, 8%; >40%, 13.7%), who were seen for follow-up for a 1-year period. Furthermore, questionnaires were filled out during the follow-up visit, thus, reducing selection bias related to patient subgroups that choose not to return questionnaires. Specific patient populations for which our results may not be entirely applicable would include those with most of patients with a primary etiology other than osteoarthritis, those using a component other than a posterior-stabilized prostheses of a standard design (not high flexion), and patients undergoing revision arthroplasty.

The present study exhibits certain limitations. It is retrospective by design and thus displays the associated limitations. In addition, several outcome measures were obtained by a self-administered instrument, which by its nature is inherently subjective, and so has limited ability to accurately assess knee function. Nonetheless, these instruments are the simplest, least invasive, and most cost-effective way to obtain normative data [3]. Finally, the number of knees tested in the study was limited to 122 and the low-flexion and high-flexion groups only contained 21 and 20 knees, respectively. A larger sample would yield greater statistical power and would allow us to make more definitive conclusions regarding the satisfaction of specific subgroups rather than overall trends.

In conclusion, this current study found that the conventional Knee Society scoring system failed to detect any change in patient's functional outcome with

the achievement of high knee flexion. However, using a higher sensitivity testing tool demonstrated that fulfillment of patients' expectations, their functional ability, and perception of their knee are in fact improved when higher flexion is achieved. In addition, there was a trend toward greater satisfaction with high knee flexion, although not significant. These results suggest that increased knee flexion, particularly to greater than 130° may lead to improved outcomes after TKA, and at minimum, greater than 110° of flexion is needed to achieve satisfactory function for most patients. Future work is needed to assess whether greater postoperative flexion is best obtained through high-flexion implants, modification of rehabilitation programs, timing of surgery, or a combination of these and other variables.

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