The impact of posterior tibial slope on knee flexion in PCI sacrificing total knee arthroplasty

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Introduction

Range of motion (ROM) is one of the critical factors in determination of the total knee arthroplasty effectiveness. Increased motion is associated with improved function and increased patient satisfaction. Posterior tibial slope has been theorized as advantageous to ROM. The purpose of this study is to evaluate and quantify the effect of the tibial slope on the postoperative maximal knee flexion.

Patients and methods

A total of 60 patients who had undergone total knee arthroplasty with the posterior stabilized prostheses were divided into two groups; each group included 30 patients. The only difference between groups was the use of a 0° (group A) or 7° (group B) posterior sloped tibial cutting block. Preoperative ROM and Hospital for Special Surgery knee scores were prospectively obtained from each patient. Similar data were obtained for all patients at 3 months after surgery and at each patient's follow-up examination. Preoperative and postoperative radiographs of each surgical knee were obtained and measured to determine the tibial slope angle.

Results

Use of the 0° cutting block in group 1 resulted in a mean postoperative proximal tibial slope of 1.3°±2.96° (range: −3° to 7°), whereas using the 7° cutting block in group 2 resulted in a mean postoperative proximal tibial slope of 7.27°±2.66° (range: 1°–11°). The difference between the groups was statistically significant (P=0.001). The mean values of the postoperative maximal flexion angles were 115.2°±12.59° (range: 91°–130°) and 122.5°±11.96° (range: 94°–136°) in groups 1 and 2, respectively. There was a significant difference in the maximal flexion between the two groups (P=0.0125).

Conclusion

An increase in the posterior tibial slope can significantly increase the postoperative maximal knee flexion.

Keywords:
posterior tibial slope, range of motion, total knee arthroplasty

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Introduction

Range of motion (ROM) is one of the critical factors in determination of the total knee arthroplasty (TKA) effectiveness. Increased motion is associated with improved function and increased patient satisfaction.

Several studies have demonstrated that patients require an average of 67° of flexion for the swing phase of gait, 83° to climb stairs, 90° to descend stairs, and 93° to rise from a seated position. In many Eastern countries, flexion greater than 105° is necessary for kneeling and squatting during activities of daily living and for religious acts [1–3].

Several factors may affect the final postoperative ROM, including the condition of the soft tissues (e.g. flexion contracture and severe tibiofemoral varus or valgus), preoperative ROM, the surgical approach chosen, surgical technique, prosthetic geometry and size, preservation or substitution of the posterior cruciate ligament, the height of the joint line, prosthetic positioning, and the anterior posterior tibial cut angle (tibial slope) [3–6].

The tibial slope is a very important factor, which is generally believed that an increased posterior tibial slope can greatly improve the postoperative maximal flexion of the knee. However, this assumption is not clearly substantiated in the literature reviews. This hypothesis is supported by some computer modeling and the cadaver simulation studies; however, some published clinical studies do not support the positive correlation between the tibial slope and the maximal knee flexion [7,8].

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Recently, Catani *et al.* [9] and Malviya *et al.* [10] have reported that an increased posterior tibial slope in-vivo can improve the maximal flexion of the knee in the PCL-retaining TKA.

Most instrumentation systems used to perform a TKA allow the surgeon to adjust the angle of the proximal tibial cut in the sagittal plane. These instruments include fixed angle cutting blocks that are available in a variety of angles and cutting jigs that can be adjusted to a desired posterior inclination. Theoretically, variation in the proximal tibial slope could be expected based on the style or type of cutting jig, jig stability, saw blade deflection, and deviation in the surgeon's hands [8].

This prospective study was performed to investigate the effect of the tibial slope in the postoperative maximal flexion in posterior stabilized TKA.

Patients and methods

This study was conducted between June 2011 and December 2013 in El-Hadara University Hospital, Alexandria, Egypt. All patients aged between 55 and 75 years with primary osteoarthritis of the knee joint requiring posterior stabilized TKR were considered eligible to participate in the study. Written informed consent was obtained from all patients, and the study was approved by the local ethical committee.

Inclusion criteria were patients with primary osteoarthritis, aged 55–75 years, varus or valgus deformity less than 10°, fixed-flexion deformity of less than 10°, preoperative ROM more than 100°, and a BMI of less than 30 kg/m^2.

Exclusion criteria were rheumatoid arthritis, previous surgery on the same joint, and arthritis of the ipsilateral or contralateral hip to avoid its effect on the final functional outcomes.

A total of 60 patients were divided into two groups; each group included 30 patients. The only difference between groups was the use of a 0° (group 1) or 7° (group 2) posterior sloped tibial cutting block. Closed envelopes were used to allocate patients to either group. NexGen LPS-Fixed Bearing Knees (Zimmer, Warsaw, Indiana, USA) cemented posterior cruciate substituting prostheses were used in all patients.

There were 23 men and 37 women, with 32 right and 28 left knees. The groups were matched for sex, age, operated side, and BMI (Table 1). The last patient was operated upon in September 2013, and a final follow-up evaluation was performed in April 2015. The mean follow-up in both groups was 21±7.4 months (range: 15–36 months).

Table 1 Demographic data of the two studied groups

	Group I	Group II	*P*
Age			
Range	55–75	55–75	0.119
Mean±SD	65.03±6.16	66.87±5.37	
Sex			
Male	10	13	0.217
Female	20	17	
BMI			
Range	26.8–29.7	26.9–29.6	0.113
Mean±SD	28.28±0.87	28.55±0.85	

The demographic and clinical details of the patients in both groups are shown in Table 1.

Preoperative ROM and Hospital for Special Surgery (HSS) knee scores were prospectively obtained from each patient by one experienced arthroplasty surgeon who did not know the group division. Similar data were obtained for all patients at 3 months after surgery and at each patient's follow-up examination visit.

All the operations were performed by the same surgeon. The standard operative techniques were used, including the anterior midline skin incision with a medial parapatellar approach; removal of hyperplastic soft tissue, menisci, and the osteophyte; and resection of the anterior and the posterior cruciate ligaments. The distal femur bone was firstly cut nearly 9 mm according to the intramedullary alignment system, with 5° valgus and 3° external rotation relative to the posterior condylar axis. Then, the tibia bone was cut perpendicularly to the long axis of the tibia with a 0° (group 1) or 7° (group 2) posterior slope cutting jig through the extramedullary alignment system; the flexion and extension gaps were measured with a distractor; if necessary, the medial or the lateral structure was released so as to obtain a balanced knee movement during the flexion and the extension. The patellofemoral tracking was evaluated with the no-thumb technique; no poor patellar tracking should exist before closure. All the femoral and tibial components were fixed using the bone cement. Perioperative antibiotic prophylaxis, thrombosis prophylaxis, and all the details of the postoperative therapeutic routine were identical in all the knee operations.

Preoperative and postoperative radiographs of each surgical knee were obtained and measured to determine the tibial slope angle. Radiographic techniques that introduced obliquity in any plane or did not contain enough of the tibial shaft to confidently determine the long axis of the tibia were excluded.

Lateral radiographs of the knee were used to determine the long axis of the tibia. A line drawn perpendicular to the long axis of the tibia was defined as the reference line and represented 0° of slope. A line was then drawn parallel to the articular surface of the proximal tibia. The angle between the reference line and the articular surface line was designated the tibial slope angle (Fig. 1). If the slope proceeded from anterior-superior to posterior-inferior, it was designated a posterior slope and was assigned a positive value. If the posterior tibia had a higher elevation than the anterior tibia, then the slope was called an anterior slope and was given a negative value.

Statistical analysis

The data were collected and entered into the personal computer. Statistical analysis was done using statistical package for the social sciences (SPSS, version 20) software (IBM's Chief Privacy Office 1 New Orchard Road, Armonk, NY, USA).

The statistical tests used were as follows: athematic mean, SD, and *t*-test, which was used to compare between the mean values of measurement before and after treatment. The level of significance was 0.05.

Figure 1

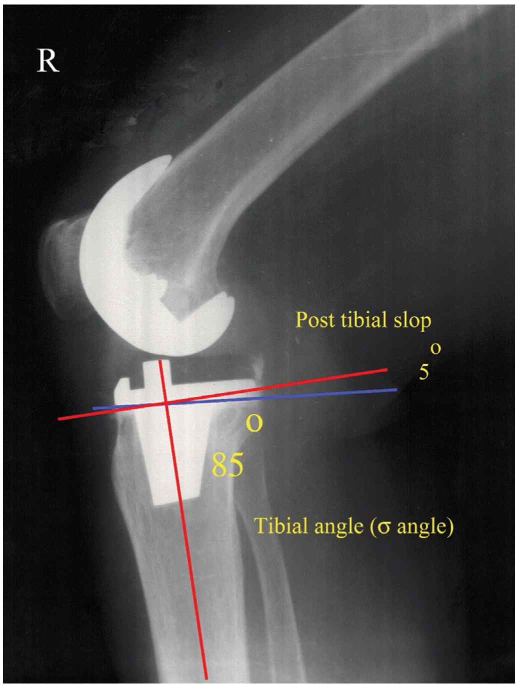


Illustration for measurement of posterior tibial slope.

Results

The demographic and the preoperative clinical data were investigated (Tables 1 and 2). No statistically significant difference was found between the two groups in the patient age, sex, BMI, preoperative flexion deformity, preoperative ROM, or HSS scores.

The mean of the preoperative proximal tibial slopes was 6.2°±2.76° in group 1 (range: 2°–14°) and 7.33°±3.01° in group 2 (range: 1°–11°). There was no statistically significant difference between the groups (P=0.429) before surgery. The mean preoperative knee extension was −2.57°±2.43° in group 1 (range: −9° to −10°) and −2.83°±2.55° in group 2 (range: −8° to −0°); the difference between groups was insignificant (P=0.339).

Mean preoperative flexion was 100.57°±15.55° in group 1 (range: 78°–124°) and 102.9° in group 2 (range: 82°–122°); the difference was insignificant (P=0.269).

The preoperative HSS score averaged 59.67±13.86 for group 1 (range: 22–73). Although the HSS score in group 2 was higher, averaging 60.33 (range: 30–78),

Table 2 Clinical data of the two studied groups

	Group I	Group II	*P*
Preoperative proximal tibial slope			
Range	2–14	1–11	0.429
Mean±SD	6.20±2.76	6.33±3.01	
Preoperative extension			
Range	−9 to 0	−8 to 0	0.339
Mean±SD	−2.57±2.43	−2.83±2.55	
Preoperative flexion			
Range	78–124	82–122	0.269
Mean±SD	100.57±15.55	102.90±13.62	
Preoperative HSS score			
Range	22–73	30–78	0.429
Mean±SD	59.67±13.86	60.33±15.09	
Postoperative proximal tibial slope			
Range	−3 to 7	1–11	0.001
Mean±SD	1.30±2.96	7.27±2.66	
Postoperative extension			
Range	−2 to 3	−5 to 0	0.079
Mean±SD	0.10±1.81	−0.62±1.18	
Postoperative flexion			
Range	91–130	94–136	0.0125
Mean±SD	115.20±12.59	122.50±11.96	
Postoperative HSS score			
Range	64–98	66–99	0.1817
Mean±SD	88.57±10.75	90.87±8.58	

HSS, Hospital for Special Surgery.

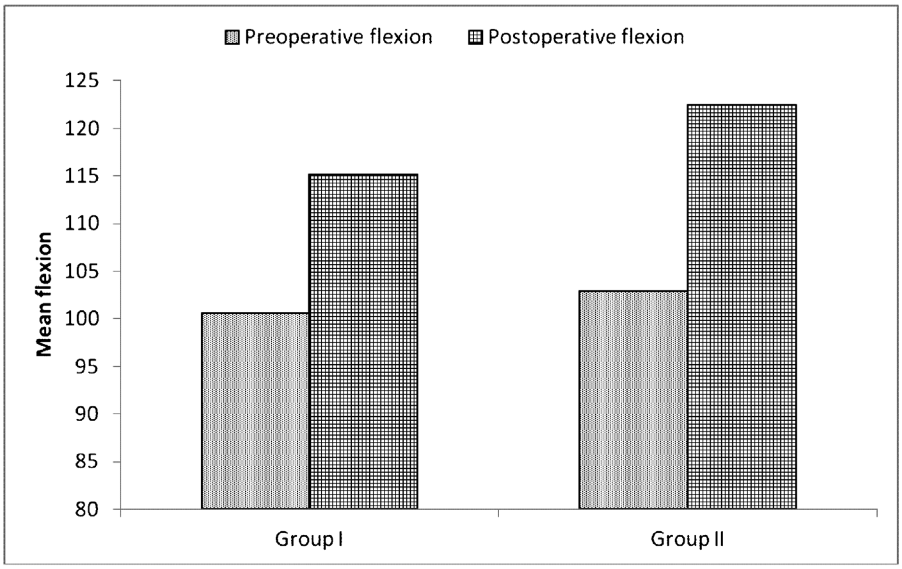
the difference between the groups was not statistically significant (P=0.429).

Use of the 0° cutting block in group 1 resulted in a mean postoperative proximal tibial slope of 1.3°±2.96° (range: −3° to 7°), whereas using the 7° cutting block in group 2 resulted in a mean postoperative proximal tibial slope of 7.27°±2.66° (range: 1°–11°). The difference between the groups was statistically significant (P=0.001).

The mean values of the postoperative maximal flexion angles were 115.2°±12.59° (range: 91°–130°) and 122.5°±11.96° (range: 94°–136°) in groups 1 and 2, respectively. There was a significant difference in the maximal flexion between the two groups (P=0.0125).

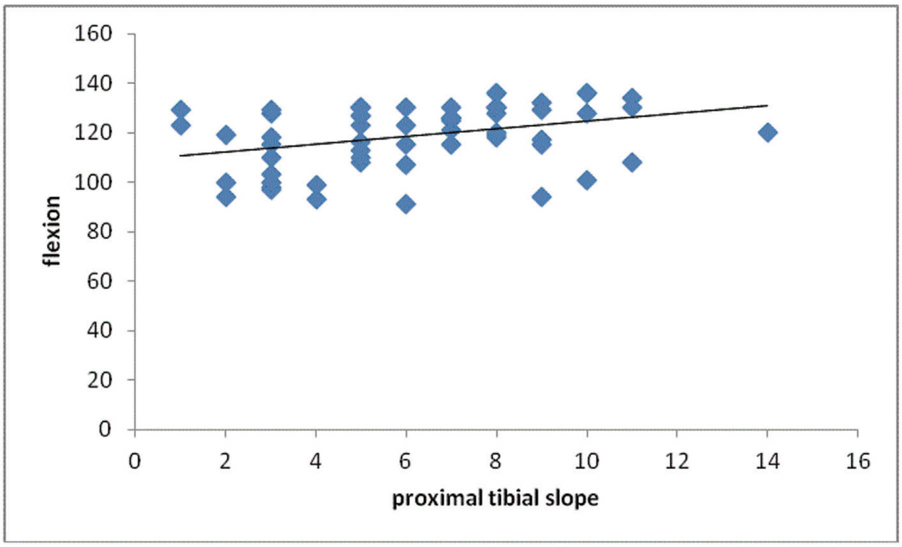
The mean plot showed that the postoperative maximal flexion was increased as a result of an increase in the posterior tibial slope (Fig. 2). The scatter plot and the Pearson's correlation analysis showed that there was a positive correlation between the posterior tibial slope and the postoperative maximal flexion (r=0.62). The liner regression showed that the regression coefficient was 1.72 (R^2=0.384, P=0.008) (Fig. 3).

Figure 2



Postoperative maximal flexion by tibial slope.

Figure 3



The scatter plot and the Pearson's correlation analysis showed that there was a positive correlation between the posterior tibial slope and the postoperative maximal flexion (r=0.62). The liner regression showed that the regression coefficient was 1.72 (R^2=0.384, P=0.008).

No significant difference was found in the postoperative extension or the postoperative HSS score between the two groups. Table 2 summarizes the results and comparisons between the groups.

Discussion

Many factors affect the ability to achieve maximum ROM after TKA. Some of these factors can be controlled by the surgeon. Others such as preoperative ROM cannot be controlled by the surgeon. Some authors have hypothesized that proximal tibial slope influences postoperative ROM [4,9].

Walker and Garg [4], in a computer modeling study, attempted to determine the effect of proximal tibial slope on postoperative ROM. The effects of a 10° posterior tilt, neutral tilt, and a 10° anterior tilt were compared. They concluded that a 10° posterior tilt produced no less than 30° of additional flexion when compared with the neutral tilt, and anterior tilt had the opposite effect.

Many of the published clinical studies have failed to find this kind of correlation between the posterior tibial slope and the maximal flexion [11–13]. It seemed to the researchers of those studies that many factors could affect the postoperative maximal flexion of the knees. However, it was difficult for them to provide objective evidence for the effect of a single variable in those clinical studies [10].

The presented study used matched groups to evaluate the effect of slope on knee flexion. One important finding of this study is the direct relationship of the tibial slope with the postoperative maximal knee flexion. The result of this study corroborates the hypothesis that a positive correlation (r=0.62) exists between the postoperative maximal flexion and the tibial slope in the posterior stabilized TKR. Moreover, an increased posterior tibial slope can lead to a greater degree of the knee flexion, with a 1.72° greater flexion angle for every extra degree of the posterior tibial slope.

Catani *et al.* [9] have also found a significant correlation between the tibial slope and the maximal flexion in an in-vivo video-fluoroscopic study on the knee kinematics of the posterior cruciate ligament (PCL)-substituting TKA implants.

Shi *et al.* [14] conducted a retrospective comparative study on 65 knees in 56 patients who had undergone posterior stabilized TKR, and they were divided into three groups according to the measured tibial slopes: group 1: less than 4°, group 2: 4°–7°, and group 3: more than 7°. They concluded that the posterior tibial slope is positively correlated with the postoperative maximal knee flexion, and increasing the tibial slope in the posterior-stabilized TKA can increase the maximal knee flexion, with an average of 1.8 greater flexion level for every extra tibial slope degree.

Meanwhile Kansara and Markel [8] in a prospective randomized controlled study revealed that the posterior tibial slope did not have any effect on the postoperative maximal flexion. According to the preoperative assumption of osteotomy, the patients in that study were divided into the 0° and 5° groups. In the 0° group, the postoperative posterior slope angle ranged from −4° to 9°, whereas in the 5° group, the posterior slope angle ranged from 1° to 12°. Thus, a great deviation from the preoperative assumption developed, which made the conclusion not reliable.

A wide range of posterior slope angles (−3° to 11°) were observed in this study, which were different from preoperative assumption. Other studies also had the same results [8,15].

The mechanical alignment systems had fundamental limitation of their ultimate accuracy. Even the most elaborate mechanical instrumentation systems relied on the visual inspection to confirm the accuracy of the limb, implant alignment, and stability; therefore, it was difficult to determine the accurate correct location of the crucial alignment landmarks [15]. These additional variations together with the necessity of preserving the joint stability in full flexion eventually resulted in a large difference between the originally targeted and the finally achieved posterior slopes [9].

In this study, cutting the proximal tibia with the intent of creating a 0° slope had the deleterious radiographic outcome of an anterior slope in some patients, which would have a higher loosening incidence of the tibial component, and also reduced the maximal flexion [16,17]. In contrast, attempting to impart a 7° posterior slope did not result in any patient having an anterior slope. Therefore, the 7° posterior slope was appropriate to eliminate the anterior slope outliers which result in anterior impingement and to obtain a much greater level of the knee flexion.

Conclusion

Increasing the tibial slope in the posterior-stabilized TKA can increase the maximal knee flexion, with an average of 1.72° greater flexion level for every extra tibial slope degree. The use of 7° cutting jig eliminates the risk of anterior slope outliers.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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