ORIGINAL ARTICLE

Effect of 45° versus 90° Knee Flexion during Wound Closure in Total Knee Arthroplasty: A Randomized Trial with 3-Month Follow-Up

Aomsub Pikulnee, MD[1], Nattaphon Surachtnanan, MD[1], Nantaphon Chuvetsereporn, MD[1], Thanasak Yakumpor, MD[1]

[1] Department of Orthopedics, Faculty of Medicine, Burapha University, Chonburi, Thailand

Background: Knee positioning during wound closure in total knee arthroplasty (TKA) affects the postoperative outcomes. Previous studies have compared knee flexion at 90 degrees with knee extension.

Objective: To evaluate the outcomes of knee flexion at 45 degrees versus 90 degrees during wound closure in TKA.

Materials and Methods: The present study was a prospective, randomized clinical trial that included 58 patients undergoing TKA with posterior-stabilized prostheses. The participants were randomly assigned to one of two groups with 29 patients in the 45-degree knee flexion group (Group I) and 29 patients in the 90-degree knee flexion group (Group II). Postoperative outcomes were assessed at three months and included pain, knee function recovery, patellar height, and complications.

Results: Three months after TKA, no statistically significant differences in pain were found between the groups (p=0.874). Group I reported a mean pain score of 2.03±1.92 compared with 2.24±2.18 in Group II. Additionally, there were no statistically significant differences in knee function recovery between the groups (p=0.389 in the Forgotten Joint Score-12, p=0.611 in the Oxford Knee Score, and p=0.556 in range of motion). No significant differences were observed in the patellar height (p=0.848) or complications.

Conclusion: There were no significant differences in postoperative pain, knee function recovery, patellar height, or complications between the 45-degree and 90-degree knee flexion positions during TKA wound closure. Both positions were equally effective and safe.

Keywords: Total knee arthroplasty; Knee flexion; Postoperative outcomes; Wound closure; Patellar height

Received 18 September 2024 | Revised 8 February 2025 | Accepted 17 February 2025

J Med Assoc Thai 2025;108(4):304-11

Website: http://www.jmatonline.com

Total knee arthroplasty (TKA) is a highly effective surgical intervention for patients experiencing end-stage knee osteoarthritis. It is designed to relieve pain, correct deformities, and restore functional mobility[1]. With a global increase in the aging population and rising prevalence of knee osteoarthritis, the demand for TKA continues to increase[2,3]. Consequently, optimizing surgical techniques to improve patient outcomes and extend the longevity of knee implants has become a critical focus in orthopedic research.

Correspondence to:

Pikulnee A.

Department of Orthopedics, Faculty of Medicine, Burapha University, 169 Long-Haad Bangsaen Road, Saen Suk Sub-district, Mueang, Chonburi 20131, Thailand.

Phone: +66-38-102222 ext. 2580, Fax: +66-38-386557

Email: aomsub@buu.ac.th

How to cite this article:

Pikulnee A, Surachtnanan N, Chuvetsereporn N, Yakumpor T. Effect of 45° versus 90° Knee Flexion during Wound Closure in Total Knee Arthroplasty: A Randomized Trial with 3-Month Follow-Up. J Med Assoc Thai 2025;108:304-11.

DOI: 10.35755/jmedassocthai.2025.4.304-311-01808

Knee positioning during wound closure is a key aspect of TKA that has garnered significant attention. The degree of knee flexion at this stage is hypothesized to influence postoperative outcomes, including pain, knee function recovery, and patellar height[4-15]. Patellar height is particularly crucial, as deviations can lead to complications such as patellar baja or alta, which can adversely affect knee biomechanics and patient satisfaction[16-18].

Most studies have compared knee flexion at 90 degrees with knee extension during wound closure, often finding that knee function at 90-degree flexion results in better knee function and range of motion (ROM)[4-15]. However, the effects of other knee flexion angles remain unexplored. Thus, the present study aimed to address this gap by rigorously comparing the outcomes associated with 45-degree versus 90-degree knee flexion during wound closure in TKA. Key metrics included postoperative pain, knee function recovery, patellar height, and incidence of complications. The present study sought to determine whether a lower extreme flexion angle could offer

comparable or superior results.

Materials and Methods

Study design and participants

The present study was a prospective, randomized clinical trial at Burapha University Hospital included patients aged 55 to 85 years scheduled to undergo TKA with posterior-stabilized prostheses. The participants, recruited between June 2022 and October 2023, met the criteria for TKA for knee osteoarthritis. The exclusion criteria included bilateral knee arthroplasty, rheumatoid arthritis, and post-traumatic osteoarthritis. Informed consent was obtained from all patients, and the study was approved by the Institutional Review board (IRB1-050/2565) and registered with the Thai Clinical Trials Registry (TCTR20230111007). The random allocation of all participants was conducted by a research assistant using computerized block randomization. Randomization determined whether participants would be assigned to the 45-degree or 90-degree knee flexion group during wound closure, with an equal number of participants in each group. Sixty-four participants were initially enrolled, but three were excluded because of bilateral TKA, two for rheumatoid arthritis, and one for post-traumatic osteoarthritis. The 58 remaining participants underwent TKA and completed follow-up assessments, and their data were analyzed at the 3-month mark (Figure 1). Participants were blinded to the group assignments.

The authors acknowledge that the selection of knee flexion angle during wound closure was determined intraoperatively and was not influenced by patient-specific characteristics or preoperative factors. To maintain study integrity, patients were randomly assigned to either the 45-degree or 90-degree knee flexion group, ensuring that the distribution of patient characteristics, such as age, body mass index (BMI), and comorbidities, was evenly balanced between groups. Additionally, the same standardized surgical technique was used in all cases, minimizing variability in intraoperative decision-making.

Surgical techniques and follow-up

All the participants received spinal anesthesia. The TKA procedures were performed by the same orthopedic team using posterior-stabilized, fixed-bearing cemented prostheses with a measured resection technique. During surgery, a tourniquet was inflated to 150 mmHg above the systolic pressure during maximal knee flexion. A midline

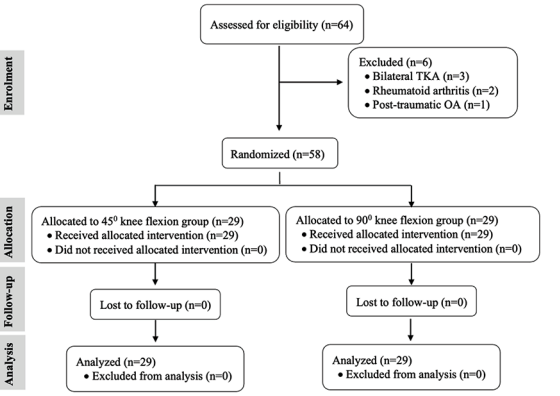

Figure 1. Participant selection flowchart.

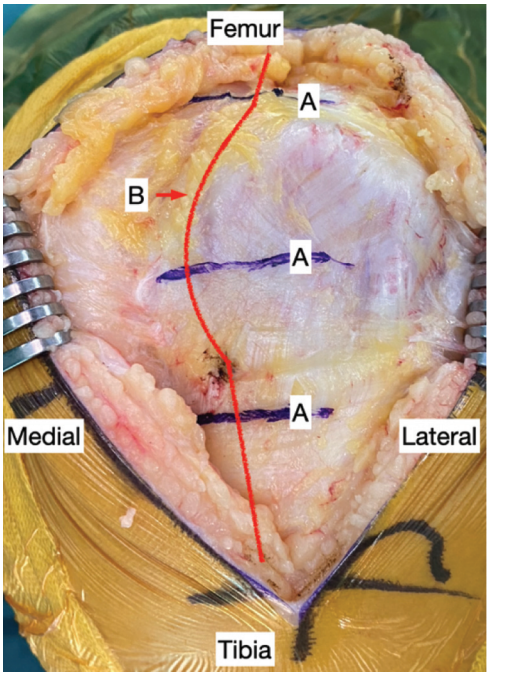

Figure 2. Surgical incision illustration.

A=marking line on the knee capsule for suture placement; B=incision line using the medial parapatellar approach

longitudinal incision was made via a medial parapatellar arthrotomy with surgical markers used for joint capsule alignment (Figure 2). The patellar tendon fat pad was partially excised, and the patella was not resurfaced. Lateral retinacular release was not observed. All participants received periarticular injections of multimodal analgesics (bupivacaine, ketorolac tromethamine, and saline). Wound closure was performed according to group assignment; the 45-degree flexion group had closure at 45 degrees, and the 90-degree flexion group at 90 degrees, as

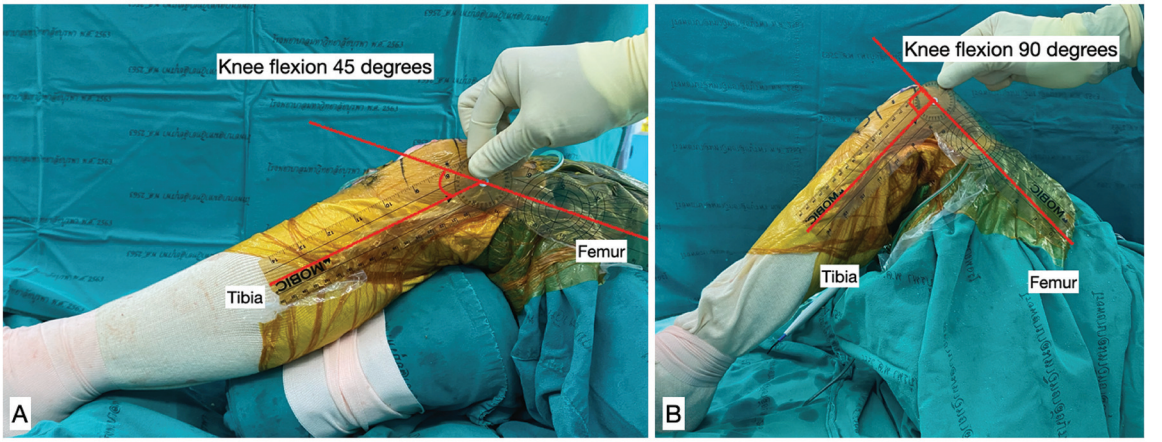

Figure 3. Knee flexion during wound closure. (A) Knee flexion at 45 degrees, (B) Knee flexion at 90 degrees.

measured using a goniometer (Figure 3). A closed suction drain was placed on all the participants.

Postoperative pain was managed by anesthesiologists, with both groups receiving identical intravenous and oral analgesics. Patients were administered intravenous patient-controlled analgesia for 48 hours after surgery. Subsequently, injections for pain relief were administered as needed when the participants experienced severe intermittent pain. The participants followed a standardized physical therapy protocol administered by the same team of physical therapists, beginning on the first day after surgery. The program included active flexion, and extension exercises for the knee joint. The participants were encouraged to bear full weight using a walker, practice using the bathroom, and navigate stairs. All participants received counseling on pain management, follow-up appointments, and monitoring for complications before discharge.

Outcomes

Outcomes in the present study were assessed preoperatively and at three months postoperatively. The primary outcome was postoperative pain, evaluated using a verbal numerical rating scale. Secondary outcomes included knee function recovery, patellar height, and complications. Knee function recovery outcomes were measured using the Thai versions of the Oxford Knee Score (OKS)[19], Forgotten Joint Score-12 (FJS-12)[20], and ROM. Patellar height was assessed employing the modified Insall-Salvati ratio (MISR). Complications included wound dehiscence, hematoma, infection, and deep vein thrombosis. Data collection was conducted by blinded research assistants with nurses collecting questionnaire data, physical therapists measuring ROM using a goniometer, and two orthopedic surgeons assessing patellar height (Figure 4).

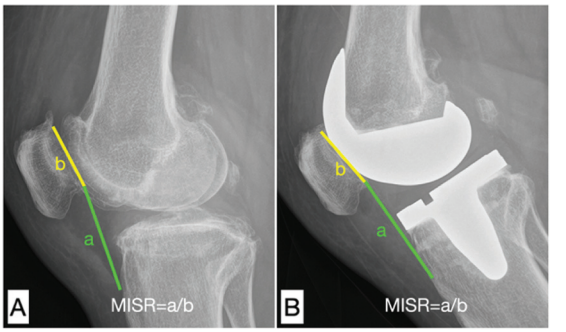

Figure 4. Radiographic measurements and calculations of patellar height using the modified Insall-Salvati ratio (MISR) method. (A) Preoperative radiogram, (B) Three months postoperative radiogram.

Radiographic evaluations

The reliability of the distance measurements and patellar height calculations was evaluated by two orthopedic surgeons, both experts in the INFINITT PACS software, who were blinded to the surgical details. To assess intra-rater reliability, ten knees similar to those in the sample group were evaluated twice, one week apart. Using SPSS with a two-way mixed-effects model for absolute agreement, the intraclass correlation coefficient (ICC) values were 0.84 and 0.85, respectively. For inter-rater reliability, both surgeons assessed the same knees, and the ICC for consistency was 0.96. These high ICC values demonstrated excellent reliability both within and between the evaluators.

Data analysis

The sample size calculation was based on detecting a clinically significant difference in pain scores between the two groups, with 80% power and a significance level of 0.05. The required sample size was 58 patients, referencing previous research by Wang et al., which investigated the effect of knee position during wound closure on early knee function recovery in TKA patients[7]. Data analysis was conducted using IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as means and standard deviations (SD) for continuous variables and as frequencies and percentages for categorical variables. Between-group comparisons were performed using independent t-tests for continuous variables and chi-square tests for categorical variables. For within-group comparisons of preoperative and postoperative quantitative data, paired Student's t-tests or Mann-Whitney U tests were applied, depending on data distribution. Qualitative data were compared using Pearson's chi-square test. To adjust for potential baseline differences and improve statistical accuracy, analysis of covariance (ANCOVA) was performed, with preoperative values as covariates to control for their potential influence on postoperative outcomes. A p-value of less than 0.05 was considered statistically significant.

Results

Fifty-eight TKA participants were randomly assigned to either the 45-degree as Group I or 90-degree as Group II knee flexion groups. The demographic characteristics are summarized in Table 1. The present study concluded that the two groups did not significantly differ in terms of demographic characteristics.

At three months postoperatively, no statistically significant differences were observed between the two groups in any of the measured outcomes.

The mean pain at rest significantly decreased from 3.83±2.36 to 2.03±1.92 in the 45-degree knee flexion group (p=0.001) and from 4.38±2.91 to 2.24±2.18 in the 90-degree flexion group (p=0.005), with no significant difference between the groups (p=0.874) (Table 2). ANCOVA analysis, adjusting for baseline pain, confirmed no significant effect of group allocation on postoperative pain (F=0.066, p=0.798), and the preoperative pain score was not a significant covariate (F=1.431, p=0.237) (Table 3).

OKS significantly improved from 17.83±7.28 to 31.38±7.73 in the 45-degree group and from 17.52±7.76 to 30.34±7.66 in the 90-degree group (both p<0.001), with no between-group difference (p=0.611) (Table 2). ANCOVA revealed no significant group effect on postoperative OKS after adjusting for baseline OKS (F=0.243, p=0.624), and the covariate was not significant (F=0.721, p=0.400) (Table 3).

There was no significant difference in FJS-12 between the groups at three months postoperatively (p=0.389).

The ROM did not differ significantly between the two groups preoperatively with 115.52±12.13° versus

Table 1. Demographic characteristics of participants

	Group I knee flexion 45°	Group II knee flexion 90°	p-value
Men/women; n	4/25	3/26	1.000[F]
Age (years); mean±SD	71.45±6.62	68.31±5.48	0.054[t]
Weight (kg); mean±SD	65.90±11.20	64.21±9.90	0.674[M]
Height (cm); mean±SD	157.93±7.47	155.10±6.60	0.130[M]
BMI (kg/m2); mean±SD	26.34±3.36	26.71±3.91	0.701[t]
Side: right/left; n	14/15	19/10	0.185[C]

SD=standard deviation; BMI=body mass index

Statistical significance was set at p<0.05, (F) Fisher's exact test, (t) independent t-test, (M) Mann-Whitney U test, (C) Pearson's chi-square test

Table 2. Comparison of pain, knee function recovery, and patellar height

	Group I knee flexion 45° mean±SD	Group II knee flexion 90° mean±SD	p-value
Pain at rest (vNRS)			
Preoperative	3.83±2.36	4.38±2.91	0.164M
Postoperative 3 months	2.03±1.92	2.24±2.18	0.874M
p-value	0.001W	0.005W	
Forgotten joint score			
Postoperative 3 months	50.31±20.85	55.08±20.97	0.389t
Oxford knee score			
Preoperative	17.83±7.28	17.52±7.76	0.876t
Postoperative 3 months	31.38±7.73	30.34±7.66	0.611t
p-value	<0.001a	<0.001a	
ROM (degrees)			
Preoperative	115.52±12.13	110.69±14.12	0.163M
Postoperative 3 months	114.31±11.63	112.48±11.93	0.556M
p-value	0.622W	0.190W	
MISR			
Preoperative	1.58±0.19	1.59±0.17	0.931t
Postoperative 3 months	1.60±0.18	1.59±0.13	0.848t
p-value	0.746a	0.981a	

SD=standard deviation; vNRS=verbal numerical rating scale; ROM=range of motion; MISR=modified Insall-Salvati ratio

Statistical significance was set at p<0.05, (M) Mann-Whitney U test, (t) independent t-test, (a) paired sample t-test, (W) Wilcoxon signed-rank test

Table 3. Summary of analysis of covariance (ANCOVA) results adjusting for baseline values

Outcome variable	F (covariate)	P (covariate)	F (group)	P (group)	Interpretation
Pain	1.431	0.237	0.066	0.798	NS between groups
Oxford knee score	0.721	0.400	0.243	0.624	NS between groups
ROM	85.273	<0.001	0.601	0.442	NS between groups (ROM influenced by baseline)
MISR	12.746	0.001	0.071	0.79	NS between groups (MISR influenced by baseline)

ROM=range of motion; MISR=modified Insall-Salvati ratio; F=F-statistic; P=probability value; NS=not significant
Statistical significance was set at $p<0.05$

110.69±14.12° or at three months postoperatively with 114.31±11.63° versus 112.48±11.93°(p=0.556) (Table 2). However, baseline ROM had a significant effect on postoperative ROM (F=85.273, p<0.001), while the group allocation had no significant effect after adjusting for this covariate (F=0.601, p=0.442) (Table 3).

The MISR showed no significant change within or between groups. At three months, MISR values were 1.60±0.18 and 1.59±0.13 in the 45-degree and 90-degree groups, respectively (p=0.848) (Table 2). ANCOVA showed that baseline MISR significantly influenced postoperative values (F=12.746, p=0.001), but no significant difference between the two groups was found after adjustment (F=0.071, p=0.790) (Table 3).

No complications, such as wound dehiscence, hematoma, infection, or deep vein thrombosis, were reported in either group at three months postoperatively.

Taken together, these findings suggest that performing wound closure in 45-degree or 90-degree of knee flexion has no significant impact on postoperative pain, functional outcomes, ROM, patellar height, or complications at three months following TKA.

Discussion

This prospective, randomized, double-blind clinical trial compared the outcomes of TKA between two groups in which wound closure was performed at either 45-degree or 90-degree of knee flexion (Figure 5). Postoperative pain was the primary outcome, while secondary outcomes included functional recovery, patellar height, and postoperative complications assessed at a 3-month follow-up. The results demonstrated no statistically significant differences in any of the outcomes measured between the two groups. Both groups experienced significant improvements in postoperative pain and OKS. Additionally, no significant differences were observed in FJS-12, ROM, or MISR between groups. No complications were reported in either group throughout the study period. To account for potential baseline differences, ANCOVA was employed. The results remained consistent after adjusting for preoperative values, confirming that knee flexion angle during wound closure had no significant impact on postoperative outcomes.

Wound closure in a 45-degree knee flexion position yielded favorable outcomes, consistent with the findings of Ainslie-Garcia et al. in their Delphi Study, which reported that semi-flexion closure is superior to extension in terms of postoperative ROM[21]. Similarly, Chen et al.'s systematic review and meta-analysis found that closure in a semi-flexed knee position is associated with superior outcomes for postoperative ROM[22]. However, neither of these studies specified the exact degree of knee flexion, unlike the present study.

Previous studies on wound closure with the knee in flexion have shown improved pain scores and knee function recovery, consistent with the findings of the present study. Lu et al. reported that patients whose knees were closed in the 90-degree flexion position had significantly lower VAS pain scores than those whose knees were closed in extension, particularly during the early postoperative stages[14]. Emerson et al. found that closing the knee in flexion at 90 to 110-degree resulted in better postoperative flexion measurements at all intervals. At six months, the flexion group had surpassed their preoperative flexion measurements, whereas the extension group did not[4]. Kömürcü et al. conducted a prospective, randomized, double-blind trial and found that postoperative flexor muscle strength improved when the knee was flexed during wound closure[6]. Wang et al. reported that flexion closure leaded to an earlier recovery of knee function and enhances overall rehabilitation outcomes[7]. Similarly, Faour et al. found that closing the knee in flexion during TKA was associated with improved ROM recovery, decreased short-term postoperative pain, and increased muscle strength, leading to faster functional recovery[12].

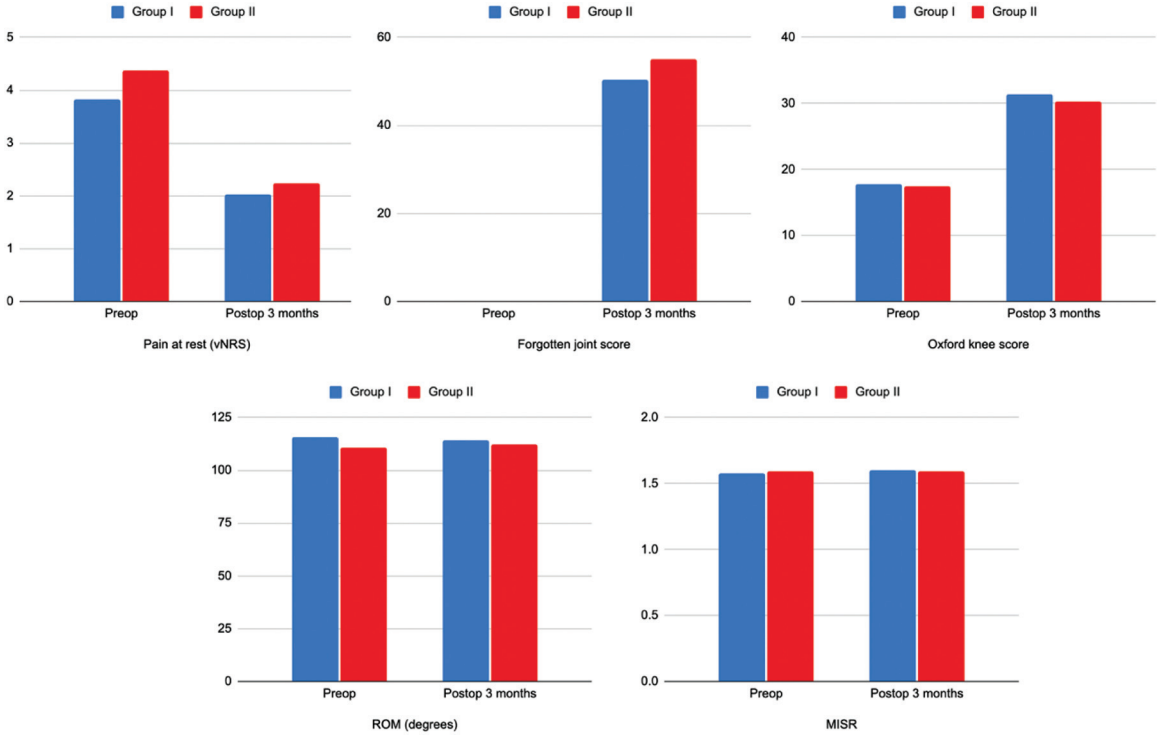

Figure 5. Bar chart illustrating the comparison of preoperative and postoperative outcomes.

Preop=preoperative; Postop=postoperative; ROM=range of motion; MISR=modified Insall-Salvati ratio

However, there were also differences in the effects of knee flexion, which led to the variations in surgical outcomes compared to those of previous studies. King et al. found that the wound length increases by up to 42% when the knee was flexed to 120 degrees compared to when it was fully extended. Suturing in the extended knee position binds the wound to a shorter length, which can cause excessive suture tightening as the knee is flexed, potentially leading to wound puckering, breakage, and wound dehiscence[23]. Masri et al. noted that closure with the knee in flexion was technically more challenging and offered no intraoperative surgical advantages, potentially increasing the procedural complexity. They found that this technique did not significantly affect early rehabilitation or postoperative function[5]. Kobayashi et al. conducted a cadaveric study to investigate the effects of closing arthrotomies with the knee positioned at approximately 30 degrees of flexion. This position was selected to simulate conditions that provide appropriate tension and ensure the integrity of the closure, particularly under high-stress activities such as deep knee flexion[24].

The findings of the present study indicated that patellar height was a critical factor affecting TKA outcomes. These results are consistent with those of previous studies that extensively explored the implications of postoperative patellar height modifications in TKA. Clark et al. investigated the effect of knee position on patellar tendon length during wound closure and found a small but significant reduction in patellar height when the knee was closed in full extension compared to flexion. However, this effect was not sustained at the 12-month follow-up, suggesting that while initial changes in patellar height could occur based on knee position during closure, these changes may not have long-term clinical significance[15]. This aligns with the findings of the current study, in which patellar height changes were observed postoperatively, but no significant differences were noted in the clinical outcomes between the groups with different knee flexion angles during wound closure.

The present study found no significant differences in postoperative complications, including wound dehiscence, hematoma, infection, or deep vein thrombosis, between the two groups. These findings are consistent with those of previous studies that compared 90-degree knee flexion and extension[4-12,15], confirming that wound closure at both 45 and 90

degrees was safe.

Suturing wounds with the knee in a more flexed position lengthened the wound edges, improved suture alignment, and created a smoother appearance. However, excessive knee flexion increased the stress on the surrounding soft tissue, making wound closure more challenging. Thus, both the 45-degree or 90-degree knee flexion positions can be safely chosen during TKA wound closure based on surgeon preference, patient characteristics, and intraoperative factors, without compromising outcomes.

In conclusion, this randomized controlled trial demonstrated that wound closure at both 45- and 90-degrees knee flexion resulted in similar outcomes in terms of postoperative pain, knee function recovery, patellar height, and complication rates at three months. These results indicated that either flexion angle could be selected based on preference or intraoperative convenience, as both techniques were effective and safe, providing flexibility in wound closure during TKA.

The present study had limitations. The small sample size of 58 patients may have limited the generalizability of the findings. Larger studies are needed to confirm the results. The 3-month follow-up provided an early postoperative assessment, but a longer duration is necessary to evaluate implant longevity, long-term function, and late complications. Conducting the study at a single center further restricted the external validity, and multicenter research is required for broader applicability. Although all procedures were performed by the same group of experienced orthopedic surgeons using a standardized surgical protocol, variations in patient comorbidities and healing capacity were not fully controlled and may have influenced outcomes. Additionally, while demographic data such as age, BMI, and laterality are reported in Table 1, detailed baseline health characteristics such as preoperative knee function and comorbidities were not explicitly analyzed, which could impact result interpretation. Future studies should incorporate stratified randomization or statistical adjustments for confounding factors to enhance validity.

Conclusion

The present study provides evidence that wound closure at both 45-degree and 90-degree knee flexion angles in TKA results in significant improvement in pain, effective knee recovery, and patellar height at three months postoperatively, with no statistically significant differences in complication rates. These findings support the flexibility of surgical techniques and emphasize the importance of patient-centered approaches in TKA.

What is already known about this topic?

Previous studies have shown that knee flexion at 90 degrees during wound closure in TKA results in better postoperative outcomes compared to knee extension, including improved knee function and ROM.

What does this study add?

This study demonstrates that there are no significant differences in postoperative pain, knee function recovery, patellar height, or complications between 45-degree and 90-degree knee flexion during wound closure in TKA, suggesting that both flexion angles are equally safe and effective.

Acknowledgments

The authors express their gratitude to Associate Professor Chaturong Pornrattanamaneewong, Department of Orthopedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, for his valuable guidance and recommendations for this study.

Authors' contributions

AP: conceptualization, data curation, formal analysis, investigation, visualization, methodology, writing-original draft, writing-review & editing, project administration. NS: investigation, validation. NC: investigation, validation. TY: investigation, methodology, writing-review & editing.

Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Funding disclosure

This study was supported by grants from the Faculty of Medicine, Burapha University (grant number 005/2565).

Conflicts of interest

The authors declare that they have no competing interests.

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