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ORIGINAL ARTICLE

Observational Study

Coronal plane stability of cruciate-retaining total knee arthroplasty in valgus gonarthrosis patients: A mid-term evaluation using stress radiographs

Pruk Chaiyakit, Pichayut Wattanapreechanon

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Abstract

BACKGROUND

Total knee arthroplasty (TKA) using implants with a high level of constraint has generally been recommended for patients with osteoarthritis (OA) who have valgus alignment. However, studies have reported favorable outcomes even with cruciate-retaining (CR) implants.

AIM

To evaluate the coronal plane stability of CR-TKA in patients with valgus OA at the mid-term follow-up.

METHODS

Patients with primary valgus OA of the knee who underwent TKA from January 2014 to January 2021 were evaluated through stress radiography using a digital stress device with 100 N of force on both the medial and lateral side. Gap openings and degrees of angulation change were determined. Descriptive statistical analysis was performed for both continuous and categorical variables. Inter-rater reliability of the radiographic measurements was evaluated using Cronbach's alpha.

RESULTS

This study included 25 patients (28 knees) with a mean preoperative mechanical valgus axis of 11.3 (3.6-27.3) degrees. The mean follow-up duration was 3.4 (1.04-7.4) years. Stress radiographs showed a median varus and valgus gap opening of 1.6 (IQR 0.6-3.0) mm and 1.7 (IQR 1.3-2.3) mm and varus and valgus angulation changes of 2.5 (IQR 1.3-4.8) degrees and 2.3 (IQR 2.0-3.6) degrees, respectively. No clinical signs of instability, implant loosening, or revision due to instability were observed throughout this case series.

CONCLUSION
The present study demonstrated that using CR-TKA for patients with valgus OA of the knee promoted excellent coronal plane stability.

Key Words: Valgus osteoarthritis knee; Cruciate-retaining; Knee arthroplasty; Stress radiograph; Coronal stability

Core Tip: Cruciate-retaining total knee arthroplasty (CR-TKA) for knee valgus osteoarthritis (OA) has been associated with high rates of postoperative tibiofemoral instability. Our study utilized a digital ligament stress device to objectively measure the coronal stability of CR-TKA in patients with knee valgus OA at a mean follow of 3 years and found no significant instability, with a median varus and valgus gap change of < 2 mm. All patients were satisfied with their knee without revision due to instability, loosening, or patellar-related complication. We also describe the step-by-step details of the surgical technique used to ensure good exposure and soft tissue balance.

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INTRODUCTION

Approximately 10%-15% of patients with valgus alignment of the knee, defined as an anatomic valgus of the tibiofemoral axis exceeding 10 degrees, require total knee arthroplasty (TKA)[1,2]. Patients with valgus knees often present with various degrees of medial soft tissue insufficiency combined with tightness or contracture of the lateral soft tissue. Performing TKA in such patients seems to be associated with higher complication rates than performing TKA in patients with varus knees, especially in terms of tibiofemoral instability[3,4]. Various knee prosthesis constraints have been utilized during TKA of valgus knees, with the general recommendation being the use of at least posterior-stabilized (PS) TKA with post and cam design or constrained condylar design (constrained condylar knee) in cases with advance deformities and/or severe ligament insufficiency[5-8]. Cruciate-retaining (CR) TKA is the least constrained knee prosthesis that depends on the function of the posterior cruciate ligament to limit posterior translation of the tibia, with the prosthesis itself not providing varus-valgus stability[7,9]. Although some studies have shown good to excellence clinical results following CR-TKA in valgus knees[10-15], others have reported that around 10%-20% of patients develop varus-valgus instability[13,16]. Moreover, most studies have evaluated instability or laxity after TKA using manual clinical examination. Notably, Mears *et al*[17] demonstrated poor inter-rater reliability when clinically testing for both antero-posterior (AP) laxity in flexion and varus-valgus laxity. To the best of our knowledge, no study has yet objectively measured varus-valgus stability after performing CR-TKA among patients with valgus osteoarthritis (OA) of the knee. The current study therefore aimed to measure varus-valgus stability after performing CR-TKA patient with valgus OA of the knee using stress radiography combined with a digital ligament stress device.

MATERIALS AND METHODS

Study population

This study was approved by the institutional review board committee of Navamindradhiraj University (COA157/2563). Informed consent was obtained from all patients prior to participation. We retrospectively reviewed data from patients with valgus OA (defined as a tibiofemoral axis greater than 10 degrees of valgus) admitted at our institution from January 2014-2021 who underwent primary CR-TKA performed by the senior author (Chaiyakit P). The exclusion criteria were secondary OA due to inflammatory joint disease or posttraumatic arthritis and a follow-up duration < 1 year after receiving index CR-TKA.

Surgical techniques

All patients underwent midvastus arthrotomy, followed by removal of the anterior cruciate ligament and osteophytes. We carefully preserved the medial soft tissues to prevent further iatrogenic laxity. The proximal tibia was resected perpendicular to its anatomical axis, guided by a conventional extramedullary device. Distal femur resection was guided by an intramedullary rod, with the valgus angle being set to 5 degrees in all cases. A spacer block and laminar spreader were used to evaluate the extension gap. If there was any asymmetry in the gaps with contracture of the lateral structures, a lateral release was performed with modification of lateral parapatellar arthrotomy[18] as shown in Figure 1. Normally, the lateral arthrotomy extends from 1 cm above the upper border of patella to just the medial side of Gerdy's tubercle.

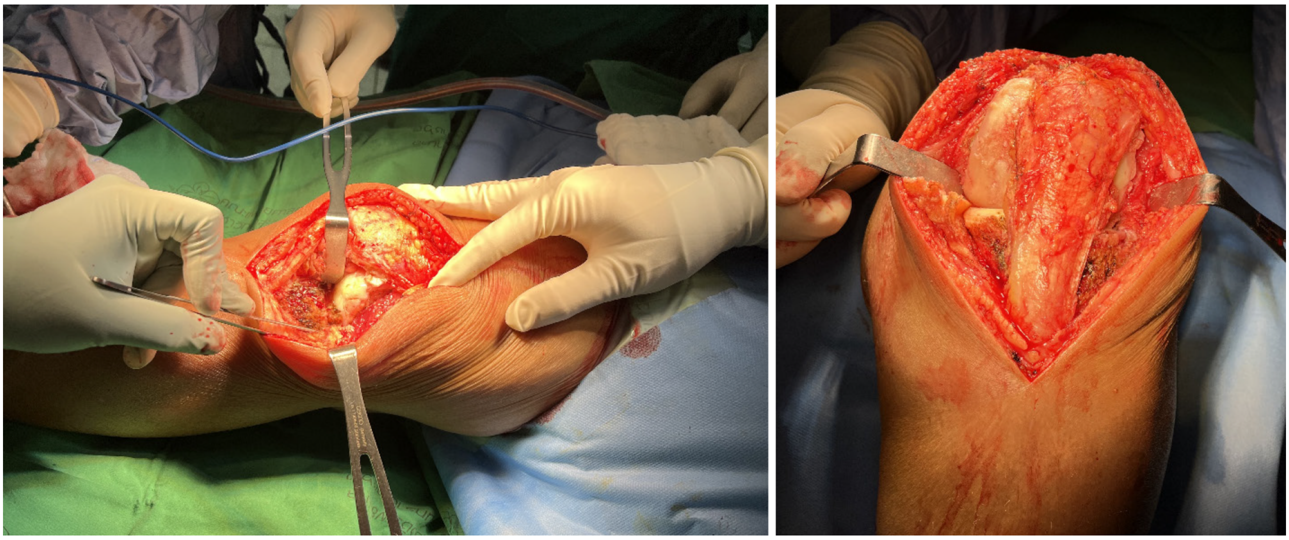

Figure 1 Midvastus arthrotomy combined with lateral parapatellar arthrotomy improved lateral side exposure and simultaneously assisted with the release of contracted lateral structures of the knee.

After additional lateral arthrotomy, the contracted iliotibial band was released subperiosteally from Gerdy's tubercle, and all lateral osteophytes on the femur and tibia were easily removed. The remaining contracted structure were released using the pie crusting technique with an 18 G needle and laminar spreader[1]. Moreover, in case of persistent tightness of the lateral structure causing an unbalanced extension gap, sliding lateral condylar osteotomy[19] was performed to correct it. Once a symmetrical extension gap was achieved, the flexion gap and femoral rotation can be addressed using soft tissue tension. The size of the femoral component was determined using the anterior referencing technique. An anterior cut, posterior cut, and chamfer cut of the femur were then performed. Thereafter, a trial reduction of both femoral and tibial components was conducted, with the tibial tray rotation being determined using the self-aligned technique[20]. Patellar tracking was assessed using the no-thumb technique in all cases, whereas extended release of the lateral structure, including the vastus lateralis, was performed as needed. Finally, all components were cemented, and the appropriate thickness of tibial polyethylene was inserted.

Outcome data collection

At the latest follow-up, all eligible patients underwent stress radiography in full extension with the use of a digital ligament stress device (Patent number 2101002860, Navamindradhiraj University, Bangkok, Thailand) as previously described by Kappel *et al*[21]. With the patient lying supine, a 100-N force was applied at the center of the knee (Figure 2), after which a true AP radiograph of the knee was obtained. Stress radiography was performed on both the medial and lateral sides of the knee to assess the integrity of the medial and lateral collateral ligaments. The gap opening in millimeters and degrees obtained from the stress radiograph were compared to those obtained from normal knee AP radiographs (Figure 3). Other radiographic parameters included the mechanical axis angles of the femur and tibia, alpha angle of femoral component, and beta angle of the tibial component[22]. We also carefully observed for radiographic signs of TKA loosening. All radiographic measurements were conducted independently by one of the authors (Wattanapreechanon P) and one trained personnel. Each investigator obtained two measurements, with a 2-week interval between each measurement, and calculated their average values. After assessing inter-rater reliability, the measurements from both investigators were averaged to report the results. The Thai version of the Western Ontario and McMaster Universities Osteoarthritis Index questionnaire (WOMAC)[23], Knee Society score (KSS)[24], and Time Up and Go test (TUGT)[25] were utilized to evaluate the patients. Complications and revision surgery following the index surgery were thoroughly reviewed.

Statistical analysis

Descriptive statistical analysis of the data was conducted using Stata version 14.1. Continuous variables with a normal distribution were reported as mean and standard deviation, whereas those with a nonnormal distribution were reported as median and interquartile range. Categorical variables were expressed as frequencies and percentages. Inter-rater reliability of the radiographic measurements was evaluated by Cronbach's alpha.

RESULTS

A total of 38 patients who were diagnosed with primary OA of the knee with valgus deformity underwent surgery from January 2014 to January 2021. Three patients were lost to follow-up during the last 3 years, whereas another three patients died of causes not associated with their knee condition. Although we were able to contact 32 patients, 7 declined to

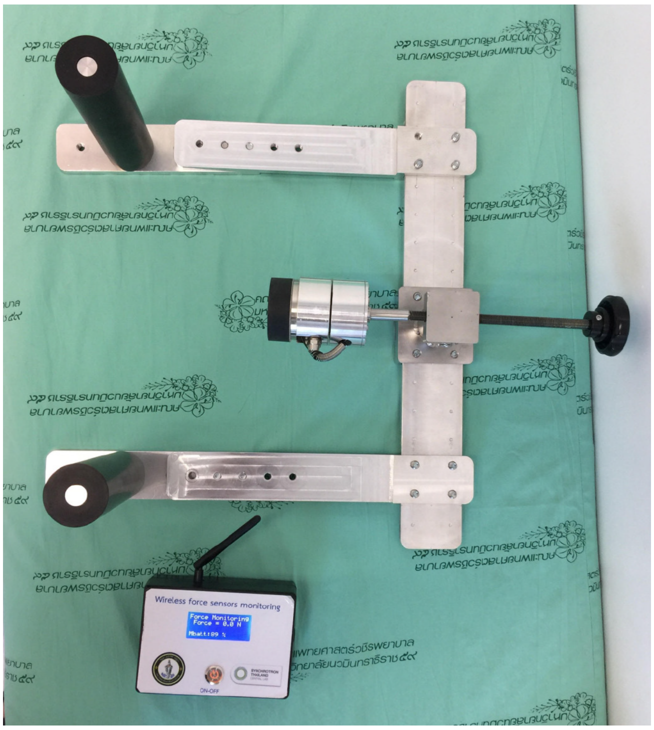

Figure 2 Digital ligament stress device (Patent number 2101002860, Navamindradhiraj University, Bangkok, Thailand) equipped with a sensor to measure the force applied during usage.

participate in the ligament stress test due to the circumstances surrounding the coronavirus disease 2019 (COVID-19) pandemic. All of them reported a well-functioning prosthesis without pain. Finally, 25 patients (28 knees) consented to participate in this study. Data for a total of 28 knees are summarized in Table 1. Accordingly, the average age of the included patients was 72 (72.6 ± 8) years old. The mean preoperative valgus mechanical axis deviation was 11.3 (range 3.6-27.3) degrees. Among the 27 knees that underwent valgus correction with the soft tissue procedure, only one needed lateral condylar sliding osteotomy (Figure 4). The mean follow-up duration was 3.4 (range 1.04-7.4) years. Our results showed that the Cronbach's alpha values of all measurements indicated good agreement between both raters (Table 2). Therefore, all measurements from both raters were averaged. The stress radiograph showed a median varus gap opening of 1.6 (IQR 0.6-3.0) mm and 2.5 (IQR 1.3-4.8) degrees and a minimal valgus gap opening of 1.7 (IQR 1.3-2.3) mm and 2.3 (IQR 2.0-3.6) degrees. All patients were satisfied with their knees, which showed no clinical signs of instability, and did not report any patellar-related complications. None of the knees showed signs of radiographic loosening at the latest follow-up (Table 3).

Through the operative technique described earlier, we were able to achieve immediate intra- and postoperative stability in all cases. Among the knees examined in this series, 17 (60.7%) were implanted with the least thick polyethylene insert available, resulting in a combined tibial thickness of < 13 mm (Figure 5). The median total WOMAC score was 20.5 (IQR 17-48), the median KSS knee score was 91.5 (85-94.5), the mean KSS function score was 71.6 ± 22.7, and the median TUGT was 13 (IQR 11.5-18.5) s (Table 4). The mean flexion ROM was 113.9 ± 12.6 degrees, whereas the mean extension ROM was 1.9 ± 3.9 degrees. Reoperation was required in two knees (two patients). The first case was diagnosed with acute hematogenous periprosthetic joint infection 1 year after the index surgery, which was successfully treated with arthrotomy debridement and polyethylene exchange combined with intra-articular infusion of antibiotics [26]. The second case presented with early postoperative wound dehiscence, which required simple re-suturing.

DISCUSSION

Some studies have shown that CR-TKA provided poor results for patients with valgus OA of the knee, which has prompted guidelines to generally recommend the use of PS-TKA for the management of valgus knees. Notably, Savov *et al*[16], who evaluated 248 patients who underwent TKA for valgus OA of the knee, found no significant differences in clinical outcomes between the CR and PS-TKA groups. However, they found that 8.0% of the patients in the CR-TKA group required reoperation due to instability, whereas none of those in the PS-TKA group required the same. Koskinen *et al*[13] also reported the need for early revisions following CR-TKA in patients with severe valgus OA of the knee, with 8 out of 52 knees (15%) in their series requiring revision surgery due to medial instability. However, PS-TKA is not as effective as CR-TKA in improving varus-valgus stability given that its post and cam mechanism was designed to improve AP stability during flexion. One report even showed a higher percentage of mid-flexion laxity after PS-TKA than after CR-TKA[27,28]. Ang *et al*[11] reported that both CR- and PS-TKA exhibited comparable postoperative clinical outcomes

Table 1 Patient demographic data (*n* = 28 knees)

Parameters	Values
Age (years)	72.6 (8.0)[1]
Sex, *n* (%)	
Female	24 (96.4)
Side, *n* (%)	
Right	18 (64.2)
BMI	27.1 (3.3)[1]
ASA classification, *n* (%)	
1	3 (10.7)
2	23 (82.1)
3	2 (7.1)
Krackow classification, *n* (%)	
1	21 (75)
2	7 (5)
Preop mechanical axis (degrees)	11.3[1] (36-27.3)
Preop tibial slope (degrees)	9.0 (4.4)[1]
Prosthesis, *n* (%)	
PFC sigma	15 (53.6)
NRG scorpio	11 (39.3)
Attune	1 (3.5)
Legion	1 (3.5)
Follow-up time (years)	3.4[1] (Range 10-7.4)

[1]Mean (standard deviation).
BMI: Body mass index; ASA: American Society of Anesthesiologists.

Table 2 Interobserver reliability of radiographic measurement data

Parameters	Cronbach's alpha
Preop mechanical axis (degrees)	0.981
Postop mechanical axis (degrees)	0.820
Preop tibial slope (degrees)	0.802
Postop tibial slope (degrees)	0.929
Varus gap opening (mm)	0.964
Varus gap opening (degrees)	0.972
Valgus gap opening (mm)	0.821
Valgus gap opening (degrees)	0.921
Alpha angle (degrees)	0.819
Beta angle (degrees)	0.757

and coronal plane laxity observed during physical examination in patients with type 2 valgus OA of the knees.

The current study was designed to evaluate postoperative coronal plane stability using a digital stress device, which allows for the accurate measurement of forces placed on the knee. One trained personnel was responsible for implementing the radiographic protocol, after which measurements were performed systematically to ensure their quality. The earliest follow-up stress radiograph was performed after 1 year (mean of 3.4 years) to ensure adequate healing of

Table 3 Postoperative radiographic outcomes

Parameters	Values
Postop mechanical axis (degrees) (negative value represents varus angle)	0.4 (-0.4 to 2.3)[2]
Postop tibial slope (degrees)	3.7 (2.4-7.1)[2]
Alpha angle (degrees)	93.7 (2.1)[1]
Beta angle (degrees)	89.6 (1.0)[1]
Varus gap opening (mm)	1.6 (0.6-3.0)[2]
Varus gap opening (degrees)	2.5 (1.3-4.8)[2]
Valgus gap opening (mm)	2.0 (1.6-2.3)[2]
Valgus gap opening (degrees)	2.3 (2.0-3.6)[2]

[1]Mean (standard deviation).
[2]Median (interquartile range).

Table 4 Postoperative clinical outcomes

Parameters	Values
WOMAC	20.5 (17-48)[2]
KSS Knee	91.5 (85-94.5)[2]
KSS Function	71.6 (22.7)[1]
Range of motion (degree)	
Extension	1.9 (3.9)[1]
Flexion	113.9 (12.6)[1]
TUGT (second)	13 (11.5-18.5)[2]

[1]Mean (standard deviation).
[2]Median (interquartile range).
WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index questionnaire; KSS: Knee Society score; TUGT: Time Up and Go test.

ligamentous structures. Ishii *et al*[29] reported that a medial-lateral laxity of 4 degrees after TKA promoted satisfactory clinical outcomes. One study that employed stress radiography also reported cutoff values for coronal plane laxity. Notably, the aforementioned study found that an inlay gap of 5.2 mm or a joint angle of 6.1° after varus stress and an inlay gap of 4.6 mm or a joint angle of 5.2° after valgus stress were correlated with the need for revision due to instability [30]. Our results showed an exceedingly small mean medial gap opening in valgus stress (2 mm), which was comparable to the mean lateral gap opening in varus stress (1.6 mm). The same results were obtained for angular changes, which showed 2.3 degrees on varus stress and 2.5 degrees on valgus stress. As such, the favorable clinical results, particularly the absence of revision due to instability, in the current study can be attributed to the fact that results obtained herein were lower than the cutoff values reported. Moreover, the insert used in our series was relatively thin, with 61% of our cases using the thinnest polyethylene insert available. These outcomes could mostly be attributed to adequate exposure and adequate soft tissue release. Our institution prefers using the midvastus approach as the main approach combined with lateral parapatellar arthrotomy for the management of valgus knees owing to various reasons. Familiarity with the medial approach allows for accurate bone resection and evaluation of all landmarks, while combining this approach with large lateral arthrotomy allows for the exposure of the lateral side of the knee for the removal of the lateral osteophyte and adequate release of lateral soft tissue. Moreover, in cases requiring extensive lateral release, the midvastus approach can secure a much larger undamaged quadriceps tendon area than can the medial parapatellar approach, which we believe would result in better overall outcomes.

The present study has been the first to provide an objective medio-lateral laxity measurement after CR-TKA in patients with valgus OA of the knee. Our results also showed that CR-TKA promoted favorable clinical outcomes based on the WOMAC score, KSS score, and TUGT, with no instability or loosening observed. However, some limitations of the current study need to be addressed. First, we could not evaluate coronal plane laxity in the knee flexion position and sagittal plane laxity. This is due to a lack of reliable diagnostic tools available at our institution. Second, we only included patients with a diagnosis of primary knee OA. For patients with secondary knee OA, the quality of the ligament, especially the posterior cruciate ligament, is usually not reliable, which could be insufficient at the time of operation or could stretch over time. Finally, the number of participants is quite limited, partly due to the COVID-19 pandemic.

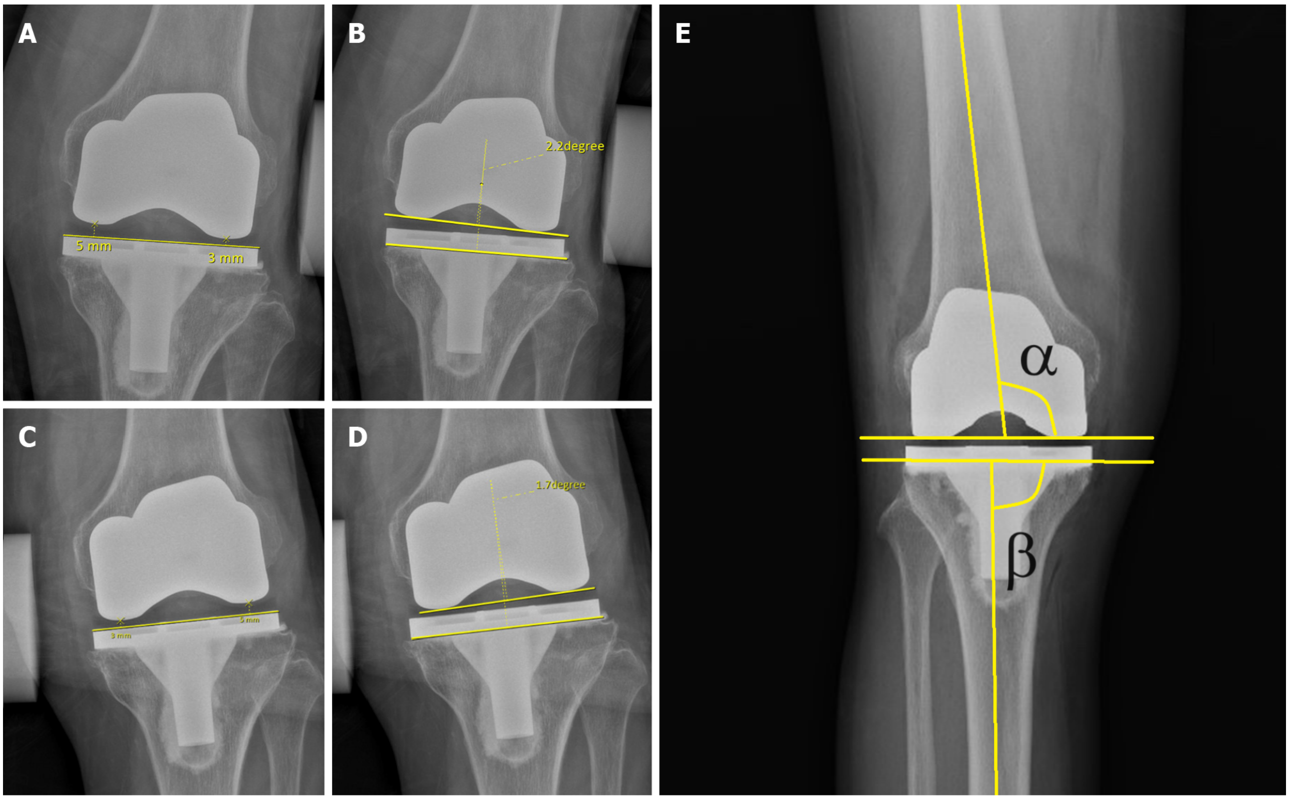

Figure 3 Measurement methods used in this study. A: The valgus gap opening distance was measured by subtracting the medial gap from the lateral gap on the stress radiograph; B: The valgus gap opening angle was determined based on the angle between the line of the tibial tray and the line of the most distal part of the femoral component on the stress radiograph; C: The varus gap opening distance was measured by subtracting the lateral gap from the medial gap; D: The varus gap opening angle was determined based on the angle between the line of the tibial tray and the line of the most distal part of the femoral component; E: The alpha (α) and beta (β) angles of the femoral and tibia components on the antero-posterior radiograph.

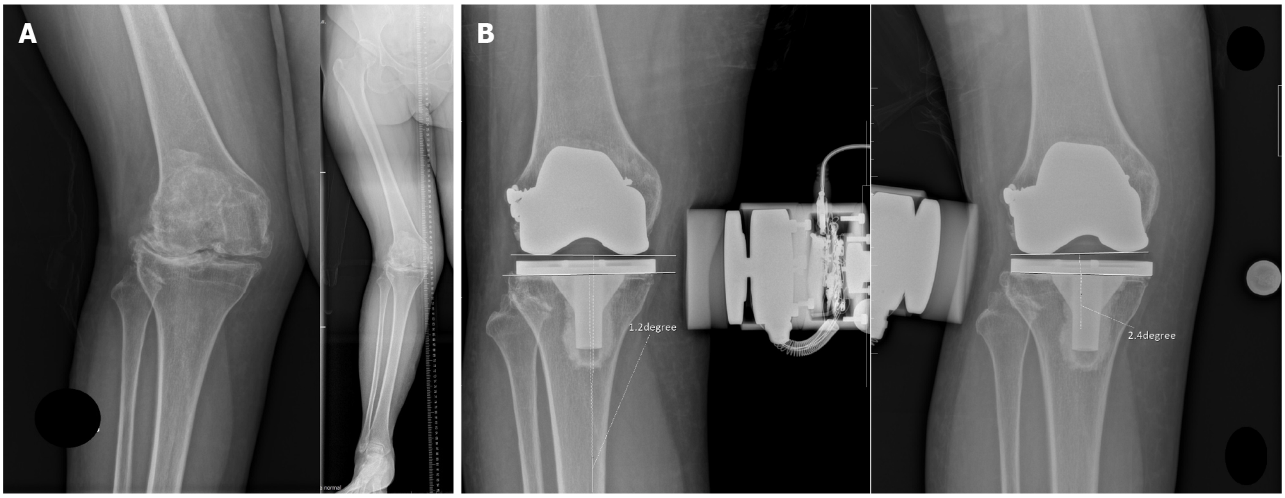

Figure 4 A case of a 65-year-old female with severe valgus osteoarthritis of the knee. A: The preoperative radiograph shows a valgus deviation of the mechanical axis of 22 degrees. After initial soft tissue release, persistent tightness of the lateral structure was still noted, causing an unbalanced extension gap. Thus, a lateral condylar sliding osteotomy was performed intraoperatively; B: The knee was stable after stress radiography.

CONCLUSION

Adequate exposure and meticulous soft tissue release are crucial for obtaining good clinical outcomes after TKA. Overall, our findings showed that the least constrained knee prosthesis, namely CR-TKA, could be utilized provided that excellent gap balance was achieved. The present study demonstrated that with good exposure and adequate soft tissue balance, CR-TKA could achieve excellent coronal stability and clinical outcomes when used for managing valgus OA of the knee.

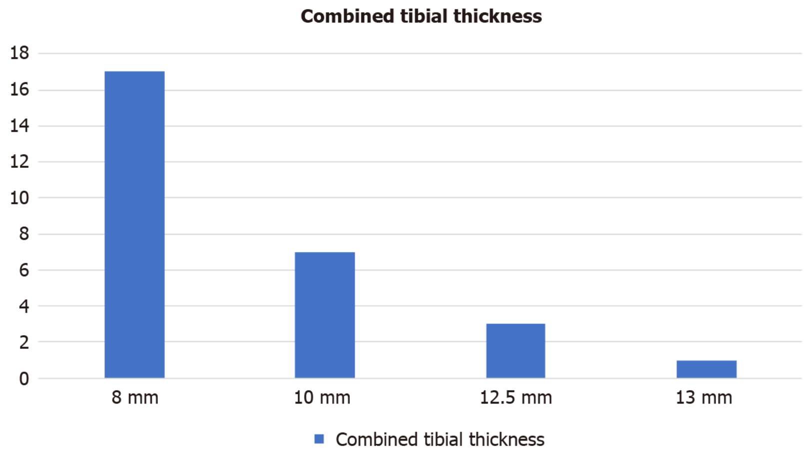

Figure 5 Distribution of the combined tibial thickness in this study. A total of 17 knees (60.7%) were implanted with a combined tibial thickness of < 10 mm; 7 knees (25%) were implanted with a combined tibial thickness of 10 mm; 3 knees (10.7%) were implanted with a combined tibial thickness of 12.5 mm; and 1 knee (3.5%) was implanted with a combined tibial thickness of 13 mm.

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FOOTNOTES

Author contributions: Chaiyakit P was the guarantor, designed the study and writing and revised the article critically for important intellectual content; Wattanapreechanon P participated in data acquisition, data analysis, and data interpretation, initial draft the manuscript, and submission process of the manuscript.

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