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Lateral femoral sliding osteotomy in total knee arthroplasty with valgus deformity greater than twenty degrees

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Abstract

Purpose Lateral femoral sliding osteotomy has been reported as an effective technique for total knee arthroplasty (TKA) with significant valgus deformity. This study aims to investigate its utility in TKA with valgus deformity greater than 20°, for which few studies have examined.

Methods Consecutive TKA patients with valgus deformity treated with the sliding osteotomy at our institution were retrospectively studied. Constraint implants were not used. Radiological and clinical parameters at follow-ups were compared with those pre-operatively. Radiological parameters included the hip-knee-ankle angle (HKA), the anatomical lateral distal femoral angle (aLDFA), the anatomical lateral plateau ankle angle (aLPTA), and the angle between the femoral mechanical axis and transepicondylar line (femoral transepicondylar angle, FTEA) which was used to reflect concurrent extra-articular valgus and corresponding local alignment. Clinical outcome measures included the Knee Society Score and Functional Score.

Results Twenty-five patients operated on between July 2011 and February 2017 were enrolled. The average follow-up time was 3.3 (1.5~7.9) years. The pre-operative HKA of $202.7 \pm 2.3°$ (equivalent to valgus of $22.7 \pm 2.3°$) was reduced to $180.4 \pm 2.3°$ at final follow-ups ($P < 0.001$). The aLFDA, aLPTA, and FTEA were all significantly improved, with the last one increased from $84.2 \pm 1.8°$ to $89.6 \pm 1.6°$ ($t = -11.35$, $P < 0.001$). All clinical scores were significantly improved without major complications.

Conclusions Lateral femoral sliding osteotomy can be effective and safe for TKA with severe valgus deformity greater than 20°.

Keywords Lateral femoral sliding osteotomy · Total knee arthroplasty · Valgus deformity

Introduction

Less than 10% of total knee arthroplasties (TKA) are performed in patients with a fixed valgus deformity [1, 2], for which correcting the soft tissue imbalance between the medial and lateral sides of the knee is critical. For a severe valgus deformity, an extensive release of the lateral supporting structures, such as the lateral collateral ligament (LCL), popliteus tendon, and the iliotibial band (IT band), is typically warranted [1]. Unlike in a varus knee wherein the release of the medial supporting structures can generally be performed in a predictable manner, the release of the lateral structures (especially the LCL) in a valgus knee is somewhat more complicated and its results are less predictable: insufficient release may lead to residual deformity; over-release, on the other hand, may incur postoperative mediolateral instability and, hence, the use of constrained implants [2]. Although using constrained implant in TKA has "excellent and very good" outcomes at short to medium-term follow-ups, its long-term outcomes beyond ten years, including the risk of prosthesis loosening due to increased stress at the bone-implant interface, were unclear [3].

Sliding osteotomy of the lateral femoral condyle—which releases the lateral soft tissues by cutting and moving their underlying bony point of attachment, with or without computer navigation—has been described as a useful technique for soft tissue release in TKA with severe valgus deformity [4, 5]. However, its surgical outcomes were only examined in a very limited number of case series with moderate valgus around 11° [5, 6]. Few studies, as of now, examined the utility of sliding osteotomy in TKA with severe valgus deformity greater than 20°, and the effects of the post-operatively changed transepicondylar line on local alignment of the knee.

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The present study, therefore, examined the surgical outcomes of a consecutive series of patients with severe valgus greater than 20° who underwent TKA using lateral femoral sliding osteotomy by one senior surgeon. Besides the conventional radiological and clinical outcomes, the effect of the osteotomy on concurrent extra-articular valgus was also examined.

Materials and methods

Patients

Following the approval of the hospital ethics committee, the medical records of consecutive patients who underwent unilateral primary TKA using the lateral femoral sliding osteotomy technique at our hospital organization between July 2011 and February 2017 were reviewed. This organization includes five hospitals wherein the registered surgeons in our hospital—a tertiary orthopaedic center—can send surgical patients to, and practice in, the other hospitals within the system. The inclusion criterion of this study was severe valgus of > 20° as shown in standing hip-knee-ankle radiography. Patients with marked medial soft tissue laxity, as revealed by the physical examination applying a gentle valgus force with the knee relaxed in 30° flexion, were not included.

Radiography used in this study included the hip-knee-ankle anteroposterior (AP) and lateral views [7], and Merchant patellar view of both knees. Patients were generally seen, and radiographs were taken at three months, one year, and then annually post-operatively. At the time of this study, all patients were contacted and followed-up again.

Operative procedure

The conventional anterior midline incision and the medial parapatellar approach were used. The proximal tibia and distal femur are prepared as in a conventional TKA without deformity except that if the femoral resection at the lateral condyle end failed to sufficiently remove the cartilage layer due to pre-existing bone defect, it was revised and completed by hand until the subchondral bone is adequately exposed. The IT band was then released subperiosteally from Gerdy's tubercle, and the posterolateral capsule released at the level of the posterolateral margin of the tibia using the inside-out pie-crusting technique. Only if significant soft tissue imbalance—a mediolateral gap asymmetry greater than 5 mm—remains after releasing, the IT band and posterolateral capsule can the sliding osteotomy be considered.

After completing the "four-in-one" osteotomy at the femoral side, the lateral femoral sliding osteotomy, in the sagittal plane perpendicular to the distal femoral cut surface, was performed as described by Brilhault et al. [5], Mullaji et al. [4], and Strauch et al. [6]. However, our osteotomy was started at the lateral one

third of the lateral femoral condyle to ensure a generous cut (Fig. 1). This was to facilitate (a) the release of the lateral soft tissue and (b) the subsequent fixation of the osteotomy block. Using the space created by the osteotomy, the posterolateral joint capsule along the lateral femoral condyle was further released. Then the spacer block was inserted into the tibiofemoral gap, and the osteotomy block moved distally and/or posteriorly, to obtain rectangular (balanced) tibiofemoral gaps in both knee flexion and extension. After a balanced tibiofemoral gap was determined, the trial components were inserted with the knee in 45° flexion, and the osteotomy block was temporarily fixed at this position (Fig. 1). The distal and posterior ends of the osteotomy block were then trimmed to be in keeping with the outline of the femoral component (Fig. 1). The trimmed osteotomy block was then fixed with two or three cancellous screws.

Again, the medial-lateral balance in both flexion and extension was examined before the tibial and femoral components were cemented. Caution was taken not to let the cement enter the osteotomy interface. If any residual imbalance was noted, a modified "pie-crusting" procedure [2], which uses a needle of a 20-cc syringe instead of a lancet, was performed to further "tweak" the structure of tightness by creating multiple pinholes in it. The patella was managed regularly before wound closure.

In all cases, the posterior cruciate ligament was resected, and the posterior stabilization prosthesis was used.

Post-operative management

Drainage and antibiotics were withdrawn within 48 hours post-operatively. Low molecular weight heparin and a mechanical foot-pump system were administered to prevent deep vein thrombosis (DVT). The patients were immediately instructed to start in-bed static quadriceps and active plantar flexion/extension exercises. After drainage removal, the patients were advised to perform active knee extension and straight-leg raise exercises with caution for three days, and then walk full weight-bearing with a long-leg knee brace which was removed after four weeks post-operatively.

Outcome evaluation

Surgical outcomes were evaluated radiologically and clinically, and compared between pre-operatively and at final follow-up.

Five radiological parameters were examined (Fig. 2). The hip-knee-ankle angle (HKA) was defined as the medial angle between the femoral and tibial mechanical axis. The anatomical lateral distal femoral angle (aLDFA) was measured between the femoral anatomical axis and the tangent line of the femoral distal lateral condyle [8]. The anatomical lateral plateau ankle angle (aLPTA) was the angle between the tangent line of the tibial plateau and the tibial anatomical axis [8]. The Insall-Salvati ratio of the knee was defined as described by Meneghini et al. [9], for which a ratio between 0.8 and 1.5 was
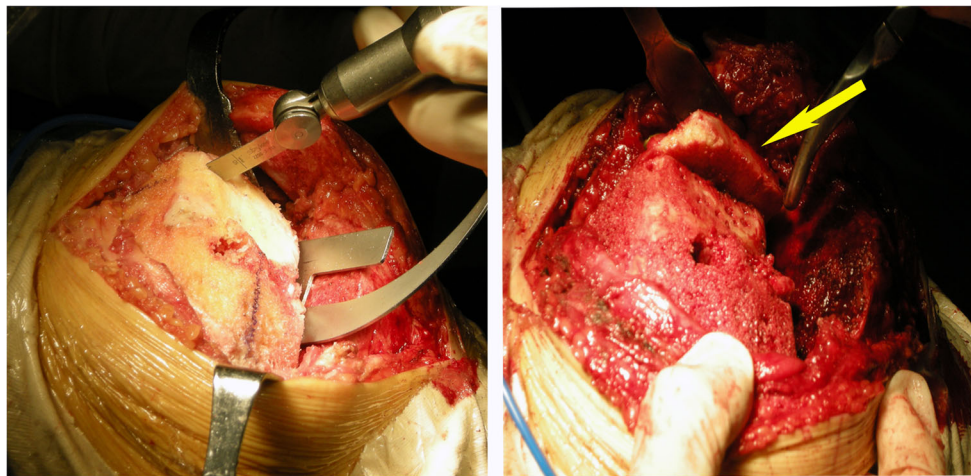
Fig. 1 Intra-operative photos showing the lateral femoral sliding osteotomy. Left: the sliding osteotomy was started at the lateral one third of the lateral femoral condyle to ensure a generous cut. Right: after a balanced tibiofemoral gap was obtained, the trial components were inserted and the osteotomy block (the yellow arrow) was temporarily fixed at this position with the knee in 45° flexion. At this point, excessive bone at the distal and posterior ends of the osteotomy block needed to be trimmed off, according to the outline of the femoral component, before the final fixation of the osteotomy block

considered normal. To examine the changed local alignment due to the osteotomy, a previously reported angle—one between the femoral mechanical axis and the transepicondylar line (femoral transepicondylar angle, FTEA)—was measured as well [10–12]. To some extent, FTEA can reflect the correction of concurrent extra-articular valgus which, from our experience, is frequently seen in severe valgus knees and features a tilted transepicondylar line due to dysplasia of the lateral femoral condyle.

Clinically, outcomes were evaluated using the conventional Knee Society Score and Functional Score. Also, the use of constrained implants, as well as surgical complications, was examined.

Statistical analysis

Descriptive statistics were reported in mean or median, dependent upon whether the data are normally distributed or not. Paired sample t test was used to compare the pre and post-operative data. R version 3.4.3 software (R Foundation for Statistical Computing) was used for data analysis. The α value was set at 0.05.

Results

Patient demographics and intra-operative information

A total of 25 patients were enrolled, including 19 females and six males, with an average age of 63.3 years (range 57~71 years). The average follow-up time was 3.3 years (range 1.5~7.9 years). The primary diagnosis included osteoarthritis in 21 patients and rheumatoid arthritis in four patients. The average pre-operative valgus degree was $22.7 \pm 2.3°$, equivalent to an HKA of $202.7 \pm 2.3°$.

The average operative time was 84 ± 15.6 minutes. All the surgeries used posterior-stabilized prostheses, including Genesis-II (Smith & Nephew, Memphis, TN) in 13 cases, AK (AK Medical, China) in six cases, and Vanguard (Vangard ™, Complete Knee System, Biomet, Inc., Warsaw, IN, USA) in six cases. The average polyethylene thickness was 9.8 ± 1.0 mm (Fig. 3).

Radiological outcomes

Radiological parameters pre-operatively and at final follow-up are listed in Table 1. Overall, significant improvement was noted in all the items. The average HKA was significantly reduced from $202.7 \pm 2.3°$ pre-operatively to $180.4 \pm 2.3°$ at final follow-ups ($t = 34.48$, $P < 0.001$); aLFDA, increased from $74.6 \pm 1.9°$ to $82.4 \pm 1.5°$ ($t = -16.46$, $P < 0.001$); aLPTA, increased from $82.7 \pm 3.3°$ to $89.6 \pm 1.2°$ ($t = -9.87$, $P < 0.001$); and the FTEA, increased from $84.2 \pm 1.8°$ to $89.6 \pm 1.6°$ ($t = -11.35$, $P < 0.001$). The Insall-Salvati ratio did not significantly differ between time points [$0.95 \pm 0.13°$ vs. $0.90 \pm 0.07°$ ($t = 1.64$, $P = 0.11$)]. At the final follow-ups, bony union at the osteotomy site was observed in all the patients.

Clinical outcomes

Constraint implants were not used in this series. The average length of hospitalization was 10.2 ± 1.2 days. The patients' Knee Society Score and Functional Score were significantly improved at follow-ups. The former was increased from 36.5 ± 4.3 pre-operatively to 89.1 ± 2.5 at final follow-ups ($t = -$
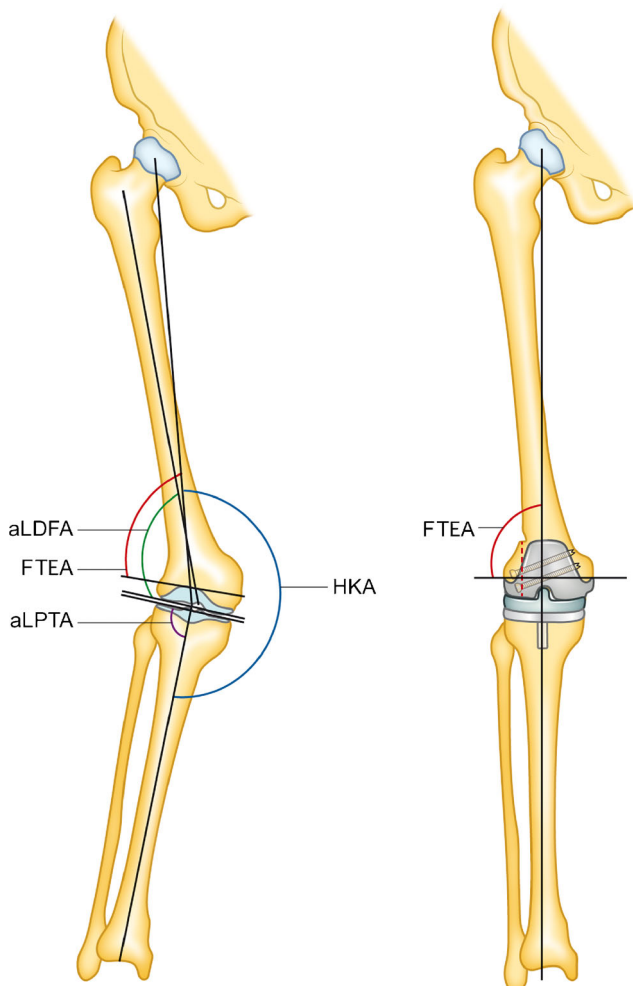
Fig. 2 Radiological parameters for evaluating the outcomes of sliding osteotomy in total knee arthroplasty with severe valgus deformity. The hip-knee-ankle angle (HKA) was defined as the medial angle between the femoral and tibial mechanical axis. The anatomical lateral distal femoral angle (aLDFA) was measured between the femoral anatomical axis and the tangent line of the femoral distal lateral condyle. The anatomical lateral plateau ankle angle (aLPTA) was the angle between the tangent line of the tibial plateau and the tibial anatomical axis. The femoral transepicondylar angle (FTEA) was the angle between the femoral mechanical axis and the transepicondylar line. Post-operatively (right), the FTEA was restored to its physiological status (90°)

53.36, $P < 0.001$); and the latter, from 40.8 ± 4.0 to 86.3 ± 2.5 ($t = -47.6$, $P < 0.001$).

Complications

The post-operative courses were in general uneventful. The rate of peri-operative complications was 8% (2/25), but only included minor ones—transient numbness in the peroneal nerve distribution area in one patient and a suture site infection presented as transient wound exudation in another—both of which resolved with non-surgical treatment. No DVT, pulmonary embolism, irreversible peroneal nerve injury,

periprosthetic infection, or prosthesis loosening were noted during the follow-up periods.

Discussion

In this series of 25 TKA patients with an average of 22.7° (range 20–29°) valgus deformity, the use of lateral femoral sliding osteotomy was able to obtain satisfactory deformity correction and clinical outcomes maintained at an average of 3.3-year follow-up, without using constrained implants. These results preliminarily established the usability of sliding osteotomy in TKA with a higher tier (over 20°) of valgus deformity as compared with that in previous reports [4–6].

Several other surgical techniques have been developed to facilitate the release of lateral supporting structures in valgus TKA, but each has its limitations. The "inside-out" release technique, featured by stepwise iterative release using the "pie-crusting" technique, is not adequate for severe valgus greater than 15° [2]. The lateral femoral epicondylar osteotomy [10], which floats a shingle of bone from the lateral side of the femoral epicondyle but keeps its caudal and cephal ends connected to soft tissues, can obtain more extensive release than a non-osteotomy technique does but, either, has not been well tested in TKA with severe valgus. Also, these techniques did not substantially reduce the use of constrained implants: in a series of 12 TKAs using the latter technique, for example, 42% required using a constraint prosthesis due to soft tissue instability [13]. The sliding osteotomy technique overcomes the limitations of these previous techniques in soft tissue releasing in two ways. First, the "release" is realized by moving freely the osteotomy block—the underlying attachment of the soft tissue—instead of cutting irreversibly the soft tissue and is, therefore, manipulated with greater control and accuracy. This also preserves the integrity of the lateral structures such as the LCL and the popliteus tendon attachment and, thus, further reduces the need for constrained implants. Second, the osteotomy provides a wider surgical view of the posterolateral capsule behind the lateral femoral condyle which facilitates the soft tissue release at this area and reduces the risk of common peroneal nerve injury.

From our experience, two key points should be noted when using this sliding osteotomy technique. First, the osteotomy should be a generous cut starting at the lateral one third of the lateral femoral condyle. This is to ensure a complete mobilization of the attachment of the soft tissue and, at the same time, create a wide surgical space for releasing the posterolateral capsule effectively and safely. A relatively big chunk of osteotomy block also facilitates its later fixation. Second, if needed, the sliding osteotomy can be supplemented by a subsequent "pie-crusting" release procedure to further "tweak" residual structures of tightness. Sometimes, for example, the final fixation of the osteotomy block at 45° flexion may leave

Fig. 3 An illustrative case (case #1). A 65-year-old woman diagnosed with osteoarthritis underwent TKA using lateral femoral sliding osteotomy. On the radiograph obtained 7.9 years post-operatively, the HKA was improved from 201 to 179.5° and the FTEA, from 82 to 90°. According to the clinical notes, she did not have any complications and, at the follow-up, said that she was "very satisfied with surgery"
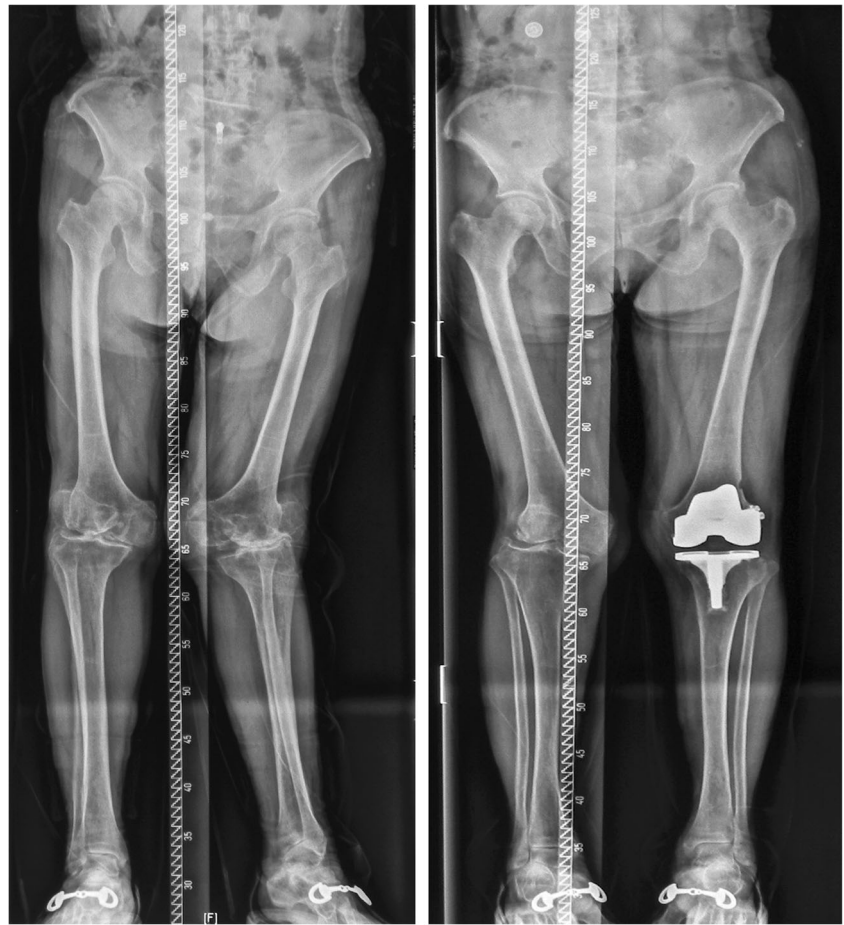
some unbalanced gaps at either 0° or 90°. In such situations, the "pie-crusting" technique can be used to further release the structure of tightness so that soft tissue balance can be optimized throughout the whole range of motion. The minimally invasive nature of the "pie-crusting" technique also helps with reducing the mid-flexion instability of the knee.

This study also examined the utility of the sliding osteotomy in correcting concomitant extra-articular valgus, a quite prevalent comorbidity in TKA patients with severe valgus [14–16]. In our series, all patients had a pre-operative aLDFA less than 81° ± 2°, indicating the involvement of some extra-articular developmental distal femoral valgus [17]. This was ascertained by the frequently seen bony defect at the posterolateral portion of the femoral distal end, the dysplasia of the lateral femoral condyle, and, correspondingly, the valgus of the femoral transepicondylar line relative to the femoral mechanical axis, in this series. From our results, the post-operative local alignment of the structures near the transepicondylar line, as assessed by the FTEA, was well restored to be close to its physiological state of 90° in all the patients, indicating a good correction of pre-operative extra-articular valgus. This result was obviously attributed to the sliding osteotomy

which rebuilt the anatomy of the distal femur. Good alignment at this area of the knee, we believe, is beneficial to the kinematics of the knee and the long-term survival of prosthesis.

It is important to note that although the TKAs in this study were performed through the medial parapatellar approach due to the authors' training, research has established the utility of both medial and lateral approaches in the setting of severe valgus knees [18, 19]. The lateral approach, as described by Keblish [18], provides more direct and better exposure of the lateral and posterolateral structures; it can also almost eliminate the patellofemoral problems associated with, and frequently seen in, a medial approach. A registered prospective randomized trial of valgus knee arthroplasty showed that using lateral and medial approached achieved similar, and satisfying, clinical outcomes on estimated blood loss, pain, functional scores, and wound healing; and the lateral approach was associated with significantly better (lower) post-operative patellar tilt in radiography [19].

The limitations of this study included limited sample size and follow-up time. Other medical complications such as gastrointestinal complications and pneumonia [20] may be omitted. The clinical meaningfulness of

Table 1 Radiological outcomes of the 25 TKA patients with severe valgus knee deformity

Case ID	FU time (year)	HKA (degree)		aLDFA (degree)		aLPTA (degree)		Insall-Salvati ratio		FTEA (degree)	
		Pre-OP	FU	Pre-OP	FU	Pre-OP	FU	Pre-OP	FU	Pre-OP	FU
1	7.9	201	180	72	83	93	91	1.40	1.05	82	90
2	3	209	184	77	82	81	88	0.83	0.82	81	88
3	2.5	202	177	75	86	82	90	0.92	0.85	84	89
4	2	202	176	74	82	78	89	1.05	0.95	84	92
5	4.5	200	182	74	83	77	88	0.84	0.83	85	89
6	3.5	207	182	72	82	80	91	0.97	0.88	83	90
7	2.6	200	181	73	83	82	90	0.91	0.86	83	88
8	2	202	182	74	82	81	89	0.95	0.90	85	90
9	2.3	203	180	73	83	85	91	0.86	0.85	84	89
10	1.5	201	179	77	81	86	90	0.98	0.91	86	92
11	4	201	183	75	81	81	89	1.10	1.06	84	91
12	3.6	203	179	78	80	82	90	0.85	0.88	85	90
13	6.5	205	183	75	80	81	88	0.86	0.88	84	88
14	5.4	204	183	76	82	80	89	0.94	0.92	82	87
15	5.1	203	180	72	81	84	90	0.88	0.85	82	87
16	4.6	201	177	76	84	85	92	0.98	0.96	84	90
17	3.9	202	181	73	82	83	89	1.02	0.98	88	92
18	2.7	204	181	73	80	82	90	0.84	0.82	83	89
19	1.9	206	184	72	82	79	88	0.90	0.87	82	88
20	4.6	200	179	77	84	84	91	0.86	0.86	84	90
21	3.8	203	177	75	83	83	92	0.96	0.94	86	91
22	2.5	200	178	76	84	86	90	0.85	0.83	88	93
23	2.6	203	182	75	85	84	88	1.20	1.06	86	90
24	1.8	204	180	73	82	82	89	0.88	0.84	84	89
25	2.4	201	181	77	83	87	89	0.92	0.88	86	89

FU follow-up; *Pre-OP* preoperatively; *HKA* hip-knee-ankle angle; *aLDFA* anatomical lateral distal femoral angle; *aLPTA* anatomical lateral plateau ankle angle; *FTEA* femoral transepicondylar angle, the angle between the femoral mechanical axis and the transepicondylar line

the changed femoral transepicondylar line after osteotomy, especially its effects on the kinematics of the knee, has yet to be studied, and the radiographic measurements, such as the FTEA, are not able to examine the complex anatomical changes, such as that due to internal rotation or posterior displacement of the femoral condyle, that are frequently seen in severe valgus knees [21]. A more three-dimensional evaluation of the biomechanical alignment in this setting is needed in future studies. In addition, previous literature has mentioned individual TKA patient(s) with a higher degree (36.5°) of valgus deformity who had been treated using this technique. However, with 25 TKA patients who had valgus deformity greater than 20°, our study preliminarily established the effectiveness and safety of the sliding osteotomy technique in TKA with severe valgus at this level. Long-term follow-up studies with more patients are needed to lend more credential to our results.

Conclusion

From our results, lateral femoral sliding osteotomy appears to be an effective and safe technique for TKA with severe valgus deformity over 20°. Satisfactory outcomes can be achieved without the use of constraint implants and the risk of common peroneal nerve injury is low. It also helps with the correction of the commonly combined extra-articular valgus in this patient population.

Compliance with ethical standards

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