CLINICAL ARTICLE

Modified Medial Collateral Ligament Indentation Technique in Total Knee Arthroplasty with Severe Type II Valgus Deformity

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Abstract

Objective: To explore the feasibility and clinical efficacy of a modified medial collateral ligament indentation technique in total knee arthroplasty (TKA) with severe type II valgus deformity.

Methods: Consecutive patients with Krackow type II valgus deformity >20° who underwent a primary unilateral TKA between May 2008 and June 2017 were studied retrospectively. A medial collateral ligament indentation technique was performed in 20 patients (MCLI group), and 23 patients received the routine lateral structures release technique (LSR group). Radiological parameters, such as the valgus angle (VA), and functional outcomes including the use of constraint implants, Knee Society Score (KSS), Knee Society Function score (KSF), and thickness of the polyethylene insert were compared between the two groups.

Results: A total of 43 consecutive patients had a minimum 2-year follow-up. The preoperative VA was comparable between the MCLI (23.5° ± 5.8°) and LSR groups (21.3° ± 3.2°, $P = 0.134$), as was the postoperative VA (1.1° ± 2.1° and 2.5° ± 3.0°, respectively, $P = 0.084$). The mean KSS and KSF scores in the MCLI group were 30.2 ± 4.8 and 38.8 ± 4.8, respectively, before surgery, and they increased to 91.3 ± 2.6 and 86.5 ± 2.4 at the last follow-up. The scores in the LSR group were 31.5 ± 7.5 and 36.5 ± 7.8 before surgery and 92.4 ± 3.5 and 88.5 ± 3.6 at the last follow-up. While no statistically significant differences in pre- or postoperative functional scores were found between the two groups, the MCLI group had thinner polyethylene inserts (9.5 ± 1.1 mm *vs* 12.9 ± 1.5 mm) and less use of constrained condylar inserts (15% *vs* 69.6%). During follow-up, the MCLI group had fewer complications.

Conclusion: A modified MCLI technique can achieve good outcomes in TKA with type II valgus deformity of >20°. It can maintain a normal joint line level, reduce the use of constrained condylar knee prostheses, and is a reliable choice for severe genu valgum.

Key words: Arthroplasty; Constrained condylar knee; Medial collateral ligament; Medial indentation; Valgus

Introduction

Approximately 10% of patients with end-stage arthropathy who have undergone total knee arthroplasty (TKA) have valgus deformities of various degrees[1,2]. The valgus deformity is often accompanied by structural abnormalities of the bones and soft tissues, including contractures of the

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posterolateral joint capsule and lateral collateral ligament, relaxation of the medial collateral ligament (MCL), a bone defect or dysplasia of the lateral femoral condyle, and a bone defect of the tibial plateau. Krackow classified valgus into three types, of which type II is defined as being combined with medial soft tissue laxity, so that the deformity cannot be completely corrected[3]. Treatment of patients with type II valgus is extremely challenging. The valgus further aggravates the relaxation of the medial ligaments, particularly in patients with severe deformity, with a valgus angle >20°. Several reconstructive options can be used to address the soft tissue imbalance in patients with severe valgus deformities treated with TKA.

The first method is relatively simple and involves extensive release of the lateral structures to match the medial side. If medial-lateral balance cannot be achieved, constrained prostheses must be used[4]. Although mid-term clinical outcomes are satisfactory, the incidence rates of prosthesis loosening and instability increase[5]. In addition, comprehensive release of the lateral soft tissue results in the need for a thicker polyethylene insert, which leads to the joint line changing, and increases the possibility of common peroneal nerve injury. A constrained prosthesis not only increases costs but also makes a possible future revision more difficult.

The second method is a tightened suture of the medial ligament or upward restoration of the MCL tension[6]. However, knee joint stability after using this method depends on the healing of the MCL itself, or its contact surface with bones. In addition, significant residual valgus together with the lower limb alignment after surgery may aggravate relaxation of the medial side. Some have adopted an upward sliding osteotomy of the medial epicondyle. However, the isotonic point of the ligament in the flexion-extension gap balancing is not easy to determine during surgery, and changes in the epicondylar axis of the femur may lead to long-term kinematic changes; therefore long-term follow-up of outcomes is needed.

The third method is indentation of the insertion point of the MCL *in situ*. Krackow[7], Whiteside[8], and Healy[9] reported this technique. The advantage lies in the indentation of the ligament *in situ* without changing the epicondylar axis of the femur, and the lateral release can be reduced. A standard thickness insert can be used without using constrained prostheses, and excellent mid-term clinical outcomes have been achieved in all cases. However, there have been only six to eight cases reported, and there may be an unstable fixation of the advanced MCL just through making a knot, with a risk of long-term relaxation of the medial ligament. To optimize the fixation effect, we made some improvements to strengthen fixation on the medial side.

This study investigated the clinical outcomes of a modified technique for indentation of the MCL (MCLI), and explored whether there is any advantage of this technique compared to the traditional lateral structures release (LSR) surgical approach.

We hypothesized that for a severe type II valgus deformity, medial indentation of the MCL with a posterior stabilized arthroplasty would be as effective as the routine release. The modified MCLI technique can achieve satisfactory mid-term outcomes and reduce the use of constrained prostheses and thick polyethylene inserts, thus maintaining the normal joint line level.

Materials and Methods

Inclusion and Exclusion Criteria

From May 2008 to June 2017, 43 patients were considered for enrollment. Inclusion criteria were as follows: (i) adult patients (≥18 years of age); (ii) patients who had end-stage osteoarthritis of the knee with a Krackow type II valgus deformity of >20°; the type of deformity, that is, the identification of medial laxity, was determined by a physical examination in which a gentle valgus force was manually applied on the knee in 20° flexion; (iii) underwent unilateral primary TKA in our hospital. The exclusion criteria were as follows: (i) patients with neuromuscular disorders such as poliomyelitis; (ii) bilateral TKA during the same hospitalization; (iii) revision operation; (iv) patients without a minimum 2-year follow-up period.

Study Items

The baseline demographic information included age, sex, body mass index, diagnosis, and follow-up (Figure 1). Radiographs used included the hip-knee-ankle anteroposterior and lateral views, and Merchant patellar view of both knees. Outcomes were clinically evaluated using the Knee Society score (KSS) and Knee Society Function score (KSF). In addition, the polyethylene insert thickness, constrained implant use, and surgical complications were examined.

Knee Society Score

According to the type of joint replacement surgery, this score evaluates the knee joint and its function in two aspects; to obtain information about joint anatomy and biomechanics, and to understand the functional recovery of the patient. Knee joint evaluation examines the impact of surgery on the joint, and postoperative recovery, including joint pain, joint range of motion, ligament stability, muscle strength, bone alignment, and contracture deformity. The functional assessment includes activities of daily living, walking ability, going up and down stairs, and whether auxiliary appliances are needed. The evaluation was quantified numerically, and scores of knee joint and functional evaluation were obtained.

Knee Society Function Score

The questions used to calculate the functional score involved the patient's ability to walk without an assistive device, walking distance, and the ability to navigate stairs and rise from a seated position without upper extremity support. To calculate the pain score, patients were asked to rate their pain when navigating stairs, walking, and at rest, as none, mild, moderate, or severe.

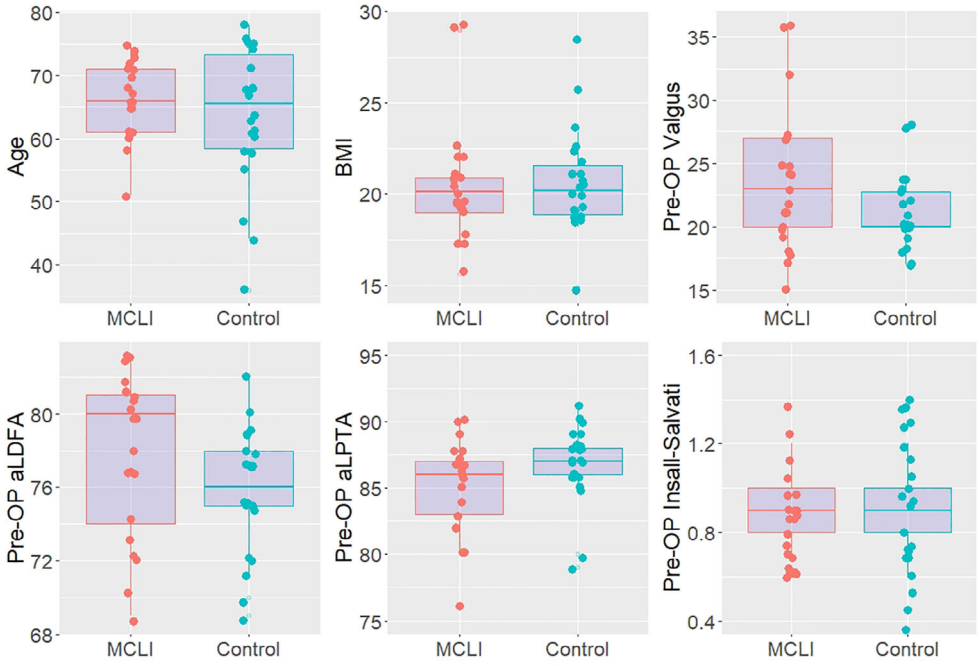

Fig. 1 Comparing patient demographics and deformity parameters between patients with and without MCL indentation technique with valgus deformity. The red points represent patients with MCL indentation technique while the light sky-blue ones represent those without, both plotted against the boxplot showing the median (the thickened horizontal line) and quartiles of a specific patient characteristic. The difference did not achieve statistical significance

Measurement Details

Valgus Angle. The valgus angle (VA) was defined as the angle between the femoral and tibial mechanical axes.

Anatomical Lateral Distal Femoral Angle. The anatomical lateral distal femoral angle (aLDFA) was measured between the femoral anatomical axis and the tangent line of the femoral distal lateral condyle.

Anatomical Lateral Plateau Ankle Angle. The anatomical lateral plateau ankle angle (aLTPA) was the angle between the tangent line of the tibial plateau and the tibial anatomical axis.

Insall–Salvati Ratio. The Insall–Salvati ratio of the knee defined between 0.8 and 1.5 was considered normal.

Patients

This was a retrospective cohort study. Eligible patients were randomly divided into two groups according to the surgical technique used: with (MCLI group) and without (LSR group) the use of the MCLI technique. Two senior surgeons with similar years of independent practice treated the two groups. For both groups, a posterior stabilized prosthesis was used. Study approval was obtained from the IRB of our hospital (ID:M2017106), and all participants provided signed informed consent for surgery.

Surgery

Through an anterior midline incision, the medial parapatellar approach was used to access the joint space of the knee and remove both the anterior and posterior cruciate ligaments. Then bone resections were performed on the femoral and tibial sides. The tibial surface was incised using an extramedullary guide with a 3° posterior tibial slope. The distal femoral surface was resected using an intramedullary guide, and the incision was set in the coronal plane, at a valgus angle according to that between the mechanical and anatomical axes of the femur. Excessive osteophytes on the lateral and posterior sides of the femoral condyle were removed. The size of the femoral component was determined by posterior referencing. Then a 4-in-1 osteotomy was performed with the rotation determined by Whiteside's line and the epicondylar axis. A spacer was used to measure the joint gap in knee flexion and extension. After the osteotomy, residual tibial plateau or femoral condyle bone defects with a depth of <5 mm were repaired by filling them with bone cement, or cancellous bone particles prepared from tibial or femoral osteotomy blocks. Cases requiring repair with metal augmentation for severe bone defects of the lateral femoral condyle were not included in this group. In case of lateral tilting or subluxation of the patella during the operation, the femoral transepicondylar axis was used as a reference to increase the femoral external rotation angle for osteotomy and to release the lateral retinaculum of the patella. If the patella was severely worn, routine patella replacement was performed. However, if the patient's patella was small and accompanied by bone loss, routine patella replacement was not performed. Osteophytes around the patella were removed, the patella cartilage surface was trimmed with a pendulum saw, and the patella periphery was thermally ablated, encircling the site, for denervation. Then the patellar track was detected using the no thumb test.

Medial Collateral Ligament Indentation Group

Lateral Structures Release. A preliminary limited lateral soft tissue release was performed, including the iliotibial band

and posterolateral joint capsule, to the extent that the lateral space could accommodate the thinnest polyethylene insert (Figure 2).

MCL Advancement. The attachment of the MCL at the medial epicondyle was exposed. After drilling with a Kirschner wire, a miniature pendulum saw was used to open a window (1.2×1.0 cm^2) on the bone at the attachment point of the MCL. An embedment device was used to press the cancellous bone inward. A number 5 non-absorbable suture was used for the braided suture of the MCL and then passed through the bone block with a window opening. A guide needle with wire was used to lead the suture thread out of the lateral epicondyle of the femur. The two needle withdrawal points were 1 cm apart. The trial component was placed. The knee joint was flexed by 30°, and the suture thread was tightened and tied for fixation (Figure 2)[9].

Fixation. An interference screw (9 mm × 2.5 cm) was applied to strengthen the fixation at the window opening, a cortical bone screw was drilled into the external epicondyle of the femur, and suture thread was fixed on the bolt at its tail end (Figure 3).

Lateral Structures Release Group

Selective Release. When the lateral structures were tight in knee extension only, we first released the iliotibial band subperiosteally from Gerdy's tubercle using the pie-crusting technique. For Krackow type II valgus patients, iliotibial band release or resection alone was not enough; comprehensive releases of the posterolateral joint capsule, popliteus tendon, and lateral collateral ligament were usually needed using the inside-out pie-crusting technique.

Insert Selection. Stability was evaluated at 0° extension, mid-flexion (30°–40°), and 90° flexion to determine the type of insert needed. A constrained condylar knee (CCK) component was used when the knee was unstable, with a mediolateral gap asymmetry of >3 mm, in any of the positions. If the medial and lateral sides reached balance, a posterior stabilized (PS) polyethylene insert could be used.

Postoperative Management

Drainage was withdrawn within 24 h postoperatively. Low-molecular-weight heparin and a foot-pump system were used to prevent deep vein thrombosis. Patients were instructed to immediately start static quadriceps and flexion-extension exercises. After drainage removal, patients in the MCLI group were advised to perform active knee extension and straight-leg raise exercises with caution, and then walk with toe touch partial weight-bearing and a long leg knee brace that was removed after 6 weeks.

Outcome Evaluation

Surgical outcomes were evaluated clinically and radiologically, and compared preoperatively, at 3 months and 1 year postoperatively, and annually thereafter.

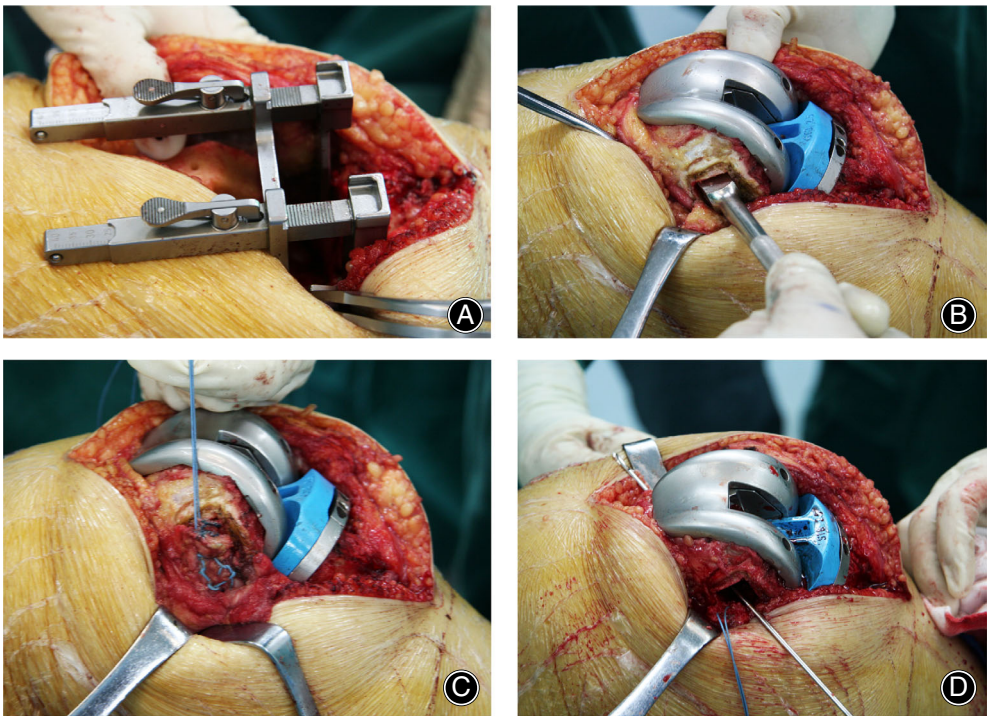

Fig. 2 Intraoperative photos showing the MCL indentation technique. (A) Apparent relaxation of the medial side of the knee after the tensor was stretched. (B) An embedment device was used to press the cancellous bone inward. (C) A number 5 non-absorbable suture was used for the braided suture of the MCL. (D) A guide needle with wire was used to lead the suture thread out of the lateral epicondyle of the femur

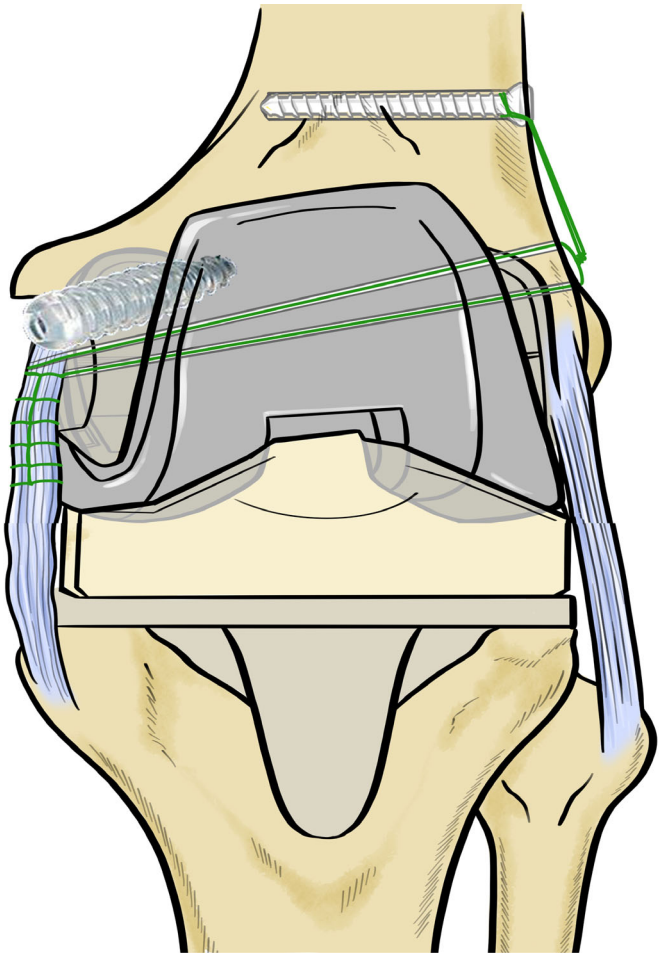

Fig. 3 A schematic diagram of MCL indentation technique. Both needle-withdrawing points were 1 cm apart, and also the suture thread was tightened and tied for fixation. A cortical bone screw was drilled right into the outside epicondyle of the femur, and stitch thread was fixed on the bolt at its tail end. An interference screw was applied to strengthen the fixation at the window opening

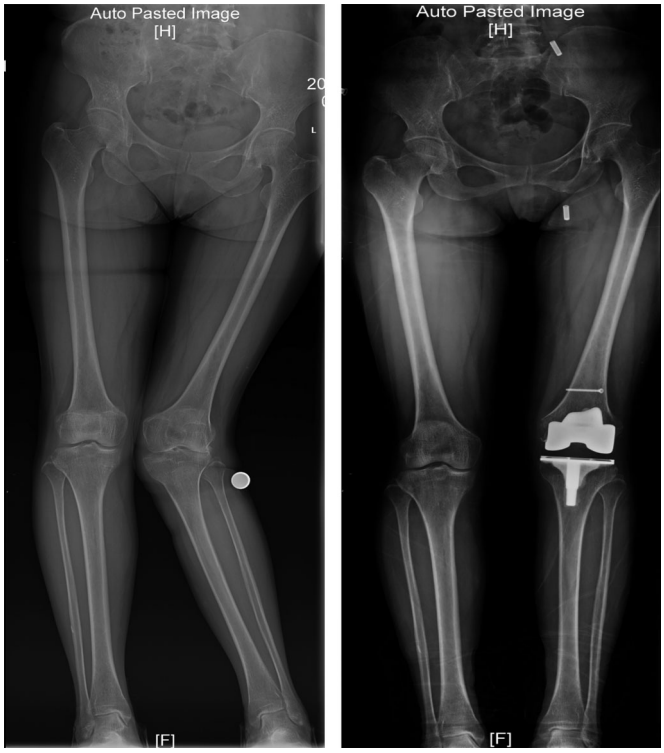

Fig. 4 An illustrative case (Case #1). A 51-year-old woman diagnosed with rheumatoid arthritis underwent TKA using the MCL indentation technique. On the radiograph obtained 2 years postoperatively, the VA was improved from 36° to 3°, and PE thickness was 11 mm. According to the clinical notes, she did not have any complications and, at the follow-up, said that she was delighted with surgery

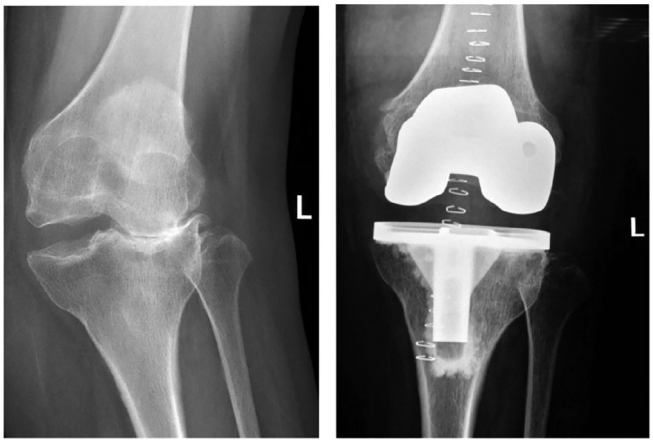

Fig 5 An illustrative case (Case #2). A 72-year-old woman diagnosed with osteoarthritis underwent TKA using the MCL indentation technique

Statistical Analyses

SPSS Version 25.0 software (IBM Corp., Armonk, NY, USA) was used for the statistical analyses. Measurement data conforming to a normal distribution are expressed as mean ± standard deviation, a paired-samples *t*-test was used for intergroup comparison, and enumeration data are expressed as rates. The difference was statistically significant when the *P*-value was <0.05.

Results

The knees of all patients in both groups were type II according to Krackow's classification, indicating a severe valgus deformity. The mean follow-up period was 62.4 months. Clinical details were recorded pre- and postoperatively. We use a goniometer to measure the range of motion. Mediolateral stability was examined at 20° of knee flexion. The KSS and KSF scores were obtained preoperatively and at the last follow-up. The deformity was significantly improved, and the pain was significantly relieved in

Fig. 6 An illustrative case (Case #3). A 64-year-old woman diagnosed with osteoarthritis underwent TKA using the MCL indentation technique. Alteration between preoperative and postoperative radiographs and appearance

TABLE 1 Comparison of several angles by radiography preoperatively and postoperatively(mean ± SD)

Total patients (43 cases)	MCLI group (20 cases)	LSR group (23 cases)	*t* value	*P*-value
Valgus Pre-Op (degree)	23.5 ± 5.8	21.3 ± 3.2	1.528	0.134
Valgus Post-Op (degree)	1.1 ± 2.1	2.5 ± 3.0	−1.768	0.084
aLDFA Pre-Op (degree)	78.0 ± 4.5	75.7 ± 3.3	1.931	0.06
aLDFA Post-Op (degree)	85.4 ± 2.0	82.9 ± 2.8	3.252	0.02
aLPTA Pre-Op (degree)	85.4 ± 3.6	86.6 ± 2.9	−1.204	0.236
aLPTA Post-Op (degree)	89.9 ± 3.5	89.0 ± 2.8	0.984	0.331
Insall-Salvati ratio Pre-Op	0.9 ± 0.1	0.9 ± 0.2	0.112	0.911
Insall-Salvati ratio Post-Op	0.9 ± 0.1	0.8 ± 0.1	0.839	0.407
PE (mm)	9.5 ± 1.1	12.9 ± 1.5	−3.028	0.02

Abbreviations: aLDFA, anatomical lateral distal femoral angle; aLPTA, anatomical lateral plateau ankle angle; PE, polyethylene.

all patients. The mean KSS and KSF scores in the MCLI group were 30.2 ± 4.8 and 38.8 ± 4.8, respectively, before surgery, and they increased to 91.3 ± 2.6, and 86.5 ± 2.4 at the last follow-up. Those in the LSR group were 31.5 ± 7.5 and 36.5 ± 7.8 before surgery, and 92.4 ± 3.5 and 88.5 ± 3.6 at the last follow-up. However, no statistically significant differences in preoperative (KSS $t = 0.481$, $P = 0.752$; KSF $t = 0.392$, $P = 0.631$) or postoperative (KSS $t = 0.449$, $P = 0.930$; KSF $t = 0.143$, $P = 0.782$) scores were found between the two groups. We list three cases to illustrate the MCLI technique (Figures 4–6).

Radiographic Outcomes

The patients' radiological parameters preoperatively and at final follow-up are listed in Table 1. Preoperatively, the mean VA was 23.5° ± 5.8° in the MCLI group and 21.3° ± 3.2° in the LSR group ($t = 1.528$, $P = 0.134$). Postoperatively, the values were 1.1° ± 2.1° and 2.5° ± 3.0°, respectively ($t = -1.768$, $P = 0.084$).

Implant Evaluation

In the MCLI group, 20 knees received a PS implant, including Genesis II (Smith & Nephew, Memphis, TN, USA) in nine cases, A3 Knee (AK Medical, Beijing, China) in eight cases, Depuy-PFC (Johnson & Johnson, USA) in two cases, and Aesculap (Tuttlingen, Germany) in one case. The mean polyethylene thickness was 9.5 ± 1.1 mm. Constrained condylar inserts were used for three patients (15%).

In the LSR group, all surgeries used PS prostheses, including Genesis II in 16 cases, Legion (Smith & Nephew, Memphis, TN) in four cases, Vanguard (Vanguard, Complete Knee System, Biomet, Inc., Warsaw, IN, USA) in two cases, and A3 Knee in one case. The mean polyethylene thickness was 12.9 ± 1.5 mm. Constrained condylar inserts were used for 16 cases (69.6%).

Complications

TKA complications were recorded in detail. Postoperatively, one patient in the LSR group had common peroneal nerve paralysis, decreased skin sensation on the dorsum pedis, and inability to perform ankle joint dorsiflexion. This might be related to nerve traction after the valgus correction, and nerve traction injury caused by seed bone removal during surgery. No special treatment was given, and the symptoms disappeared after 3 months. One patient developed knee joint dislocation 30 days postoperatively and underwent revision with a thicker polyethylene insert. One patient had a periprosthetic fracture due to trauma 1 year after surgery and underwent internal fixation. In the MCLI group, one patient had medial knee joint instability, and the medial laxity exceeded 4 mm during the valgus stress test. Considering that MCL function was weakened, a knee brace was provided for protection, and the symptoms disappeared after 3 months. No cases of infection, prosthesis loosening, or pulmonary embolism occurred during the follow-up period.

Discussion

Reconstruction Methods for Type II Valgus Knee Deformity

Compared to that on the medial side of the knee, controllability of the release on the lateral side of the knee is imperfect, owing to the lack of a soft tissue sleeve. An extensive lateral release may lengthen the lateral structure, which increases the risk for common peroneal nerve paralysis. A larger joint space will require a thicker polyethylene insert, and a lower joint line will cause patella baja[10]. If medial-lateral balance cannot be reached, instability on the medial side will often occur after surgery. If the correction is insufficient, residual valgus may also gradually aggravate the relaxation on the medial side[11]. Some authors believed that constrained condylar knee (CCK) prostheses could avoid this problem. However, the CCK prosthesis is semi-constrained[12,13]. The interface between the prosthesis and the bone cement bears great stress, and the postoperative loosening rate is high[14]. Pour *et al.* believed that the use of higher constrained prostheses such as hinged knees is associated with a high revision rate and relatively large bone defects during revision, which makes revision surgery difficult[15].

Clinical Outcomes of the MCLI Technique

Reconstruction of the relaxed medial side is another option. Some have considered folding the MCL or moving up its attachment point, but stability of the knee joint afterwards depends on the MCL healing[6]. In addition, if significant residual valgus occurs, it may aggravate the laxity on the medial side. The method of MCL indentation used in our research was first proposed by Krackow[3], and was also reported by Healy[9] and Whiteside[8]. Whiteside applied the MCL advancement method in six cases of valgus >25°. He believed that more bone in the distal femur would be removed for the genicular lateral space to accommodate the prosthesis, and relaxation on the medial side would also increase. After the MCLI technique was applied, a 6-year follow-up did not show valgus recurrence or ligament relaxation. Healy reported the outcomes of eight cases of type II valgus for whom MCL reconstruction was performed, with a mean valgus angle of 22.4°, using a cruciate retaining prosthesis in seven cases and a PS prosthesis in one case, all without a constrained prosthesis. After a mean follow-up period of 5.88 years, the valgus angle was corrected to a mean of 5.4°. Despite some residual valgus, no patients had residual medial relaxation. None of the patients had a significant change in the patellar position or tibiofemoral joint line, as measured using the Insall–Salvati ratio technique on lateral radiographs. Healy used non-absorbable sutures to fix the MCL during surgery. Based on Healy's method, we added interference screws to the medial femoral condyle, and bolts of cortical bone screws were added to the lateral femoral condyle at the tail end of the suture. Thus, the effects of multiple fixations can be achieved, while reducing the adverse effects caused by suture breakage.

We found that for type II valgus with severe medial laxity, the MCLI technique is a safe and effective treatment method that can achieve satisfactory function, maintain a normal joint line level, and reduce the use of CCK prostheses. Compared to the conventional LSR group, the MCLI group showed no statistically significant differences in KSS and KSF scores, with thinner polyethylene inserts, and had no common peroneal nerve paralysis. CCK inserts were used in a smaller proportion of patients in the MCLI group than in the conventional LSR group (15% *vs* 69.6%).

Superiority of the MCLI Technique

Advantages of the MCLI technique include the unchanged position of the femur's epicondylar axis, limited release of lateral structures, stabilization of the flexion-extension gap, and the use of a standard thickness insert, with which the original joint line can be maintained. If the medial and lateral sides reach balance, the probability of using a CCK component is decreased. The risk of common peroneal nerve injury is correspondingly reduced when the lateral release range is decreased. In this MCLI group, no cases of common peroneal nerve paralysis were found, while one occurred in the control group. A bone-to-bone contact surface was attained with good bone healing potential after the medial ligament was tightened. The critical points of this technology are to carefully dissect the MCL attachment, separate the bone blocks at the endpoint of the MCL using a miniature electric saw, and separate the two guide pins of the femoral condyle by 1 cm to avoid cutting osteoporotic bone with the suture thread. Among these patients, one still had significant medial relaxation 6 weeks after the operation and continued wearing a brace protection for 3 months. This experience implies that if the overall lower limb alignment is corrected satisfactorily after the TKA and reaches the neutral position, the relaxed MCL would gradually contract, and the instability would be improved accordingly.

Study Limitations

Although this study is by far the largest cohort reported using this method, there were some limitations, including the number of cases and its retrospective nature. If the modified MCLI technique is used, patients must wear braces for 6 weeks after surgery, so the recovery rate will slow down. For cases with a ruptured MCL, or an accidental injury of the MCL during surgery, this technique is not suitable, and the constrained prosthesis is still an effective rescue treatment[16]. In addition, there was a relatively short follow-up time, so there is no conclusion on how the tension of the MCL changes over the long-term. Mechanical stability of the MCL contraction fixation requires further study using biomechanical tests.

Conclusion

A modified MCLI technique can achieve good outcomes in TKA with type II valgus deformity >20°. It can maintain a normal joint line level, reduce the use of CCK prostheses, and is a reliable choice for severe genu valgum.

Acknowledgements

Study approval was obtained from the Clinical Trials and Biomedical Ethics Committee of the Peking University Third Hospital, and all participants signed informed consents for the surgery. F.L. and C.W. contributed equally to this work and should be considered as equal first authors.

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