Treatment Strategies and Clinical Outcomes of Knee Osteoarthritis With Extra-Articular Deformity

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Research article

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Abstract

Objective

To evaluate the methods, indications, and efficacy of the treatment of knee osteoarthritis with extra-articular deformity.

Methods

A retrospective study of eight patients (three males and five females) with knee osteoarthritis complicated with extra-articular femoral deformity from February 2011 to April 2019; with an average age of 62.9 years (range 57 to 70 years). There were eight cases of coronal malformation with a mean angle of 15.5° (range 5° to 24°), and three cases of sagittal deformity with a mean angle of 14.0° (range12–16°). All eight patients underwent total knee arthroplasty (TKA). Three patients underwent femoral osteotomy and one-stage total knee arthroplasty, and one underwent femoral osteotomy and second-stage total knee joint replacement.

Results

The mean follow-up time was 45.6 months (range 2 to 96 months). The average HSS score improved from 41.1 points (range, 28–53) preoperatively to 88.5 points (range, 71–95) at the time of the last follow-up. The average VAS score improved from 6.6 points (range, 3–10) preoperatively to 0.3 points (range, 0–1) at the time of the last follow-up. The average arc of knee motion improved from 66.3° (range 50° to 85°), preoperatively to 104.4°(range 95° to 120°) postoperatively. The average deviation of the mechanical axis of the knee improved from 17.3° (range 13° to 20°) preoperatively to 2.6°(range -6° to 6°) postoperatively. The differences between the preoperative data and postoperative follow-up data were statistically significant (\(P < 0.05\)). At the last follow-up visit, none of the eight patients had postoperative complications such as prosthesis loosening, infection, or deep vein thrombosis of the lower limbs. No bone nonunion, delayed union, or other complications occurred in the four patients with osteotomy.

Conclusion

Although it is difficult and complex to perform TKA surgery in patients with extra-articular deformity, a preoperative surgical plan should be made individually according to the patient’s condition, and if necessary, the mechanical axis of the lower limbs can be effectively restored with the help of computer navigation technology or 3D printing technology, to achieve satisfactory surgical results.

Background

Osteoarthritis (OA) is a common disease, with a predilection for the knee joint, which is the foremost force-bearing articulation. Many studies show that this disease has a high disability rate of 53% [1]. Total knee arthroplasty (TKA) is one of the standard surgeries for the treatment of advanced knee OA, which can effectively relieve the pain and rehabilitate knee joint functions [2]. Advanced knee OA combined with extra-articular deformities of the femur and tibia significantly increases the surgical difficulty. Extra-articular deformity generally refers to the deformity above 5cm from the articular surface, the femoral deformity is higher than the femoral condyle, the tibial deformity is lower than the tibial condyle [3]. Specific causes include malunion after fracture, metabolic bone disease, congenital or developmental abnormalities, or iatrogenic factors. [4]. At present, three different operation plans are widely used: 1. Isolated TKA with soft-tissue balance; 2. Simultaneous extra-articular corrective osteotomy and TKA; 3. Staged extra-articular corrective osteotomy followed by delayed TKA after 8–12 months [4, 5]. In this study, we report a retrospective series of eight TKAs performed for knee OA combined with extra-articular deformity. The results were analyzed to explore the surgical options in such cases and their clinical efficacy.

Patients And Methods

1.1 Preoperative Findings
We selected eight patients who were operated on between February 2011 and April 2019 at the joint surgery department of The Third Affiliated Hospital of Southern Medical University. All patients were diagnosed with knee OA combined with extra-articular deformities. The study population comprised three males and five females, with a mean age of 62.9 years (range, 57–70 years), and mean age of onset of 50.0 years (range, 33–66 years). All eight cases were caused by posttraumatic malunion. The mean time from trauma to admission was 39.4 years (range, 20–58 years). Four patients received conservative treatment after trauma. The other four patients were treated with open reduction and internal fixation. All internal fixation devices were removed before the time of admission.

Standard standing weight-bearing X-ray films of the affected limbs were taken before surgery [6]. Patients were required to adopt a natural standing position for imaging, keeping their limbs as close together as possible, eyes looking straight ahead, patellae facing forward, and toes facing forward. This was an attempt to avoid misjudgment of the deformity caused by femoral physiological anterior bowing or curvature.

Extra-articular deformities may occur in the coronal plane (varus or valgus), sagittal plane (flexion or hyperextension), or axial plane (internal or external rotation). Any individual plane or combination is accepted. The coronal deformity is the most common. Due to the difficulty of axial-deformity measurement, no data on axial deformities were obtained in this study. According to the preoperative imaging examinations, five cases of deformities occurred in the coronary or the sagittal plane and three cases occurred in two planes. The average angle of the coronal deformity was 15.5° (range, 5–24°) and the average angle of the combined sagittal deformity was 14.0° (range, 12–16°). The average offset angle of the line of gravity of the lower limb was 17.3° (13–20°) (Table 1, Figure 1).

1.2 Surgical Technique

Subarachnoid-epidural anesthesia was the first choice. General anesthesia was used if necessary. The median incision of the knee joint was routinely used for surgery. The original incision was preferred for patients with a previous history of knee surgery, to avoid postoperative skin necrosis or excessive scar area, which may lead to postoperative limitation of knee motion.

The location of the femoral deformity was determined by preoperative X-rays. An extramedullary alignment guide was considered if the deformity occurred in the middle of the distal femur, as it could affect the insertion of a femoral extramedullary nail. Meanwhile, in the case of a superior femoral deformity, an intramedullary alignment guide was considered. To ensure the nail gets through the deformity successfully and reduce the impact of deformity on implantation, the site of extramedullary insertion should be determined according to the residual deformity of the femoral coronal anatomical axis. In the case of the varus deformity, the site should be outside the conventional, while for valgus deformity, the site should be located in the medial [7].

Isolated TKA and extra-articular osteotomy were our main surgical options. Each case was prepared by adequate preoperative assessment before operating. The results of the preoperative assessment were used to recommend whether extra-articular corrective osteotomy should be performed. When the chief doctor finds the intraoperative effect of lower extremity power line correction unsatisfactory, osteotomy procedures should be completed through a C-arm X-ray system, deemed necessary as the first step. Next, TKA was performed using an extramedullary alignment guide. A posterior stabilized prosthesis (PS) was the preference. In the case of lateral and rotational instability of the joint as a result of collateral ligament injury or other causes, a constrained condylar knee (CCK) prosthesis was considered.

Extra-articular osteotomy and TKA were performed simultaneously in three cases. Only one staged osteotomy with delayed TKA was performed. Plates and screws for internal fixation were applied in the above cases of the extra-articular osteotomy. Four isolated TKAs were performed in this series. In three cases of femoral deformity located in the lower 1/3 of the femur, TKA was performed using computer navigation technology (iAssist, Zimmer Biomet, Warsaw, IN, USA). In all cases, a posterior stabilized prosthesis was used (Depuy, Johnson & Johnson, New Brunswick, NJ, USA).

1.3 Outcome assessments
Follow-up was conducted at 1, 3, 6, and 12 months after the operation. It was conducted annually if there were no postoperative complications. The main evaluations included: standing weight-bearing X-ray, anteroposterior and lateral films of the knee, range of motion, HSS score, and VAS score. Femoral X-ray (lateral view) was taken in cases of the femoral osteotomy. SPSS (version 22.0; IBM SPSS Statistics for Windows, Armonk, NY, USA) statistical software was used to analyze all follow-up data. The clinical assessment results were analyzed using Student’s t-test, with the significance threshold set at $P < 0.05$.

**Results**

All eight patients were followed up for an average of 45.6 months. The mean HSS score increased from $41.1 \pm 8.2$ preoperatively, to $88.5 \pm 8.5$ at the last postoperative follow-up. VAS pain score improved from an average of $6.6 \pm 2.0$ to an average of $0.3 \pm 0.5$ at the last follow-up. The mean preoperative range of motion was $66.3^\circ \pm 14.3^\circ$, which improved to $104.4^\circ \pm 8.6^\circ$ after the operation. The mean varus angle of the line of gravity of the lower limb improved from $17.3 \pm 2.7^\circ$ to $2.6 \pm 3.8^\circ$. There were statistically significant differences between the above preoperative data and the postoperative follow-up data ($P < 0.05$). The results are listed in Chart 3. Up to the last follow-up, eight patients had no postoperative complications such as prosthesis loosening, infection, deep vein thrombosis, etc. The four patients treated by osteotomy had no complications such as the non-union or delayed union of the bone (Figure 2). In this study, one case was found to have overcorrected lower limb alignment after surgery. The alignment was changed from varus $14^\circ$ to valgus $6^\circ$ after surgery.

**Discussion**

One of the important diagnostic bases of knee OA is clinical symptoms in middle-aged and older people, such as limitation of motion, knee pain, etc. The guidelines of the Chinese Orthopedic Association and the Chinese Rheumatic Association all consider the onset age of knee OA to be $\geq 38$ years [8], while the guidelines of the UK National Institute for Health and Clinical Excellence (NICE) consider the onset age of knee OA to be $\geq 45$ years, and the guidelines of the American Rheumatic Association (ACR) consider the onset age of knee OA to be $\geq 50$ years [9]. According to the above guidelines, the age of onset is roughly defined as over 40 years old. According to the epidemiology of primary OA in people over the age of 40 in China [10], the prevalence rate is 30.1% in those aged 40–49 years, 48.7% in the 50–59 years age-group, 62.2% in those 60–69 years, and 62.1% in those aged over 70. Therefore, OA is more common in people over 60 years of age. The mean age of onset of the eight cases of OA in this study was 50 years old (Chart 4). This was mainly due to the changes in the patients’ femoral and tibial mechanical axes caused by the extra-articular deformity. These changes cause changes in limb alignment which give rise to altered stress distribution of the knee joint and aggravate damage to the normal anatomical structure. This is, therefore, an important factor in the development of knee OA [11, 12].

Knee OA combined with extra-articular deformity is relatively rare. Correspondingly, the difficulty of operation will also increase significantly. The key to successful TKA surgery lies in an accurate soft tissue balance, an appropriate prosthesis, the accurate placement of the prosthesis, and the restoration of limb alignment. Proper soft tissue balance and limb alignment are the basis for good long-term survival after TKA [13, 14]. The deformity can cause abnormal changes to the femoral or tibial anatomic axis. Limb alignment also changes. The anatomic axis on the side of the deformity fails to provide a reference. The direction of intra-articular osteotomy is also affected by extra-articular deformities. This effect is related to the distance from the knee joint and the deformity angle. According to the study of Wolff et al. [15], the closer the location of the femur malformation to the knee and the larger the deformity angle, the greater the influence on the intra-articular osteotomy in the joint.

Differences between individual patients with OA combined with extra-articular deformity are more obvious than in patients with OA alone. Therefore, precise preoperative planning or even the use of surgery computer simulation is of great significance for the accurate individual TKA. The clinical treatment plans are divided into two categories according to whether or not extra-articular osteotomy is to be performed: TKA with extra-articular osteotomy and primary TKA. Both of these surgical options
have their advantages and disadvantages. In clinical practice, surgical plans should be selected according to the specific situation.

TKA with extra-articular osteotomy can be simultaneous extra-articular corrective osteotomy and TKA or staged extra-articular corrective osteotomy and delayed TKA. Osteotomy can effectively reduce or even eliminate extra-articular deformity and restore the anatomical axis of the long bone, with relatively little impact on the soft tissue. A non-restrictive prosthesis would also be given priority. However, the disadvantages of this surgical plan are also obvious: 1. The long length of stay; 2. Long operation time, large operation trauma, and blood loss; 3. Increased risk of postoperative complications, such as deep venous thrombosis, poor incision healing, incisive infection, nonunion of bone after osteotomy, fracture of internal fixation, deformity recovery after osteotomy, etc. [16, 17]. 4. Overcorrection tends to occur in clinical work after osteotomy of extra-articular deformities [18].

Intra-articular compensatory osteotomy can be completed through a single operation, without the need for extra-articular osteotomy. By this approach, postoperative complications such as bone nonunion and fracture of internal fixation caused by osteotomy can be avoided, the operative time and hospitalization time can be effectively shortened, surgical trauma can be reduced, and hospitalization costs can be reduced. However, there are disadvantages: 1. Relatively difficult operation; 2. Intra-articular osteotomy increases bone mass loss and the collateral ligament may be damaged during the operation (Fig. 3); 3. The joint space generally needs to be supplemented by soft tissue release to achieve balance, and excessive soft tissue release may lead to postoperative instability in cases of serious deformity.

At present, the most commonly-used techniques to achieve soft-tissue balance in clinical practice include the following: 1. Sliding osteotomy techniques: the insertion of soft tissue is changed by osteotomy. The bone mass attached to the soft tissue is stabilized by compression with cortical bone screws after a satisfactory flexion and extension gap balance has been obtained. According to Mihalko et al. [19], sliding osteotomy can achieve good postoperative soft-tissue balance, which will not affect the release effect due to the refixation of bone mass. 2. Insall laxity technique: by stripping the tendon insertion site of ligaments or tendons, the length of soft tissue is extended to correct the unbalanced joint space. Studies [20, 21] have shown that this technique can achieve satisfactory long-term follow-up results. 3. Pie crusting technique: this involves poking holes in the tissue to change the tightness of the tissue. Meneghini et al. [22] found through mechanical research that soft tissue tension drops in multiple steps and rebound occur after tissue tension drops, which confirmed the safety of this technique to some extent. However, He [23] and other researchers believe that the difference between pie crusting and the traditional release technique is that the method changes the length of the tissue by damaging the ligament or tendon tissue itself. The long-term clinical effects still need further validation. This technique is recommended in situations in which an imbalance still exists after other laxity techniques have been used.

At present, there is no consensus on the choice of treatment. However, it is generally considered that TKA surgery for extra-articular deformity > 10° is challenging and requires individual preoperative planning. Wang et al. [24] believed that satisfactory short-term postoperative results could be obtained without extra-articular osteotomy when the extra-articular deformity of the femur was < 20° in the coronal plane and extra-articular deformity of the tibia was < 30° in the coronal plane. Cao et al. [4] believed that intra-articular compensatory osteotomy was feasible and effective under the following conditions: 1. The extra-articular deformity of femur or tibia was < 20°; 2. The forward angle of the sagittal plane was <10° and the backward angle was <20°; 3. Patients with rotation deformity < 10° and low levels of activity.

In the treatment of patients with knee OA combined with an extra-articular deformity in our department, an appropriate surgical plan is generally selected based on comprehensive consideration of the angle of extra-articular deformity, the position of the deformity, and the compensatory ability of the joint. We believe that intra-articular osteotomy combined with soft tissue balance in TKA is feasible when the following conditions are met: 1. Coronal plane deformity of the femur < 15°, coronal plane deformity of the tibia < 20°; 2. The forward angle of sagittal plane deformity < 10° and backward angle < 20°; 3. Rotation deformity < 10°.
With the development of scientific technology in recent years, a large number of new technologies have been applied to orthopedic surgery. Computer navigation-assisted TKA can improve the accuracy of limb alignment, improve the accuracy of prosthesis placement [25], effectively control blood loss, and shorten the operation time. However, the long-term postoperative clinical effect of navigation technology on TKA remains unclear. Studies [13, 26] in recent years found that 3D printing can provide more precise preoperative plans and more accurate three-dimensional structure cognition. Patients can obtain satisfactory postoperative prosthesis positioning and better limb alignment. However, 3D printing technology is not yet sufficiently mature. The biggest limitation is the inability to evaluate the soft tissue balance in advance, making it impossible to guide the intraoperative soft tissue balance.

Conclusions

Although OA of the knee joint combined with an extra-articular malformation is relatively rare clinically, such malformations affect the anatomical and mechanical axes of the lower limbs, making the operation more difficult. Adequate preoperative preparation is important for the accurate implementation of TKA. Intra-articular compensatory osteotomy results in less trauma, fewer postoperative complications, and faster recovery. Therefore, intra-articular compensatory osteotomy + TKA is the preferred surgical method. If conditions permit, computer navigation technology is recommended to assist osteotomy. Considering the angle and location of femoral malformations, if intra-articular compensatory osteotomy fails to achieve satisfactory surgical results, extra-articular osteotomy combined with TKA can be considered. If conditions permit, 3D printing technology can be used to assist osteotomy correction. All the eight patients in our study were followed up after the operation and showed satisfactory postoperative efficacy, so the surgical plan of this study is feasible. However, the number of cases included in this study is small, and the number of patients with multiple plane malformations is small. The surgical plan to treat knee OA with complex extra-articular malformations needs to be further studied.

Abbreviations

TKA: total knee arthroplasty; HKA: hip knee ankle; 3D: three-dimensional; BMI: body mass index; ROM: range of motion; HSS: Hospital for Special Surgery; VAS: Visual Analogue Score; OA: osteoarthritis;

Declarations

Author contributions

Xinjie Wang, and Jiabang Huo collected the data. Yufan Bu and Mingzhen Tao were the major contributors in writing the manuscript. Guangxin Huang and Haiyan Zhang analyzed and checked all preoperative results. Yufan Bu and Mingzhen Tao were responsible for analyzing the data. Daozhang Cai and Chang Zhao reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

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

Ethics approval and consent to participate

The study was approved by the local institutional review board.

Consent for publication
Written consents for publication were obtained from all study participants.

**Competing interests**

The authors declare that they have no competing interests.

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Tables

Chart1  Clinical data
| Case | Gender | Age | Extra-articular deformity | Pre-op Diagnosis | Years | Site | Plane | Deformity | Post | Strategy | Type of implant |
|------|--------|-----|--------------------------|------------------|------|------|-------|----------|------|----------|-----------------|
| 1    | M      | 70  | Fracture Malunion        |                  | 44   | Distal 1/3 femur | Coronal | 13°      | 20°  | TKA (intra-articular bone resection) | PS              |
| 2    | F      | 60  | Fracture Malunion        |                  | 51   | Proximal 1/3 femur | Coronal | 19°      | 14°  | TKA (extra-articular correctional osteotomy) | PS              |
| 3    | M      | 61  | Fracture Malunion        |                  | 20   | Middle 1/3 femur  | Coronal | 24°      | 18°  | TKA (extra-articular correctional osteotomy) | PS              |
|      |        |     |                          |                  |      |                  | Sagittal | 14°      |      |                      |                 |
| 4    | F      | 61  | Fracture Malunion        |                  | 44   | Middle 1/3 femur  | Coronal | 5°       | 13°  | TKA (intra-articular bone resection) | PS              |
| 5    | F      | 58  | Fracture Malunion        |                  | 25   | Distal 1/3 femur  | Coronal | 8°       | 19°  | TKA (intra-articular bone resection) | PS              |
| 6    | F      | 69  | Fracture Malunion        |                  | 58   | Distal 1/3 femur  | Coronal | 13°      | 18°  | TKA (intra-articular bone resection) | PS              |
| 7    | F      | 57  | Fracture Malunion        |                  | 38   | Proximal 1/3 femur | Coronal | 22°      | 20°  | Staged extra-articular correctional osteotomy | PS              |
|      |        |     |                          |                  |      |                  | Sagittal | 16°      |      |                      |                 |
| 8    | M      | 67  | Fracture Malunion        |                  | 35   | Distal 1/3 femur  | Coronal | 20°      | 16°  | TKA (extra-articular correctional osteotomy) | PS              |
|      |        |     |                          |                  |      |                  | Sagittal | 12°      |      |                      |                 |

HKA: hip-knee-angle; HSS: hospital for special knee score; VAS: visual analog scale/score; M: month; “+”: varus; “−”: valgus

Chart 2 Follow-up data
| Case | ROM (°) | HKA(°) | VAS | HSS | Complications | Follow-up period (Months) |
|------|---------|--------|-----|-----|---------------|-------------------------|
|      | Pre-op  | The last follow-up | Pre-op | The last follow-up | Pre-op | The last follow-up |               |
| 1    | 50      | 110     | 20  | 2   | 6            | 0           | 36          | 90            | not available | 94 |
| 2    | 75      | 100     | 14  | -6  | 7            | 0           | 44          | 95            | not available | 23 |
| 3    | 70      | 95      | 18  | 2   | 6            | 0           | 47          | 71            | not available | 31 |
| 4    | 50      | 95      | 13  | 4   | 6            | 1           | 33          | 95            | not available | 17 |
| 5    | 70      | 110     | 19  | 6   | 10           | 0           | 28          | 95            | not available | 15 |
| 6    | 85      | 100     | 18  | 3   | 3            | 0           | 53          | 83            | not available | 2  |
| 7    | 50      | 120     | 20  | 6   | 8            | 0           | 43          | 94            | not available | 87 |
| 8    | 80      | 105     | 16  | 4   | 7            | 1           | 45          | 85            | not available | 96 |

**Chart 3 Analysis of patient data**

| Evaluation Indicators | Pre-operation | The Last follow-up | P-Value |
|-----------------------|---------------|--------------------|---------|
| HSS scores           | 41.1±8.2      | 88.5±8.5           | 0.001   |
| VAS scores           | 6.6±2.0       | 0.3±0.5            | 0.001   |
| ROM                  | 66.3±14.3     | 104.4±8.6          | 0.001   |
| Offset               | 17.3±2.7      | 2.6±3.8            | 0.001   |

Statistical significance between groups was considered at P<0.05.

**Chart 4 Analysis of patient data**

| Gender | Age of admission | Process\Years| Age of onset | Age of injury |
|--------|------------------|--------------|--------------|--------------|
| Male   | 70               | 4            | 66           | 26           |
| Female | 60               | 5            | 55           | 9            |
| Male   | 61               | 20           | 41           | 41           |
| Female | 61               | 20           | 41           | 17           |
| Female | 58               | 25           | 33           | 23           |
| Female | 69               | 8            | 61           | 11           |
| Female | 57               | 8            | 49           | 19           |
| Male   | 67               | 13           | 54           | 32           |

**Figures**
Figure 1

a. The normal lower limb force line is connected from the center A of the femoral head to the midpoint C of the talus, and the line segment AC passes through the center B of the knee joint; b. When the femoral coronal varus deformity occurs, the force line of the lower limbs can pass through the medial articular surface of the knee joint, aggravating the wear of the medial articular surface of the knee joint and leading to the varus knee; c. The angle between line AB and line BC is the angle of the lower limb force line offset, which is defined as HKA (hip-knee angle).

Figure 2

A 61-year-old male patient with osteoarthritis of the left knee with malunion of the middle femur, osteotomy of the femur with one stage TKA. a. Preoperative coronal deformity of 24 °; b. Preoperative sagittal deformity of 14°; c. 8 months after the
osteotomy, the lower limb force line returned to normal and the osteotomy site healed.

Figure 3

A represents the center of the femoral head, B represents the center of the knee joint, M represents the medial collateral ligament, and L represents the lateral collateral ligament. The osteotomy line is a straight line perpendicular to the mechanical axis ab of the femur through the femoral condyle. a The lateral collateral ligament is complete, and compensatory osteotomy can be considered; b The lateral collateral ligament may be damaged during the operation, and the correction of intra-articular osteotomy is not considered.