Clinical Efficacy of Unicompartmental Knee Arthroplasty in the Treatment of Spontaneous Osteonecrosis of the Knee

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Abstract

Background

This retrospective study aimed to evaluate the short-term effectiveness of unicompartmental knee arthroplasty (UKA) in the treatment of spontaneous osteonecrosis of the knee (SONK).

Methods

The patients who were diagnosed as SONK and received UKA in our hospital from January 2012 to January 2018 were retrospectively analyzed. The patients were diagnosed and staged by X-ray and MRI techniques before surgery. The range of motion (ROM), femorotibial angle (FTA), and visual analog scale (VAS) score of patients' knee joints were assessed before and after surgery. Clinical outcomes were evaluated by the hospital for special surgery (HSS) knee score.

Results

A total of 18 patients with spontaneous osteonecrosis (4 males and 14 females; mean age: 62.5 years) met the inclusion criteria participated in this study. According to the Mont grades, 12 cases (66.7%) were in stage III, and 6 cases (33.3%) were in stage IV. The average follow-up was 19.6 months. At the last follow-up, it was found that the hospital for HSS score was increased from 61.22 ± 2.90 to 91.0 ± 2.89 ($P < 0.05$); VAS score was decreased from 6.44 ± 1.04 to 1.94 ± 0.99 ($P < 0.05$); FTA was improved from 178.42 ± 0.84 to 176.17 ± 0.87 ($P < 0.05$); ROM (120.17 ± 5.88) was not significantly different from that before surgery (119.61 ± 5.56, $P = 0.601$).

Conclusion

The encouraging results of this study indicate that UKA has an excellent short-term clinical effect in the treatment of SONK.

Introduction

Knee osteonecrosis is defined by necrosis of the bony structures, including femoral condyle, tibial plateau, and patella, that constitute knee joint[1]. The knee joint is the second most common site of osteonecrosis after the femoral head, accounting for appropriately 10% of osteonecrosis[2]. According to the characteristics and clinical manifestations of osteonecrosis, osteonecrosis of the knee joint can be divided into spontaneous osteonecrosis and secondary osteonecrosis. In 1968, Ahlback and colleagues[1] first described spontaneous osteonecrosis of the knee (SONK) as an independent disease. Up to date, the etiology and pathogenesis of SONK are still inconclusive, but subchondral bone microfracture or local blood circulation disorder have been widely considered as the two causes of this disease[3–5]. The typical patients with SONK are mostly middle-aged and elderly women (over 55 years old), who have three times the incidence rate compared to males. It has been reported that the occurrence of osteonecrosis is not related to the risk factors, such as alcohol abuse, corticosteroid treatment history,

and hematologic diseases[6]. The main clinical feature of SONK is sudden severe knee pain, usually limited to the medial side of the knee joint, and patients can often clearly describe the exact time of the onset of pain[7].

Unicompartmental knee arthroplasty (UKA) has been proved to be a practical approach for the treatment of single compartment lesions of the knee joint[8, 9], which only treats the diseased compartment and retains sufficient bone mass, anterior and posterior cruciate ligament, thereby improving proprioception[10]. SONK is often characterized by single compartment involvement, and the lesions are mostly confined to the medial femoral condyle. In the early stage, SONK typically involves one single medial compartment, rather than affecting multiple compartments, the pathophysiological characteristics of which are similar to those of anteromedial osteoarthritis[11]. Therefore, UKA could be considered as an appropriate therapeutic approach for this indication. A number of clinical studies have been reported on the application of UKA on SONK[12, 13]. However, the effectiveness is still controversial.

UKA has been started to be performed on SONK patients in our hospital since 2012. To investigate the effectiveness of UKA as a treatment of SONK, we retrospectively analyzed the follow-up data of patients who were diagnosed with advanced SONK, aiming to assess the short-term clinical efficacy of UKA for the treatment of SONK, and to explore intraoperative precautions and technical points of UKA for the treatment of SONK.

Materials And Methods

Clinical data

This study was approved by the Ethics Committee of the Second Affiliated Hospital of Shanxi Medical University. Written informed consent was obtained from all patients who participated in the study.

The clinical data of patients who were diagnosed as SONK and treated with UKA from January 2012 to January 2018 in our hospital were retrospectively collected. According to the clinical information, the third-generation Oxford cement prosthesis (Oxford® Unicompartmental Knee,Biomet, UK) was selected for the knee replacement; the femoral side was spherical Cobalt-chromium-molybdenum alloy single column prosthesis; the tibial side was a smooth horizontal grooved prosthesis; the tibial plateau prosthesis was fixed with bone cement with the polyethylene mobile bearing between them.

Diagnostic criteria of SONK

Diagnostic criteria of SONK are listed as follows: a. the pain of medial joint line of the knee joint; b. The weight-bearing area of the affected femoral condyle is slightly flattened indicated by X-ray, and the translucent area of local necrosis of subchondral bone is surrounded by a sclerotic band; c. The high signal of adipose tissue of the femoral condyle is replaced by a discontinuous middle, and low signal in the subchondral area on T1 weighted MRI scan, and the necrosis high signal shadow is surrounded by reactive edema band on T2 weighted image.

Inclusion and exclusion criteria

Inclusion criteria: a. The lesion was limited to the medial compartment, while the lateral compartment and patella-femoral compartment were normal or slightly degenerated; b. The joint was stable, while anterior, posterior cruciate ligament, and collateral ligament were intact; c. The Mont stage of osteonecrosis of the knee joint was at stage III or above; d. The range of motion of knee joint was greater than 90°, the flexion contracture was less than 15°, while the varus deformity was less than 10°; e. Effectiveness was not observed after more than three months of conservative treatment.

Exclusion criteria: a. Multi-compartments or anterior cruciate ligament injury; b. Secondary osteonecrosis of the knee joint with definite inducement; c. Intolerable operation and anesthesia with major underlying diseases; d. Rheumatoid arthritis, Charcot's disease, and traumatic arthritis; e. The Mont stage I-II; f. Core decompression, arthroscopic microfracture, autologous osteochondral transplantation or high tibial osteotomy had been performed prior to this study.

A total of 18 patients (18 knees) were enrolled, including 4 males and 14 females, with an average age of 62.5 (range, 52–73) years and body mass index (BMI) of 24.7 (range, 23-26.6) kg/m2. All lesions were located in the medial femoral condyle, including 10 cases on the right and 8 cases on the left. According to the Mont osteonecrosis stage system listed in Table. 1, 12 cases were at stage III, and 6 cases were at stage IV.

Table.1 Mont staging classification system

Stage	Imaging features
I	X-ray is normal, positive findings are found at radionuclide scanning and MRI
II	X-ray shows sclerosis or cystic change, the shape of the distal femur or proximal tibia is normal
III	X-ray shows subchondral bone collapse and crescent sign
IV	X-ray shows secondary degenerative changes of the articular surface, such as joint space stenosis

Surgical methods

Anesthesia and positioning. After spinal or general anesthesia, patients were in a supine position. The hip was flexed 30°, while the thigh was placed on a special bracket. The knee joint was in flexion state to ensure that the passive flexion of the knee joint was at least 120° during the operation. The thigh tourniquet was used to control bleeding and improve vision.

Incision and exposure. The knee was flexed 90° to take the medial parapatellar approach. The upper end was flat on the upper edge of the patella. The lower end was 2 cm below the joint line. The patella was

not everted, while part of the sub-patellar adipose tissue and medial osteophyte was removed. The integrity of anterior cruciate ligament and lateral articular cartilage were examined.

Osteotomy. The tibial side osteotomy was performed by an extramedullary positioning method, which maintained a 7° posterior angle and avoided damage to the medial collateral ligament and cruciate ligament during the operation. The femoral side osteotomy was conducted using the intramedullary positioning method. The posterior condyle osteotomy was performed at 6° valgus, and distal bone was carefully ground to completely remove the necrosis. After curettage, remaining small bone defects were filled with bone cement. On the other hand, large bone defects were suppressed and filled with autologous bone graft.

Prosthesis implantation and incision closure. The suitable femoral and tibial test models were selected to measure the balance of knee joint extension and flexion gap at the 20° and 90° flexion position of the knee. After checking the alignment of the patellar trajectory and lower limb, the prosthesis was fixed in a 45° flexion position with bone cement. The hemostasis was thoroughly performed by a loose tourniquet, and pulse pressure irrigator was used to rinse the joint. The cocktail analgesic mixture was injected into the surrounding soft tissue. No drainage tube was placed. Suture, bandage, and elastic bandage were carried out in sequence.

Rehabilitation

All patients underwent the operation according to the same protocol. Antibiotics were administered intravenously for 24–48 h after the operation. Conventional multimodal analgesia was used. Low molecular weight heparin was subcutaneously injected or orally taken with rivaroxaban to prevent deep vein thrombosis of lower limbs. Immediately after the operation, patients participated in the active contraction of the quadriceps muscle and ankle pump training. On the second day, patients started to have knee flexion and straight leg lifting exercise, followed by walker-assisted walking two days later. One week after the operation, they started going up and downstairs.

Evaluation of clinical efficacy

The patient's clinical symptoms, signs, and joint range of motion were recorded. The full-length weight-bearing anteroposterior position of both lower limbs was used to measure FTA, thereby assessing the alignment of lower limbs. The VAS score was used to evaluate the degree of pain. The HSS knee score scale was used to assess clinical efficacy. In addition, complications were recorded.

Statistical analysis

SPSS software (version 26.0; SPSS, Chicago, IL) was used to perform statistical analysis. The data were expressed by mean ± standard deviation. The statistical significance of differences in continuous data was compared using a paired data t-test. All statistical data were two-sided and evaluated at a 5% level of significance.

Results

Clinical follow-up

The average follow-up time was 18.4 months, ranging from 13 to 24 weeks. One week after the operation, the passive flexion of the knee joint could reach 90°. After two months, the knee joint could perform active and painless flexion to the maximum angle.

In this study, SONK lesions were in the medial femoral condyle, including 10 cases on the right and 8 cases on the left (Fig. 1). According to the Mont stage classification, there were 12 cases (66.6%) at stage III and 6 cases (33.3%) at stage IV. The average proportion of necrotic area in the involved femoral condyle was 35.42%, ranging from 29.26–42.61% (Table 2). The preoperative HSS knee score was 61.22 ± 2.90, which was increased to 91.00 ± 2.89 at the last follow-up ($P < 0.05$). The VAS scores before and after the operation were 6.44 ± 1.04 and 1.94 ± 0.20, respectively, which showed a significant decrease after the surgery ($P < 0.05$). The averaged range of motion of the knee joint was 120.17 ± 5.88°, ranging from 115° to 128°. No significant difference was observed before and after the operation ($P = 0.601$) (Fig. 2). The HSS score of all patients was higher than 85 at the last follow-up, with 100% of the excellent and good rate.

Table 2
Patient demographic data

Stage	Imaging features
I	X-ray is normal, positive findings are found at radionuclide scanning and MRI
II	X-ray shows sclerosis or cystic change, the shape of the distal femur or proximal tibia is normal
III	X-ray shows subchondral bone collapse and crescent sign
IV	X-ray shows secondary degenerative changes of the articular surface, such as joint space stenosis
Variable	**Value**
Number of patients	18
Male/female	4/14
Age at surgery (year)*	62.5 ± 6.01
BMI*	24.7 ± 1.14
Follow-up (months)*	18.4 ± 3.45
The proportion of necrosis area to the femoral condyle	35.42 ± 2.36
Lesion area	18
MFC	0
MTP	
Right/left	10/8
Mont grade	0
I	0
II	12
III	6
IV	
*Values are expressed as mean ± SD	
MFC = medial femoral condyle; MTP = medial tibial plateau.	

Imaging follow-up

During the follow-up period, three patients had radiolucent lines under the tibial prosthesis, the widths of which were less than 2 mm. After two years of follow-up, no significant change was observed in the

radiolucent lines, while no evidence of prosthesis loosening was found. Therefore, the radiolucent lines were considered physiological radiolucent lines. There was a significant difference between preoperative FTA 178.42 ± 0.84° and last follow-up FTA 176.17 ± 0.87°. There was no apparent sign of prosthesis loosening, meniscus dislocation, prosthesis subsidence, contralateral compartment progressive osteoarthritis, or osteolysis (Fig. 3).

Complication

All patients did not occur incision infection, deep vein thrombosis, or severe nerve and vascular injury. Only one patient with a large necrotic area (Fig. 4) developed unexplained knee pain 6.5 months after the operation. No obvious abnormality was found based on the imaging examination. Symptoms were improved after local injection.

Discussion

UKA has been proved to be an effective method for the treatment of single compartment knee osteoarthritis, which retains the kinematic characteristics of the normal knee joint. In comparison with total knee arthroplasty, UKA exhibits less surgical trauma, less bone loss, short recovery period, and a good range of motion as its advantages[14, 15]. A large number of successful applications of UKA have been reported recently, and the 10-year survival rates of the prosthesis are up to 99.8%[8]. Foran and colleagues[16] reported that UKA had a 15-year survival rate of 93% and a 20-year survival rate of 90%. In 2015, Pandit[17] followed up 1000 patients who undertook UKA for 15 years and concluded that the 10-year and 15-year prosthesis survival rates were 94% and 91%, respectively. However, there are still few reports on the clinical efficacy of UKA in the treatment of SONK, which may be related to the low incidence of SONK. According to statistics, the cases of joint replacement attributes to SONK account for only 0.05–7% of all knee arthroplasty[18, 19]. The incidence rate of SONK is 3.4% in people over 55 years old and 9.4% in people aged 65[20].

At present, the best treatment for SONK is still controversial, while the treatment selection mainly depends on symptoms, stage of the disease, and size of the lesion[7, 21]. For many patients at an early stage, who have no apparent clinical symptoms, a small range of injury, and no collapse of the articular surface, conservative treatment can usually lead to better clinical outcomes. Juréus et al.[22] reported that, after following up 40 patients for an average of 9 years and evaluating the natural course and long-term effects of SONK, they suggested that the size of osteonecrosis could predict the outcome. Aglietti et al.[4] indicated that conservative treatment is not valid when the necrotic focus area is more significant than 5 cm2 or the width is more than 40% of the femoral condyle involved. Soucacos et al.[21] demonstrated that patients with imaging stage I ~ II can be treated conservatively, while patients with stage III ~ IV should be treated more actively if articular cartilage has collapsed. The typical surgical treatment approaches include arthroscopic debridement of the articular cavity, autogenous cartilage transplantation, core decompression, high tibial osteotomy, UKA, and total knee arthroplasty (TKA).

Although SONK can also occur in the lateral condyle of the femur or tibial plateau, the most common necrotic area is still the weight-bearing surface of the medial condyle of the femur. When SONK develops to late-stages, e.g., Mont stage III-IV, it often accords with the characteristics of single compartment lesions. UKA is a suitable surgical choice, which has been demonstrated to be effective in treating osteoarthritis and SONK in recent literature[23]. Servien et al.[18] prospectively compared 33 cases of SONK and 35 cases of knee osteoarthritis with an average follow-up of 5 years. It was found that the preoperative functional score of the SONK group was significantly lower than that of the osteoarthritis group. Still, the postoperative pain degree, knee score, and functional evaluation of the two groups were similar. The two groups showed identical 10-year survival rates (93% vs. 95%). Langdown et al.[24] retrospectively analyzed the clinical data of 29 knees with spontaneous osteonecrosis of the medial compartment treated with UKA and compared with 28 cases of osteoarthritis in the same period. The patients were followed up for an average of 5 years, ranging from 1 to 13 years. No significant difference was observed between the two groups.

In addition, it has been suggested that TKA may produce better results than UKA in the treatment of SONK. However, the studies were not performed rationally, which might lead to unreliable results[25]. Myers et al.[26] discussed the clinical efficacy of TKA and UKA in the treatment of SONK through literature review in 2006. They said that both surgical methods had achieved sound clinical effects after 1985. On the other hand, poor outcomes of UKA in the treatment of SONK mainly attributed to secondary osteonecrosis of patients who enrolled in the studies before 1985. In recent years, the improvement of surgical techniques, the development of prosthesis design, and the strict selection criteria have led to the significantly improved clinical efficacy and long-term survival rate of UKA[27]. Although TKA was not used as a control group in the current work, our practice has indicated that the late stage of SONK is entirely consistent with single compartment disease, while UKA treatment provides positive outcomes, thereby additional TKA is not required.

Choy et al.[28] retrospectively analyzed the data of 21 cases (22 knees) with SONK. The average follow-up period was 70.3 months, ranging from 48 to 93 months. The average HSS score was increased from 64.3 points before the operation to 92.0 points at the last follow-up. The average flexion angle was increased from 138.6° before the operation to 145.6° at the last follow-up. FTA was changed from 0.98° varus preoperatively to 3.22° valgus postoperatively, with an average correction of 4.2°. On the other hand, 84.2% of patients could complete squat, and 90.5% of patients could complete cross-leg movement. Guo et al.[29] performed UKA on 27 patients with SONK. During the average follow-up period of 27.8 months, there were no severe complications occurred. The VAS score of pain was decreased from (6.9 ± 0.9) points before the operation to (2.0 ± 1.1) points at the last follow-up. Additionally, the HSS score increased from (61.3 ± 9.7) points to (93.0 ± 4.8) points at the last follow-up. The overall satisfaction rate was 96.3%. Improved knee joint function, alleviated pain symptoms, and enhanced limb alignment were observed in this study, which exhibited similar results with other UKA studies.

Few reports have been published on the complications of UKA in the treatment of SONK. Bruni et al.[12] followed up 84 patients with SONK for an average of 98 months. A total of 10 patients underwent

revision surgery: four cases were caused by the sinking of the tibial prosthesis; three cases attributed to aseptic loosening of the tibial prosthesis; one case was due to aseptic loosening of the femoral prosthesis; one case was due to medial tibial fracture; one case was due to prosthesis infection. None of these patients underwent revision because of the progression of osteoarthritis to the lateral and patellofemoral compartment of the knee joint. No severe postoperative complications were observed in this study. However, the provided evidence is limited according to the short follow-up time. One patient developed unexplained pain again in the medial knee joint 6.5 months after the operation and was treated with local block treatment. One year after the surgery, the pain symptoms were improved, but there was still occasional mild pain. It was found that after the necrotic bone tissue was removed during the operation, the defect became larger based on the data of this case. We thus consider that the pain may be related to massive necrosis, intra-articular soft tissue adhesion, synovitis, and other factors.

It is worth mentioning that the surgical performing techniques of UKA in the treatment of SONK and knee osteoarthritis are not entirely consistent. First, typical SONK is often accompanied by bone defects on the weight-bearing surface of the medial femoral condyle. If the defect is not correctly identified, it will cause the distal grinding bolt to be inserted too deeply, grind out more bone, and make the flexion and extension gap unbalanced[29]. Secondly, when the necrotic area is large, and collapse is deep, the dead bone should be scraped off rather than being grinded in a wide range to retain sufficient bone mass. Finally, the necrotic bone becomes hard around it, which is difficult to grind and easily causes residual necrotic bone. If the prosthesis is installed on the necrotic bone, it may result in early failure. Therefore, the scraping of necrotic focus is critical. Small residual bone defects can be filled with bone cement, while significant bone defects can be filled with autologous bone graft[30–32]. In the current study, most of the necrotic foci were removed by conventional osteotomy. Two cases of small residual lesions after conventional osteotomy were filled with bone cement after curettage. No loosening or subsidence of prosthesis was observed during the follow-up period.

However, there are still several potential limitations of this study. First, the current study was a retrospective study of a single institution without a control group, which may easily cause selection errors. Secondly, only 18 UKA were identified as late-stage SONK. The low incidence rate of SONK in the population is responsible for the small patient size. Finally, the follow-up time was relatively short, while more long-term studies are required to identify possible complications, such as loosening and revision.

Conclusion

Based on this study, UKA used for medial unicompartmental SONK is a reliable surgical approach with excellent clinical and imaging outcomes and satisfactory short-term results. However, the determination of long-term survival rates will need further follow-up.

Abbreviations

UKA

Unicompartmental knee arthroplasty

SONK

Spontaneous osteonecrosis of the knee

ROM

Range of motion

FTA

Femorotibial angle

VAS

Visual analog scale

HSS

Hospital for special surgery

TKA

Total knee arthroplasty

Declarations

Availability of data and materials

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

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Contributions

LI H have made substantial contributions to conception and design of the study, written the manuscript; LI H and LIU T earched literature, extracted data from the collected literature and analyzed the data; ZHANG M revised the manuscript; All authors approved the final version of the manuscript.

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Ethics declarations

Ethics approval and consent to participate

The protocol for the study has been approved by the Human Ethics Committees of the Second Affiliated Hospital of Shanxi Medical University. Written informed consent to participate was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest.

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Figures

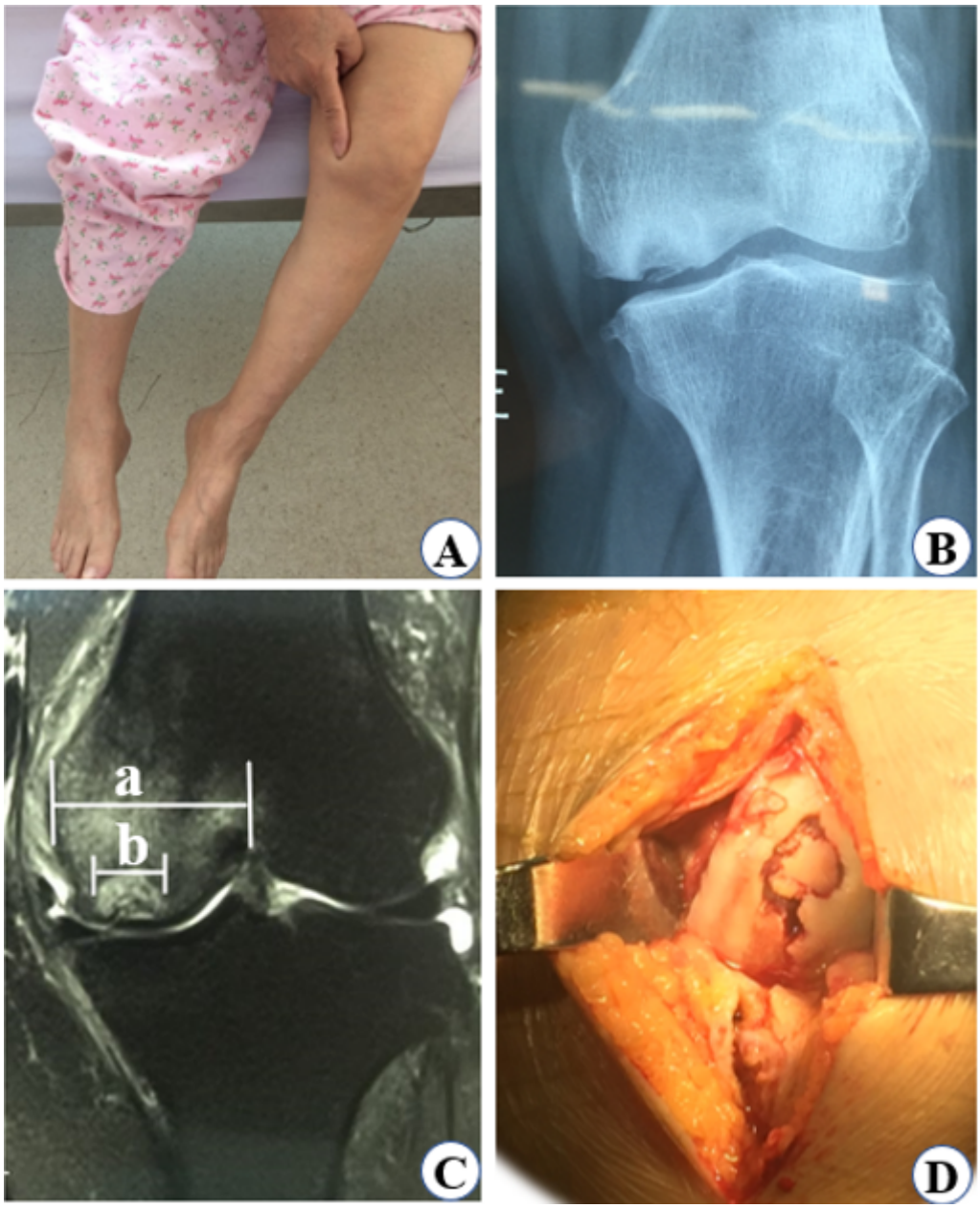

Figure 1

A representative case of a 65-year-old woman with SONK of the medial femoral condyle. (A) The pain site was limited to the medial side of the knee, with obvious nocturnal pain. (B) The preoperative X-ray exhibited a focal translucent area in the weight-bearing area of the femoral condyle. The articular surface collapsed and was surrounded by sclerotic bone. The b/a ratio represents the ratio of lesion width to the condyle. (C) Coronal T2WI showed localized hyperintensity. (D) Necrosis of the femoral condyle was found during the operation.

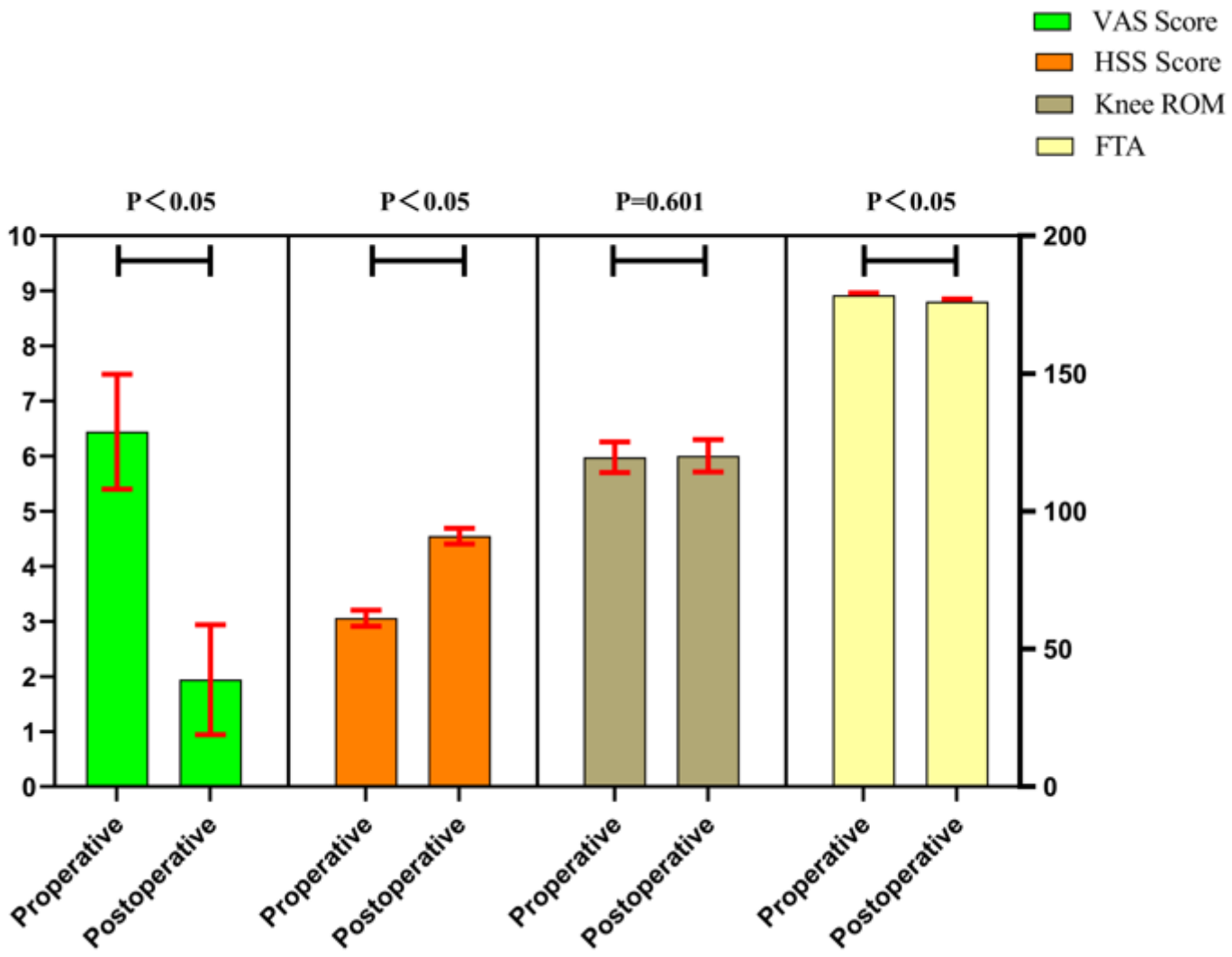

Figure 2

Comparison of main indices before and after the operation

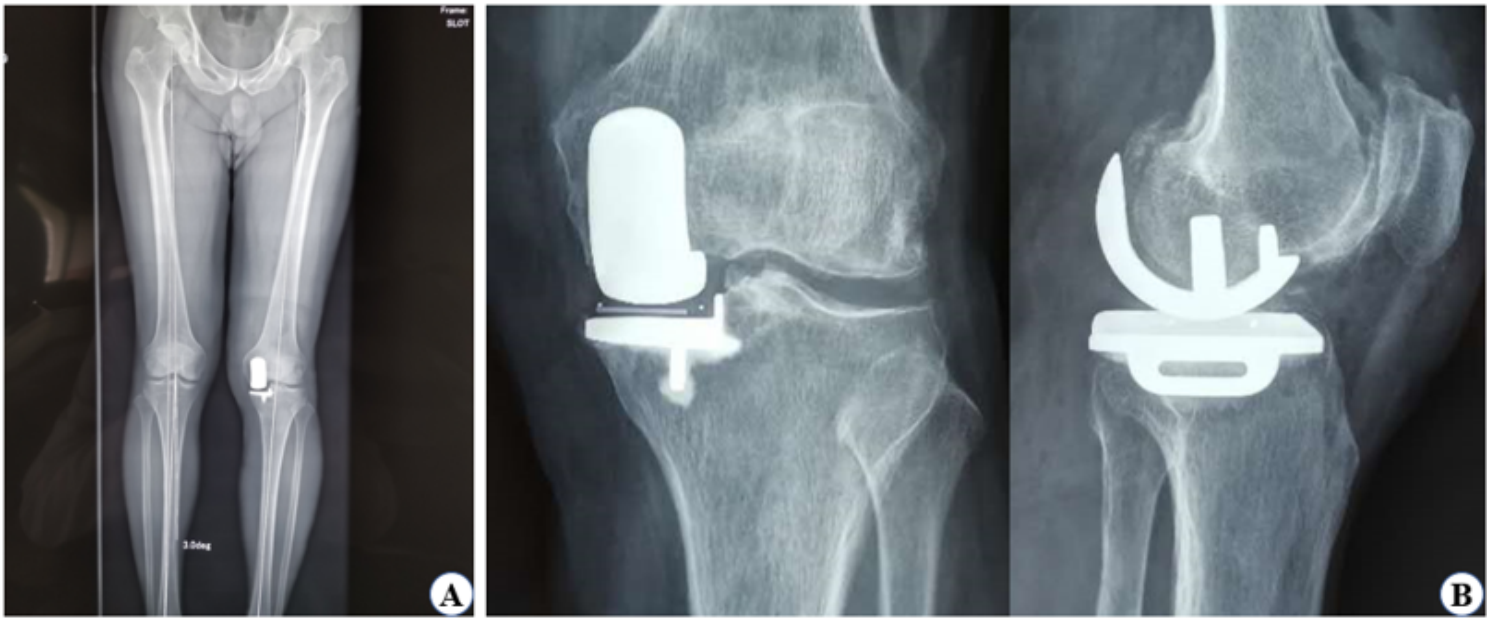

Figure 3

(A) 20 months after the operation, WBL of left lower limb passed through the center of the knee joint. (B) Image of anteroposterior shows a good component position.

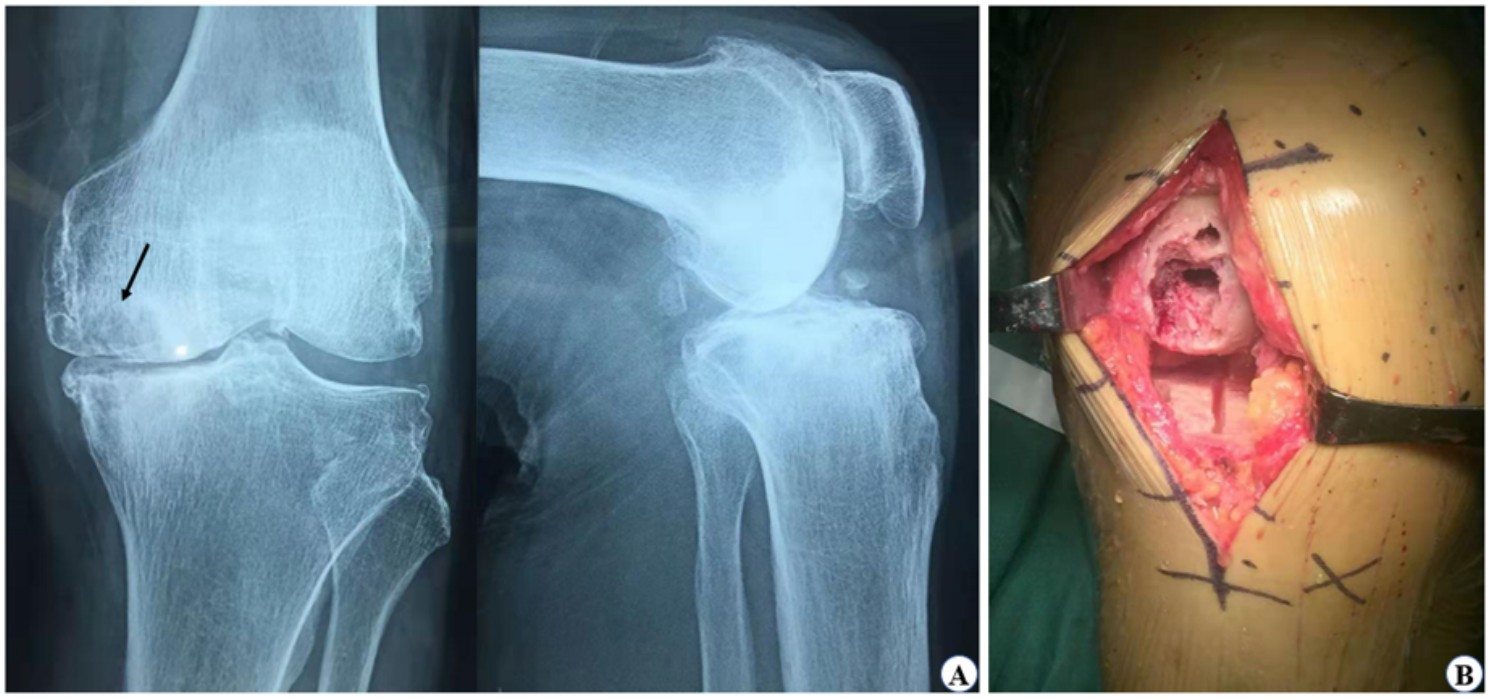

Figure 4

A Preoperative X-ray showed a large area of low-density lesions with sclerosis around the medial femoral condyle (black arrow) B Large residual defect after curettage of necrotic bone tissue