

## CLINICAL ARTICLE

# A Mid-term Follow-up Study on the Reimplantation of Autoclaved Femoral and Tibial Components as Spacers for Treating Infected Total Knee Arthroplasty

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**Objective:** Infection after total knee arthroplasty (TKA) is a rare but devastating complication. Different types of spacers have been used in two-stage revision. The study aimed to evaluate the effect of autoclaved femoral and tibial components as spacers for treating periprosthetic infections after TKA.

**Methods:** A retrospective study was performed for 13 patients (five males, eight females) with a mean age of  $69 \pm 6$  (range, 57–80) years and suffering from periprosthetic infection after TKA. They were treated with unconventional two-stage revision from May 2008 to June 2017. In the first-stage surgery, the autoclaved femoral and tibial components were reimplanted with a new liner as a spacer after a thorough debridement. After 4–6 months, the second-stage surgery was performed according to the patients' requirements. The knee society score (KSS) and knee range of motion (ROM) were assessed before and after surgery. The reinfection rate was calculated.

**Results:** The mean duration of follow-up was  $5.7 \pm 2.1$  (range, 3.1–8.8) years. Culture-positive infections comprised 69% of the cohort. All patients were able to walk 24 h after the first stage surgery, and the knee ROM could reach  $90^\circ$  in 1 week. Two patients (15.4%) experienced an infection recurrence. One patient was reinfected 1 year after the first stage surgery. Another patient developed reinfection 3 years after surgery but did not choose re-revision and died of pneumonia. Only one patient underwent the second stage revision. The remaining 10 patients refused to receive a new prosthesis. At the time of the final follow-up, six patients had slight pain in the knee while walking, and one patient required crutches to walk. There were no signs of prosthesis dislocation, rupture, deep vein thrombosis, pulmonary embolism, or delayed wound healing. No radiolucent lines or osteolysis were found. The mean KSS improved from  $51 \pm 10$  (range, 35–63) points preoperatively to  $79 \pm 5$  (range, 60–85) points at the final follow-up. The average ROM before and after the first stage surgery were  $62^\circ \pm 29^\circ$  (range,  $10^\circ$ – $100^\circ$ ) and  $104^\circ \pm 9^\circ$  (range,  $90^\circ$ – $120^\circ$ ) ( $t = 4.659$ ,  $P < 0.01$ ) respectively. The infection control rate was 84.6%.

**Conclusion:** Reimplantation of the autoclaved original femoral and tibial components as an articulating spacer during the first stage surgery is a valuable addition for treating an infected TKA.

**Key words:** Arthroplasty; Component; Disinfection; Infection; Replantation; Spacer

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## Introduction

Periprosthetic joint infection (PJI) is a devastating complication of total knee arthroplasty (TKA). Although surgical and aseptic techniques have progressed, PJI occurs in 1%–2% of the TKA cases.<sup>1,2</sup> PJI is a significant problem for patients and surgeons because of its relatively high incidence, severity of symptoms, and difficulty of operation. The treatment of PJI mainly includes using chronic suppressive antibiotics, irrigation and debridement with retention of components, resection arthroplasty, one-stage or two-stage revision, and remedial measures such as arthrodesis and amputation.<sup>3,4</sup> Among these methods, two-stage revision is considered the gold standard with infection control rates of 85%–100%.<sup>5–8</sup>

Different spacers have been advocated for treating infected knee arthroplasty in a two-stage revision: static spacers, articulating spacers, and antibiotic-loaded acrylic cement spacers. Antibiotic cement was initially formed as a static spacer with a limited range of motion (ROM). Static spacers are generally effective at infection control. However, they suffer from bone loss, instability, the difficulty of exposure during second-stage surgery, and complications resulting from prolonged immobility.<sup>9,10</sup> Spacers with articulating components were introduced to address these concerns. Articulating spacers are not superior at infection control compared to static spacers and may cause prolonged operation time and additional costs. Yet, their popularity has increased due to their better postoperative ROM, less bone loss, and better patient-rated function during the two-stage revision in comparison studies.<sup>5,10,11</sup>

The use of original prosthesis as an articulating spacer in two-stage revision surgery has been reported. Hofmann *et al.*<sup>12</sup> first reported 26 cases of infection after TKA. In this study, the femoral and tibial components were removed, and the femoral component was autoclaved and reinserted along with a new polyethylene liner fixed using antibiotic-impregnated bone cement. After the first-stage surgery, patients generally ambulated with a walker or crutches, allowing 50% weight bearing on the affected limb. New femoral and tibial components were used during the second-stage surgery. This surgical method effectively controlled the infection while maintaining good joint movement. Recently, some scholars achieved comparable good results using Hofmann's method.<sup>11,13</sup> However, retaining autoclaved prosthesis in two-stage revision is controversial; there are limited data on patients that maintained the tibial component as the spacer.

Therefore, this study evaluated the clinical efficacy of treating periprosthetic infections after TKA using autoclaved femoral and tibial components as the spacers. The surgical method and the clinical and imaging results were reported. The study aimed to determine whether this method could improve postoperative pain and function, have acceptable eradication of infection, and have tolerable outcomes demonstrated by patients who retained their spacers indefinitely as functional knee implants.

## Patients and Methods

### Study Design

The ethics committee of Nanfang Hospital, Southern Medical University approved the study (No.: NFEC-2016-096), and a retrospective review was performed. From May 2008 to June 2017, 13 patients (13 knees; five males, eight females) with infections after TKA were selected; their mean age was  $69 \pm 6$  (range, 57–80) years. They were treated using articulating antibiotic spacers prepared from autoclaved femoral and tibial components.

### Inclusion and Exclusion Criteria

The inclusion criteria were: (i) primary TKA infection; (ii) knee pain and limited movement; and (iii) treatment with two-stage revision surgery with original prosthesis. Patients with diseases known to induce severe immunity deficiencies, such as a malignant tumor, nephrotic syndrome, systemic lupus erythematosus (SLE), HIV infection, and organ transplantation, were excluded from the study. Patients with rheumatoid arthritis or diabetes were included.

### Diagnosis of Infection

The diagnosis of infection was based on the criteria by Parvizi *et al.*<sup>14</sup> It was mainly analyzed by the presence of positive cultures from either preoperative joint aspiration or intraoperative tissue and fluid samples. In four cases (31%), the cultures were negative, and the infection was diagnosed by the presence of knee pain with a deep draining sinus tract. The preoperative X-ray indicated prosthesis loosening and periprosthetic radiolucent lines. Inflammatory markers like erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), synovial white blood cell count, polymorphonuclear differential cell count were elevated. Gross purulence was encountered within the joint, and positive intraoperative histopathologic tissue indicated acute inflammation. Infection types were divided into an early infection (less than 3 months), delayed infection (3 months to 2 years), and late infection (more than 2 years) based on the postoperative time until the onset of infection symptoms.<sup>15</sup>

### First-stage Surgery

All patients were operated on by the same senior surgeon. All components and any remaining bone cement were removed carefully to minimize bone loss in the first-stage surgery. Bone defects were evaluated based on the Anderson Orthopaedic Research Institute (AORI) classification<sup>16</sup>: one case belonged to type I, four cases belonged to type II A, and eight cases belonged to type II B. The original femoral and tibial components were subsequently cleaned of any residual cement and autoclaved for 30 min. Thorough irrigation and debridement (I&D) of the bone and soft tissue was performed using a bacitracin-impregnated solution and a complete synovectomy; the collateral ligaments were carefully spared. The joint fluid and inflammatory tissue specimens were collected intraoperatively for bacterial culture. The

antibiotic-impregnated bone cement was prepared in a ratio of 2 g vancomycin to 40 g bone cement. After partially curing the bone cement to a dough state with reduced fluidity, the autoclaved tibia and femur components were implanted in the bone bed to avoid the cement penetrating the trabecular bone and causing bone loss.

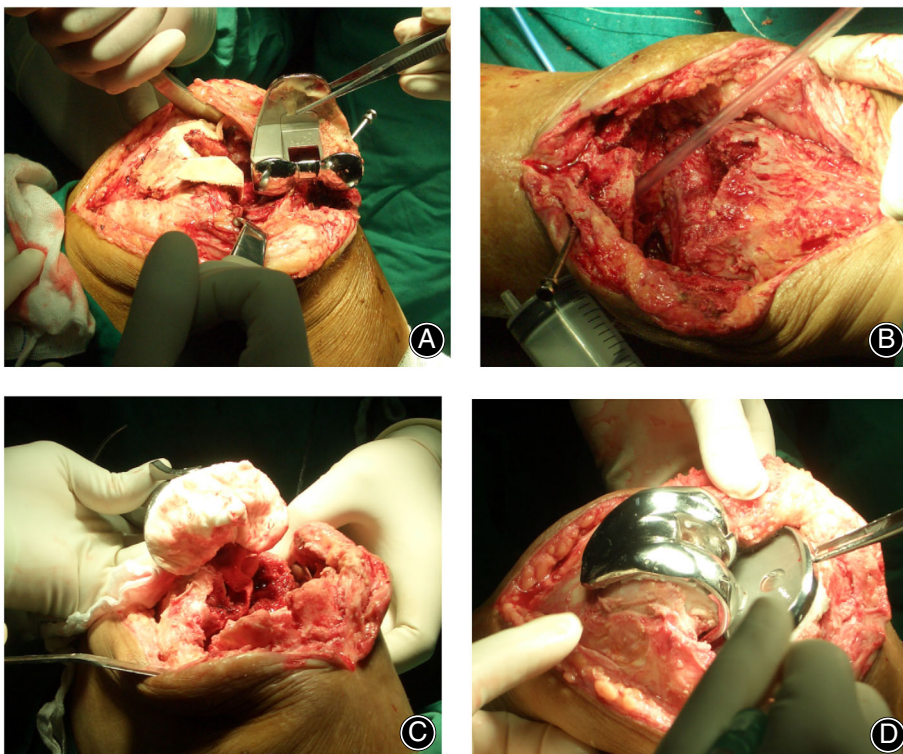
According to the test model, an appropriate size of new polyethylene liner was placed to create proper tension in the collateral ligaments. The limb was fully extended, allowing the femoral and tibial components to seek their own level. The bone defect was solved by bone cement. Care was taken to prevent the cement from adhering to the bony surfaces by occasionally toggling the component until the cement was fully cured. The cement was applied early to the components and late to the femur and tibia to allow molding to the defects and bone without adherence to the bone. This method ensured the prevention of further damage to the bone bed in the second-stage surgery after removing the prosthesis (Fig. 1). The wound was sutured in one stage, and 3–4 suction drainage was used. The wound was flushed until a clear drainage fluid was obtained to prevent hematoma formation in the joint, and the necrotic tissue was removed.

Patients generally ambulated by the second postoperative day with a walker or crutches, allowing the affected limb to bear the weight. Continuous passive motion (CPM) was given, and the knee was allowed a gentle but complete unrestricted range of motion under guidance. The wound healing of the patients was carefully observed, and the blood routine parameters, CRP, ESR, and other inflammatory

factors were regularly reviewed. All patients continued the tailored intravenous antibiotic therapy 6–8 weeks after surgery. According to the drug sensitivity reports, nine patients (69%) exhibited positive bacterial culture results and were administered sensitive antibiotic treatment. The remaining four patients with localized joint infection symptoms and elevated blood inflammatory factors were treated with broad-spectrum antibiotics encompassing the viable bacteria. After 4–6 months, the blood inflammation factors were tested, and a knee X-ray was taken.

### Second Stage Surgery

After the infection was controlled, the second-stage surgery was performed according to the activity level, presence of comorbidities, and requirements of the patients. Reimplantation with a new total knee prosthesis occurred only after careful intraoperative evaluation. During this time, the joint was examined for purulence, and frozen tissue samples were evaluated for acute inflammation. A new prosthesis was implanted if the infection was well controlled, and no residual infection was observed during the operation. The restricted total knee prosthesis was used in the second-stage surgery. The prosthesis was fixed with vancomycin antibiotic-impregnated bone cement in the same ratio as first-stage surgery. However, the prosthesis was firmly combined with the bone bed at this time. Any evidence of persistent infection led to repeated procedures of I&D and sterilizing the original prosthesis as a spacer; this was



**Fig. 1** Intraoperative photography. (A) The femoral and tibial components of an infected TKA were removed. (B) Thorough irrigation and debridement of bone and soft tissue was performed. (C) After partially curing the bone cement to a dough state, molded it to the defects and bone without adherence to bone. (D) Reimplanted the autoclaved femoral and tibial components with antibiotic-impregnated bone cement

followed by reimplanting a new prosthesis in the second-stage surgery after infection control.

### Follow-Up

Both clinical and radiological evaluations were performed during the follow-up. The Knee Society Scores (KSS) were determined before surgery and final follow-up. Other clinical parameters assessed were knee ROM, ESR, CRP concentrations, and complications, whereas the radiological follow-up included checking for radiolucent lines and osteolysis.

### Evaluation Indexes

#### The Knee Society Score (KSS)

The KSS evaluated the postoperative recovery of the knee based on pain, stability, and range of motion. The KSS scores of 80–100 were classified as excellent, 70–79 as good, 60–69 as fair, and <60 as poor.<sup>17</sup>

### Inflammation Markers

CRP and ESR parameters were selected to monitor the recurrence of patient infection. An elevated ESR (>30 mm/h) or a high level of CRP (>10 mg/L) indicated inflammation. Patients underwent monthly tests while they continued antibiotic treatment, and the CRP and ESR levels were examined at each follow-up session.

### Radiological Evaluation

Radiological evaluation was performed using standard standing anterior–posterior and lateral views and a full-length radiograph of the lower extremity. The serial radiographs were evaluated for radiolucent lines and osteolysis (indicating component

loosening) according to the Modern Knee Society Radiographic Evaluation System and Methodology.<sup>18</sup>

### Statistical Analysis

Skewed distributed data were expressed as median (inter-quartile range). SPSS 22.0 (IBM, Armonk, NY, USA) statistical software was used for statistical analysis. The preoperative and postoperative knee ROM and KSS scores were compared using paired t-test, and  $P < 0.05$  was considered statistically significant.

## Results

### General Results

All 13 patients were followed up as described above (Table 1). The mean duration of follow-up after first stage surgery was  $5.7 \pm 2.1$  (range, 3.1–8.8) years. According to the classification criteria, there was no early infection; delayed infection was observed in four cases and late infection in nine cases. The distribution of pathogenic bacteria in the 13 patients was as follows: *Staphylococcus epidermidis* in four patients, *Staphylococcus aureus* in three patients, *Streptococcus verticm* in one patient, *Staphylococcus saprophyticus* + *Enterococcus faecalis* in one patient. Four patients (31%) were negative for pathogenic bacteria.

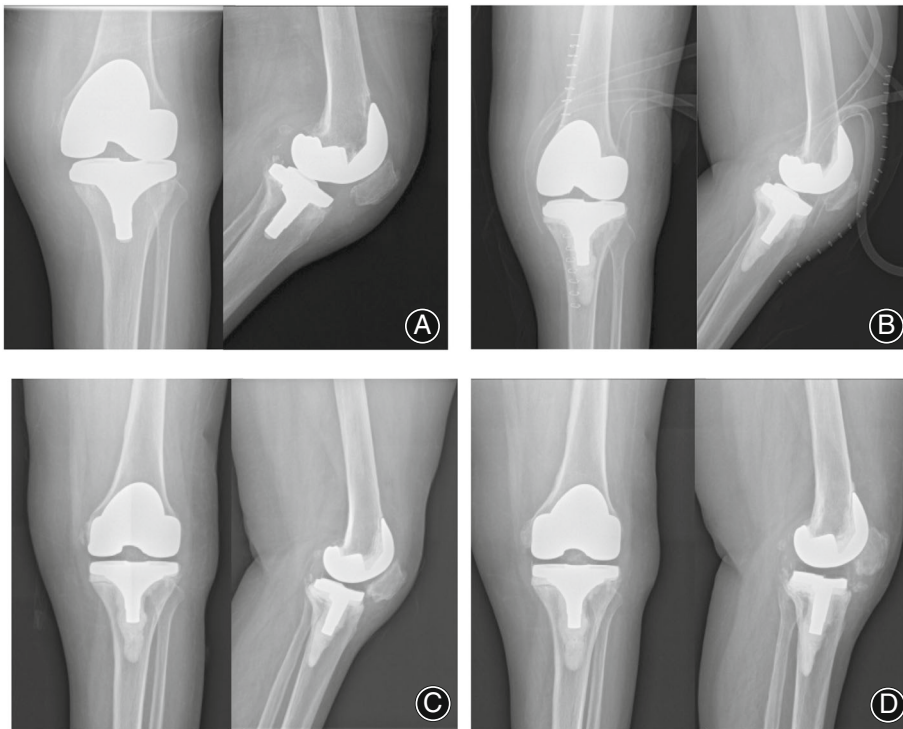
### Clinical Outcomes

All patients walked using either a walker or crutches 24 h after the first-stage surgery. The knee ROM reached 90° 1 week after CPM treatment. Two patients (15.4%) experienced an infection recurrence. One patient developed reinfection after the first stage revision for 1 year. After repeated

**TABLE 1** Data on patients with infection after primary TKA

Case	Age (years)	Sex	Time to infection (months)	1st-stage and 2nd-stage surgery	AORI classification	Bacterial culture	Comorbidities	Follow-up (years)	Outcomes
1	68	female	41	1st-stage	Type IIB	none	Hyper tension	4.8	Good
2	72	male	22	1st-stage	Type IIB	none	Diabetes mellitus	8.8	After re-revision Good
3	57	female	6	1st-stage	Type I	none	-	8.2	Excellent
4	66	female	8	1st-stage	Type IIA	<i>S. epidermidis</i>	Hyper tension	8.5	Good
5	63	female	16	1st-stage	Type IIB	<i>S. epidermidis</i>	-	8.6	Good
6	74	male	54	1st-stage	Type IIB	<i>S. aureus</i>	Diabetes mellitus	7.0	Fair
7	72	male	31	1st-stage	Type IIB	none	Hyper tension+ Diabetes mellitus	3.1	Died of pneumonia
8	68	male	29	1st-stage	Type IIA	<i>S. epidermidis</i>	Hyper tension	4.0	Good
9	71	female	24	1st&2nd-stage	Type IIA	<i>S. aureus</i>	-	5.1	Good
10	80	male	36	1st-stage	Type IIB	<i>S. verticm</i>	Hyper tension+ Diabetes mellitus	4.8	Fair
11	76	female	52	1st-stage	Type IIB	<i>S. saprophyticus</i> + <i>E. faecalis</i>	Hyper tension	4.3	Fair
12	64	female	26	1st-stage	Type IIA	<i>S. aureus</i>	-	3.8	Excellent
13	66	female	18	1st-stage	Type IIB	<i>S. epidermidis</i>	Diabetes mellitus	3.5	Good

Abbreviations: *E. faecalis*, enterococcus faecalis; *S. aureus*, Staphylococcus aureus; *S. epidermidis*, Staphylococcus epidermidis; *S. saprophyticus*, Staphylococcus saprophyticus; *S. verticm*, Streptococcus verticm.



**Fig. 2** Typical case. (A) Anteroposterior and lateral radiograph of a 63-year-old woman who developed septic loosening of prosthesis 20 months after primary TKA for osteoarthritis, shows a delayed infected TKA with radioluencies. Bacterial culture revealed *Staphylococcus epidermidis*. (B) The original prosthesis was autoclaved and reimplanted as a spacer. (C) 1 year after first stage surgery, the components were stable. (D) 5 years postoperatively, the prosthesis was stable and functional; there was no evidence of reinfection. The KSS score was 85

I&D, the original prosthesis was removed and re-autoclaved; the prosthesis was reimplanted, and the infection was controlled. No signs of infection recurrence were found at the most recent follow-up; the patient refused to implant a new prosthesis. Another patient had reinfection 3 years after the first-stage surgery, but the patient did not undergo re-revision and died of pneumonia soon after. Among the remaining 11 patients without any signs of reinfection, only one patient underwent the second stage surgery to implant a new prosthesis. The remaining 10 patients retained spacers indefinitely for an average of  $5.8 \pm 2.0$  (range, 3.5–8.6) years.

At the final follow-up, the 12 patients could walk with weight-bearing, six patients had slight pain in the knee when walking, and one patient required crutches to walk. Further, the 10 patients who retained spacers refused the second-stage surgery because of satisfactory knee function (Fig. 2).

#### KSS Score and Knee ROM

The mean KSS improved from  $51 \pm 10$  (range, 35–63) points preoperatively to  $79 \pm 5$  (range, 60–85) points at the final follow-up ( $t = 7.952$ ,  $P < 0.01$ ). The values for the preoperative and postoperative average ROM were  $62^\circ \pm 29^\circ$  (range,  $10^\circ$ – $100^\circ$ ) and  $104^\circ \pm 9^\circ$  (range,  $90^\circ$ – $120^\circ$ ); the infection control rate was 84.6%. The difference in the knee ROM before and after the first-stage surgery was statistically significant ( $t = 4.659$ ,  $P < 0.01$ ).

#### Radiographs and Inflammation Markers

At the last follow-up, no radiolucent lines or osteolysis were found in the 12 patients. All patients had normal ESR, CRP concentrations, and routine blood test parameters.

#### Complications

At the final follow-up, prosthesis dislocation, rupture, deep vein thrombosis, pulmonary embolism, and delayed wound healing were not observed.

#### Discussion

Different types of articulating spacers are used in two-stage revision for treating infected TKA, and no significant difference in the outcomes between them was found in a recent systematic review.<sup>19</sup> Thus, the autoclaved technique was an attractive and cost-effective option. In this study, the original femur and tibia components in the first-stage surgery were autoclaved and reimplanted as spacers to treat the knee infection after TKA. By following up on the preoperative and postoperative activity and infection control rate of the patients, this technique effectively controlled the infection and enabled patients to have good knee ROM after the first-stage surgery.

#### Operative Technique and Clinical Outcomes

The two-stage revision method of disinfecting and reinserting the original prosthesis as a spacer was first

described by Hofmann *et al.*<sup>12</sup> An articular antibiotic spacer was used and the original femoral component was reinserted after disinfection. This method reduced the problem of movement restriction, pain, soft tissue contracture, and bone loss between the two stages of surgery. However, there is some controversy over using the original prosthesis after sterilization to treat PJI. Similar methods were used in this study. At first, a reasonable and practical antibiotic treatment plan was established before the operation. Then, the original prosthesis was fixed by tightly matching the bone cement with the bone bed after partially curing the antibiotic bone cement to a dough state during the first-stage surgery. This fixing prevented bone cement penetration, bone loss, and further damage to the bone bed when the prosthesis was removed during the second-stage surgery. The use of CPM was emphasized after the first-stage surgery, and patients started early partial weight-bearing exercises to avoid excessive muscular atrophy, lower limb thrombosis, pulmonary embolism, delayed wound healing, and revision difficulties due to limited joint movement.

The patients in the current study exhibited good overall outcomes, satisfaction, and functionality. They demonstrated the wound healing properties of the technique that allowed partial weight-bearing and the use of a functional joint during the articulating spacer stage.

#### **Infection Recurrence Rate of Temporary Autoclaved Articulating Spacers**

Culture-negative infections comprised 31% of the study cohort. This percentage was consistent with the broader literature reports indicating 14% to 30% of culture-negative frequencies.<sup>6,20</sup> The infection recurrence rate in this study was 15.4%, with an average follow-up of 5.7 years. This rate was similar to the results of other scholars who treated infected TKA with original prostheses after disinfecting in two-stage revision. Hofmann reported no recurrent infection in his 1995 study. However, his later study included more patients, and the follow-up time was longer. Here, six out of 50 patients (12%) exhibited recurring infection and needed repeated spacer replacement.<sup>6,12</sup> Emerson *et al.*<sup>21</sup> adopted Hofmann's method in 22 patients and obtained a recurrence rate of 9% at a mean follow-up of 3.8 years. Cuckler *et al.*<sup>22</sup> used articulated spacers consisting of the sterilized femoral and polyethylene components with antibiotic cement that maintained the motion and bone stock. They obtained a recurrence rate of 2%. Lee *et al.*<sup>11</sup> reported a recurrence rate of 5% upon using a temporary articulating system comprising the autoclaved femoral component, low temperature, hydrogen peroxide gas plasma sterilized polyethylene liner, and antibiotic-impregnated bone cement. Previous reports indicated comparable infection control in using an autoclaved prosthesis and other methods<sup>13,19</sup>; but, skepticism is persistent. However, recent work demonstrated that autoclaving caused complete prosthesis sterility and virtually eradicated all residual biofilms.<sup>23,24</sup>

#### **Compared with Other Spacers in Two-Stage Revision**

Using antibiotic bone cement as a static spacer during the two-stage revision surgery demonstrates a high infection control rate.<sup>25-27</sup> However, after cement spacer implantation, the lower extremities of the patients are almost in the state of immobilization for at least 6 weeks or even longer, leading to joint stiffness, pain, and bone loss. Simultaneously, long-term immobilization can cause lower-extremity thrombosis, severe muscle atrophy, and other complications. Additionally, joint stiffness can reduce the ROM of the knee joint. It can also cause difficulty in exposing the reimplantation during the second-stage surgery.<sup>28,29</sup>

Presently, articulated antibiotic-loaded spacers are prepared using total bone cement modeling or industrially produced using polymethylmethacrylate spacer during the first-stage surgery.<sup>13,30,31</sup> Although this spacer maintains a good interval activity and prevents biofilm formation, the friction of bone cement is greater, and the stability is not as good as that of a joint prosthesis. Moreover, the possibility of replacing the spacer due to postoperative spacer fracture, defect, and joint pain is greater.

Using the original prosthesis as a spacer fully activates the knee joint after the first-stage surgery. It avoids the complications such as joint stiffness, bone loss, and excessive muscle atrophy. It is beneficial for postoperative functional recovery and reduces the difficulty of second-stage surgery. Studies have shown no significant difference in reinfection rates among articulating spacers. Nodzo *et al.*<sup>32</sup> reported 140 articulating antibiotic spacers divided into three cohorts (prefabricated, hand-made mold, and autoclaved) and did not observe a significant difference in infection control. Spivey *et al.*<sup>19</sup> compared reinfection rates among the different articulating constructs in 34 studies and found no significant difference among metal-on-polyethylene (8%) and hand-made (10%), prefabricated (4%), or molded (8%) cement-on-cement articulating spacers.

The current study employed an articulating spacer that comprised the autoclaved femoral and tibial components with a new polyethylene liner. Here, the primary replacement prosthesis was used as the spacer. The infection control rate was 84.6%. Marson *et al.*<sup>33</sup> also described the use of primary cemented knee replacement implants as spacers and reported no reinfection cases, suggesting acceptable outcomes for using this articulating spacer.

In compared with other types of articulating spacers, the most significant difference in this study was that the tibial component was also reimplanted after sterilization. The tibial and femoral components were both reimplanted, and they restored the joint status properly after the primary TKA. The articular surface height was easier to control during surgery; the prosthesis was more stable, and the friction was less.

#### **Retention of Spacers**

Retaining articulating spacers has been reported in some studies. One of the main reasons for retention was that the

spacers were unfit for second-stage surgery or lost to follow-up. Gomez *et al.*<sup>34</sup> in 2015 reported 72 cases with retained spacers. Two of these cases were due to patient preference, 15 patients were unfit for surgery, and the remainder were lost to follow-up or deceased before the second-stage surgery. In 2017, Petis *et al.*<sup>35</sup> reported a cohort of 34 retained knee spacers wherein 12 patients were implanted with articulating spacers. Five patients were medically unfit for surgery, and seven preferred to retain the spacers.

However, 10/13 (76.9%) patients retained their spacers in the present study because of satisfactory knee function. They displayed encouraging functional results, considering it was a small cohort of first-stage spacers that were retained indefinitely for an average of 5.8 years. In addition, retention of the prosthesis in chronic infection exhibited an excellent infection control rate. Vahedi *et al.*<sup>36</sup> reported 24 patients with acute reinfection after two-stage revision in 2019. They found that irrigation, debridement, and polyethylene exchange for acute reinfection following 2-stage revision TKA with well-fixed implants had a 71% success rate. Although all patients in the current cohort were late or delayed infection cases, indicating further difficulty in treatment, the present study demonstrated a similar success rate.

The revision procedure this study adopted was somewhat similar to one-stage revision, and the infection control rates were comparable to previous reports<sup>37,38</sup>. In contrast to two-stage revision TKA, one-stage revision TKA involves only a single surgical intervention. Thus, it potentially improves patient-reported outcomes and reduces revision surgery-associated morbidity and mortality rates. Klemm *et al.*<sup>39</sup> reported 44 patients with one-stage revision TKA matched with 88 patients following two-stage revision TKA. No difference was observed between one-stage and two-stage revision TKA in the reinfection rates (25.0% vs. 27.2%). Thus, one-stage revision TKA provides an effective alternative to two-stage revision in patients with chronic TKA PJI.

In a systematic review, Vaishya *et al.*<sup>40</sup> supported the use of one-stage revision surgery in infected TKA as an alternative to a conventional two-stage procedure.

In this study, most patients refused to take second-stage surgery to implant new prostheses because of satisfactory recovery in joint function after first-stage surgery. This fact reduced the recovery period of patients and also their economic burden. Thus, this technique was an acceptable treatment for hard-to-treat deep TKA infections.

### Limitations

This study has some limitations. First, it was a retrospective analysis of clinical and radiological data. Second, the cohort size was rather small to determine the success rate of this procedure rigorously. Third, because it lacked a control group, we failed to prove any advantage over using other kind of articulating spacers. Furthermore, due to the limitation of early technology, the positive culture rate of pathogenic bacteria was low. Therefore, large randomized controlled trials are needed to further determine the clinical efficacy of this technique.

### Conclusions

This study demonstrated that using autoclaved femoral and tibial components as the spacers displayed similar infection control to that reported in the prior literature. The technique supported wound healing allowed partial weight-bearing, and a functional joint during the articulating spacer stage. These patients had good overall outcomes, satisfaction, and functionality, suggesting that retained articulating spacers were a viable option. Reimplantation of the autoclaved original femoral and tibial components with antibiotic-impregnated cement as an articulating spacer during the first stage surgery is a proven and valuable addition for treating an infected TKA.

### References

- Nagra NS, Hamilton TW, Ganatra S, Murray DW, Pandit H. One-stage versus two-stage exchange arthroplasty for infected total knee arthroplasty: a systematic review. *Knee Surg Sports Traumatol Arthrosc.* 2016;24:3106–14.
- Gehrke T, Alijanipour P, Parvizi J. The management of an infected total knee arthroplasty. *Bone Jt J.* 2015;97:20–9.
- Siddiqui MM, Lo NN, Ab Rahman S, Chin PL, Chia SL, Yeo SJ. Two-year outcome of early deep MRSA infections after primary total knee arthroplasty: a joint registry review. *J Arthroplasty.* 2013;28:44–8.
- Leone JM, Hanssen AD. Management of infection at the site of a total knee arthroplasty. *Instr Course Lect.* 2006;55:449–61.
- Castelli CC, Gotti V, Ferrari R. Two-stage treatment of infected total knee arthroplasty: two to thirteen year experience using an articulating preformed spacer. *Int Orthop.* 2014;38:405–12.
- Hofmann AA, Goldberg T, Tanner AM, Kurtin SM. Treatment of infected total knee arthroplasty using an articulating spacer: 2- to 12-year experience. *Clin Orthop Relat Res.* 2005;430:125–31.
- Kurd MF, Ghanem E, Steinbrecher J, Parvizi J. Two-stage exchange knee arthroplasty: does resistance of the infecting organism influence the outcome? *Clin Orthop Relat Res.* 2010;468:2060–6.
- Qiu XS, Sun X, Chen DY, Xu ZH, Jiang Q. Application of an articulating spacer in two-stage revision for severe infection after total knee arthroplasty. *Orthop Surg.* 2010;2:299–304.
- Jacobs C, Christensen CP, Berend ME. Static and mobile antibiotic-impregnated cement spacers for the management of prosthetic joint infection. *J Am Acad Orthop Surg.* 2009;17:356–68.
- Fehring TK, Odum S, Calton TF, Mason JB. Articulating versus static spacers in revision total knee arthroplasty for sepsis. The Ranawat Award. *Clin Orthop Relat Res.* 2000;380:9–16.
- Lee JK, Choi CH. Two-stage reimplantation in infected total knee arthroplasty using a re-sterilized tibial polyethylene insert and femoral component. *J Arthroplasty.* 2012;27:1701–6.
- Hofmann AA, Kane KR, Tkach TK, Plaster RL, Camargo MP. Treatment of infected total knee arthroplasty using an articulating spacer. *Clin Orthop Relat Res.* 1995;321:45–54.
- Goltz DE, Sutter EG, Bolognesi MP, Wellman SS. Outcomes of articulating spacers with autoclaved femoral components in total knee arthroplasty infection. *J Arthroplasty.* 2018;33:2595–604.
- Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, et al. New definition for periprosthetic joint infection: from the workgroup of the Musculoskeletal Infection Society. *Clin Orthop.* 2011;469:2992–4.
- Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. *N Engl J Med.* 2004;351:1645–54.
- Engh GA, Ammeen DJ. Bone loss with revision total knee arthroplasty: defect classification and alternatives for reconstruction. *Instr Course Lect.* 1999;48:167–75.
- Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the knee society clinical rating system. *Clin Orthop Relat Res.* 1989;248:13–4.
- Meneghini RM, Mont MA, Backstein DB, Bourne RB, Dennis DA, Scuderi GR. Development of a modern knee society radiographic evaluation system and methodology for total knee arthroplasty. *J Arthroplasty.* 2015;30(12):2311–4.

- 19.** Spivey JC, Guild GN 3rd, Scuderi GR. Use of articulating spacer technique in revision total knee arthroplasty complicated by sepsis: a systematic meta-analysis. *Orthopedics*. 2017;40:212–20.
- 20.** Di Benedetto P, Di Benedetto ED, Buttironi MM, et al. Two-stage revision after total knee arthroplasty. *Acta Biomed*. 2017;88:92–7.
- 21.** Emerson RH Jr, Muncie M, Tarbox TR, Higgins LL. Comparison of a static with a mobile spacer in total knee infection. *Clin Orthop Relat Res*. 2002;404:132–8.
- 22.** Cuckler JM. The infected total knee: management options. *J Arthroplasty*. 2005;20:33–6.
- 23.** Lyons ST, Wright CA, Krute CN, Rivera FE, Carroll RK, Shaw LN. Confirming sterility of an autoclaved infected femoral component for use in an articulated antibiotic knee spacer: a pilot study. *J Arthroplasty*. 2016;31:245–9.
- 24.** Leary JT, Wergler MM, Broach WH, Shaw LN, Santoni BG, Bernasek TL, et al. Complete eradication of biofilm from orthopedic materials. *J Arthroplasty*. 2017;32:2513–8.
- 25.** Hanssen AD. Managing the infected knee: as good as it gets. *J Arthroplasty*. 2002;17:98–101.
- 26.** Brunnekreef J, Hannink G, Malefijt MW. Recovery of knee mobility after a static or mobile spacer in total knee infection. *Acta Orthop Belg*. 2013;79:83–9.
- 27.** Bowman EC, Malkani AL. Point/counterpoint: static vs articulating spacers-static spacers for resection arthroplasty of the knee. *J Arthroplasty*. 2020;35: S35–9.
- 28.** Anderson JA, Sculco PK, Heitkemper S, Mayman DJ, Bostrom MP, Sculco TP. An articulating spacer to treat and mobilize patients with infected total knee arthroplasty. *J Arthroplasty*. 2009;24:631–5.
- 29.** Vasso M, Del Regno C, Corona K, D'Apolito R, Schiavone PA. Articulated spacer provides long-term knee improvement after two-stage reimplantation. *Knee Surg Sports Traumatol Arthrosc*. 2016;24:3100–5.
- 30.** Romanò CL, Gala L, Logoluso N, Romanò D, Drago L. Two-stage revision of septic knee prosthesis with articulating knee spacers yields better infection eradication rate than one-stage or two-stage revision with static spacers. *Knee Surg Sports Traumatol Arthrosc*. 2012;20:2445–53.
- 31.** Tian MQ, Yang XT, Tian XB, Sun YB, Duan YH, Sun L. Short-term follow-up of antibiotic-loaded articulating cement spacers in two-stage revision of infected total knee arthroplasty: a case series. *Orthop Surg*. 2018;10: 128–33.
- 32.** Nodzo SR, Boyle KK, Spiro S, Nocon AA, Miller AO, Westrich GH. Success rates, characteristics, and costs of articulating antibiotic spacers for total knee periprosthetic joint infection. *Knee*. 2017;24:1175–81.
- 33.** Marson BA, Walters ST, Bloch BV, Sehat K. Two-stage revision surgery for infected total knee replacements: reasonable function and high success rate with the use of primary knee replacement implants as temporary spacers. *Eur J Orthop Surg Traumatol*. 2018;28:109–15.
- 34.** Gomez MM, Tan TL, Manrique J, Deirmengian GK, Parvizi J. The fate of spacers in the treatment of periprosthetic joint infection. *J Bone Joint Surg Am*. 2015;97:1495–502.
- 35.** Petis SM, Perry KI, Pagnano MW, Berry DJ, Hanssen AD, Abdel MP. Retained antibiotic spacers after total hip and knee arthroplasty resections: high complication rates. *J Arthroplasty*. 2017;32:3510–8.
- 36.** Vahedi H, Aali-Rezaie A, Shahi A, Conway JD. Irrigation, débridement, and implant retention for recurrence of periprosthetic joint infection following two-stage revision total knee arthroplasty: a matched cohort study. *J Arthroplasty*. 2019;34:1772–5.
- 37.** Zahar A, Kendoff DO, Klatté TO, Gehrke TA. Can good infection control be obtained in one-stage exchange of the infected TKA to a rotating hinge design? 10-year results. *Clin Orthop Relat Res*. 2016;474:81–7.
- 38.** Srivastava K, Bozic KJ, Silverton C, Nelson AJ, Makhni EC, Davis JJ. Reconsidering strategies for managing chronic periprosthetic joint infection in total knee arthroplasty: using decision analytics to find the optimal strategy between one-stage and two-stage total knee revision. *J Bone Joint Surg Am*. 2019;101:14–24.
- 39.** Klemm C, Tirumala V, Oganessian R, Xiong L, van den Kieboom J, Kwon YM. Single-stage revision of the infected total knee arthroplasty is associated with improved functional outcomes: a propensity score-matched cohort study. *J Arthroplasty*. 2021;36:298–304.
- 40.** Vaishya R, Agarwal AK, Rawat SK, Singh H, Vijay V. Is single-stage revision safe following infected total knee arthroplasty? A critical review. *Cureus*. 2017;9: e1629.