Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Comparative Study of the Efficacy of One-Stage versus Two-Stage Revision for Chronic Periprosthetic Joint Infection Following Total Knee Arthroplasty

Jiangping Wang
Northwest Minzu University of China
Zhenhao Liu
[redacted]
Xiaoheng Wang
Northwest Minzu University of China
Qifeng Song
[redacted]
Jianan Su
Northwest Minzu University of China
Shengjie Zhang
[redacted]
Qihang Bao
[redacted]
Shenghu Zhou
zhoushenghu120@163.com
[redacted]
Yongjie Qiao
[redacted]

Research Article

Keywords: one-stage revision, two-stage revision, periprosthetic joint infection, antibiotics, bacteria

Posted Date: November 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11294633/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Objective To compare the clinical efficacy, functional recovery, and medical economic burden of one-stage versus two-stage revision for chronic periprosthetic joint infection (PJI) following total knee arthroplasty, and to evaluate the feasibility and effectiveness of one-stage revision as an alternative treatment strategy.

Methods This retrospective cohort study enrolled 108 patients with chronic PJI following total knee arthroplasty (TKA-PJI) who underwent surgical treatment at our center between January 2018 and December 2023 and who met the inclusion criteria. Patients were assigned to a one-stage revision group (n = 56) or a two-stage revision group (n = 52) according to the surgical strategy, a grouping that was determined by institutional selection criteria rather than randomization. The primary outcome measure was the infection control rate at a mean postoperative follow-up of 28 months. Secondary outcome measures included the visual analog scale (VAS) score, range of motion (ROM), and the Knee Society Score (KSS).

Results Except for total hospitalization costs, baseline characteristics did not differ significantly between the two groups ($P > 0.05$). At the final follow-up, the infection control rate was 96.4% (54/56) in the one-stage group and 96.2% (50/52) in the two-stage group, with no statistically significant difference between groups ($P = 0.981$); the relative risk for two-stage versus one-stage revision was 1.08 (95% CI, 0.15–7.96), equivalently 0.93 (95% CI, 0.14–6.36) for one-stage versus two-stage; the absolute risk difference was − 0.3% (95% CI, -8.7% to 8.0%), so the risk of the event cannot be considered different between the two groups. In the early postoperative period, the one-stage group showed a statistically significant but clinically modest advantage in pain control at 14 days after surgery (VAS: 3.1 vs 3.6, $P < 0.01$) and in ROM recovery at 3 months after surgery (105.8° vs 103.3°, $P = 0.026$), and this difference did not recur at any other time point. At the final follow-up, however, the KSS was approximately 88 in both groups, with no statistically significant difference ($P = 0.426$). With regard to medical costs, the total hospitalization cost in the one-stage revision group was significantly lower than that in the two-stage revision group ($P < 0.01$).

Conclusion In this single-center retrospective cohort with a mean follow-up of 28 months, the infection control rate of one-stage revision did not differ statistically significantly from that of two-stage revision, and hospitalization costs were lower. Provided that prerequisites are strictly met—thorough debridement, soft tissue conditions permitting primary closure, and a preoperatively identified pathogen with confirmed antibiotic susceptibility—a sinus tract was amenable to one-stage revision in our experience. In summary, one-stage revision can serve as one of the treatment options for chronic TKA-PJI, but its long-term efficacy still requires confirmation by prospective multicenter studies.

Introduction

Total knee arthroplasty (TKA) is one of the effective treatments for end-stage knee disease; however, PJI remains a serious complication of this procedure [1]. Epidemiological studies show that although the

overall incidence of PJI after primary joint arthroplasty is approximately 1%–2%, the absolute number of PJI cases continues to rise as surgical volumes increase [2]. The economic burden of PJI is predicted to continue increasing substantially over the next decade, accompanied by an increase in revision surgery, severe functional loss, and growing medical costs, making it an urgent public health problem [3][4].

Two-stage revision achieves an infection eradication rate of 85%–95% and is the gold standard for the treatment of chronic PJI [1][5]. However, the "two-operation" model has obvious drawbacks. The two operations and the lengthy spacer interval readily lead to joint stiffness and muscle atrophy, causing delayed functional recovery [6]. Although optimized perioperative management has been shown to keep morbidity and mortality at low levels, it cannot fundamentally reverse the long-term functional impairment caused by this procedure [7].

Because of the shortcomings of two-stage revision, one-stage revision has regained clinical attention owing to its advantages of a single operation, no spacer interval, and rapid rehabilitation. The core of the current controversy over surgical strategy is the extreme paucity of evidence-based data. The recommendation grade in international guidelines is only C-III expert consensus [8]. At present, the prospective randomized trial published by Fehring et al., which directly compared one-stage and two-stage exchange for PJI, reported 2-year success rates of 97% and 91%, respectively [9]. The traditional view that negative preoperative cultures, a sinus tract, and immunosuppression are contraindications to one-stage revision is being challenged. A meta-analysis showed that the proportion of culture-negative PJI is as high as 9%–42% and that its clinical outcomes do not differ significantly from those of culture-positive PJI [10]. Studies have confirmed that patients with negative preoperative cultures or a sinus tract can achieve satisfactory infection control rates with one-stage revision [11]. Other studies emphasize that although a sinus tract is an important diagnostic marker, it should not be the sole criterion for deciding the surgical approach [12]. In addition, pathogen resistance is a major challenge. Studies have confirmed that rifampin resistance and the MDR/XDR phenotype in Staphylococcus epidermidis are extremely strong risk factors for predicting treatment failure [13]. Regarding the duration of antibiotic therapy, studies suggest that, provided debridement is thorough, appropriately shortening systemic antibiotic exposure is feasible [14]. Change-point analysis has identified the first postoperative year as a high-risk period for recurrence, providing a basis for follow-up strategies [15].

In recent years, one-stage revision combined with new technologies has been applied to the treatment of high-risk and complex PJI. With regard to new applications, investigators have explored the use of antibiotic-loaded hydrogel-coated implants [8]; conducted a randomized controlled trial evaluating intra-articular antibiotic infusion to reduce systemic side effects [16]; and proposed the concept of "antimicrobial brachytherapy" to enhance local antibiofilm efficacy [17]. In the subgroup with severe soft tissue defects, studies have confirmed that the reinfection rate of one-stage revision combined with gastrocnemius muscle flap reconstruction does not differ significantly from that of two-stage surgery [18], and free flaps are also a reliable means of soft tissue reconstruction [19]. A large prospective study further confirmed that, in unselected patients with chronic PJI, a one-stage exchange strategy combined with extensive debridement achieved a same-pathogen relapse rate as low as 4.8% [20].

Through a retrospective analysis, this study systematically compared the two surgical approaches used at our center for the treatment of chronic TKA-PJI with respect to infection control rate, perioperative inflammatory markers, and functional recovery, aiming to provide more targeted evidence-based medical evidence for individualized clinical decision-making.

Materials and Methods

Patient selection

This retrospective study was approved by the Ethics Committee of the 940th Hospital of Joint Logistics Support Force of the Chinese People's Liberation Army (approval number: 2026KYLL049); because the study was retrospective, the Ethics Committee waived the requirement for informed consent. Data were collected retrospectively and covered patients with chronic TKA-PJI who underwent one-stage or two-stage revision between January 1, 2018, and December 31, 2023. Inclusion criteria: (1) patients diagnosed with chronic PJI according to the 2018 International Consensus Meeting (ICM) criteria; (2) patients with chronic TKA-PJI who underwent one-stage or two-stage revision; (3) patients with complete medical records. Exclusion criteria: (1) incomplete medical records; (2) poor follow-up compliance, including inability to complete the scheduled follow-up or refusal of follow-up; (3) follow-up duration of less than 1 year; (4) patients for whom debridement, antibiotics, and implant retention (DAIR) was the initial surgical procedure during the study period (n = 53) were not included in this analysis.

Treatment allocation

All revision procedures during the study period were performed by the same senior surgeon. One-stage revision was selected when all of the following conditions were met: (1) the patient was diagnosed with chronic PJI according to the 2018 International Consensus Meeting (ICM) criteria; (2) the causative organism was identified on preoperative culture and antimicrobial susceptibility was confirmed; (3) the soft tissue conditions permitted primary closure of the incision; and (4) the patient's general condition allowed tolerance of a single definitive operation. Patients were informed that two-stage exchange is the internationally prevailing treatment; the advantages of single-stage exchange are avoidance of a second operation, a shorter hospital stay, and lower costs. The final treatment plan was decided by the patient after full discussion based on the clinical examination findings, the patient's physical condition, and the patient's preferences, with respect for the patient's right to autonomous choice.

Outcome measures and clinical definitions

The primary outcome was the postoperative infection control rate, defined as the absence of PJI recurrence or reinfection during follow-up. Secondary outcomes included VAS, ROM, and KSS. Criteria for determining infection recurrence included deep infection requiring repeat surgery, sinus tract formation with drainage, or fulfillment of the MSIS diagnostic criteria. Infection status was assessed by a

multidisciplinary team comprising orthopedic surgeons, infectious disease specialists, and clinical microbiologists, all of whom were blinded to the surgical approach. Assessment was based on clinical examination, laboratory parameters (ESR, CRP), and microbial culture. In this study, "confirmed pathogen" was defined entirely on the basis of conventional culture results (preoperative joint aspiration culture and intraoperative cultures of synovial fluid and periprosthetic tissue; cultures were extended to 5–21 days when the initial culture was negative). Pathogens were detected in all 108 patients in this cohort, and there were no cases of culture-negative PJI.

Patient enrollment flowchart

Case series

We reviewed cases of chronic PJI after TKA treated at our institution between January 1, 2018, and December 31, 2023. According to the inclusion and exclusion criteria, 168 patients were initially screened. Fifty-three patients who received DAIR and 7 patients lost to follow-up were excluded. A total of 108 patients were ultimately included in the analysis, comprising 56 patients in the one-stage revision group and 52 patients in the two-stage revision group. The two groups did not differ significantly in age, sex, body mass index (BMI), or affected limb (all $P > 0.05$). Total hospitalization costs differed significantly ($P < 0.05$) and were significantly lower in the one-stage revision group than in the two-stage revision group. Detailed baseline data are shown in Table 1.

Table 1
Baseline characteristics of patients with chronic TKA-PJI undergoing one-stage versus two-stage revision

Characteristic	One-stage (n = 56)	Two-stage (n = 52)	P value
Male: female, n	27: 29	27: 25	0.700b
Left: right, n	26: 30	25: 27	0.864b
Age ($\bar{X}$ ± S) (years)	64.00 ± 6.18	65.60 ± 5.26	0.153a
BMI (M (Q1, Q3)) (kg/m²)	24.10 (20.93, 29.18)	24.65 (24.20, 25.60)	0.218c
Duration of postoperative antibiotics ($\bar{X}$ ± S) (weeks)	7.93 ± 1.41	7.98 ± 1.23	0.839a
Follow-up duration ($\bar{X}$ ± S) (months)	28.11 ± 1.76	28.3 ± 1.81	0.575a
Sinus tract, n	35	30	0.610b
CCI score ($\bar{X}$ ± S)	2.54 ± 0.85	2.52 ± 0.96	0.925a
ASA (1: 2: 3)	13: 33: 10	9: 28: 15	0.369b
Total hospitalization cost (CNY)	61726.0 (48105.3, 75831.3)	135055.0 (116892.5, 150270.0)	< 0.01c

a Independent-samples t test; b chi-square test; c Mann-Whitney U test.

CCI, Charlson comorbidity index; BMI, body mass index; Q1, first quartile; Q3, third quartile; ASA, American Society of Anesthesiologists physical status classification system.

Surgical technique and perioperative management

Preoperative preparation: All patients discontinued antibiotics for at least 2 weeks before surgery. All patients underwent preoperative joint aspiration, with specimens sent for microbial culture and drug susceptibility testing. When the initial culture was negative, specimens were cultured for 5–21 days to increase the pathogen detection rate. All patients underwent preoperative weight-bearing radiography to assess prosthetic loosening, bone defects, and lower limb alignment. Routine laboratory tests were also completed, including complete blood count, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), synovial white blood cell (WBC) count, polymorphonuclear neutrophil percentage (PMN%), interleukin-6 (IL-6), and procalcitonin (PCT). All operations were performed by the same senior surgeon.

One-stage revision

1. 1. Debridement, irrigation, and disinfection: After general anesthesia, the patient was placed in the supine position, and a pneumatic tourniquet was applied at the root of the thigh of the affected limb (pressure 35 kPa, duration 90 minutes). After surface marking, routine disinfection and draping were

performed, and an approximately 16-cm incision was made along the original surgical incision, sequentially dividing the skin, subcutaneous tissue, and deep fascia; when the mass in the lower portion of the wound was incised, a large amount of pus drained out, and pus and tissue were collected for bacterial culture. The joint capsule was incised, and turbid pus drained from the joint cavity and the proximal tibia; joint pus was collected for culture. Necrotic tissue and pus around the knee joint were thoroughly removed to achieve a "bare" appearance; the wound was repeatedly irrigated 3 times with povidone-iodine, hydrogen peroxide, and normal saline. Exploration revealed loosening of the tibial and femoral prostheses; the bone cement between the prosthesis and bone was removed with an osteotome, the prostheses were extracted, and the bone cement and necrotic tissue within the medullary canal were thoroughly cleared. The wound was again repeatedly irrigated with hydrogen peroxide, dilute povidone-iodine, and normal saline, with an irrigation volume > 10000 mL. Reaming was performed through the original femoral opening, and distal femoral and intercondylar notch osteotomies were performed, after which the prosthesis size was measured; after tibial alignment was determined by extramedullary guidance, osteotomy was performed and the prosthesis size was measured. Trial components were inserted and showed an enlarged joint space and a large bone defect that a conventional prosthesis could not fill, so a constrained prosthesis with augments was used; after placement of the augments, the flexion and extension gaps were measured and found to be appropriate, the trial components moved well, and the joint was stable. The trial components were removed, pulsed lavage was performed, and the joint cavity was soaked in concentrated povidone-iodine for 15 minutes.

2. 2. Intraoperative conversion: To avoid cross-contamination, the patient was re-draped, the surgical team re-scrubbed and changed surgical gowns and gloves, and entirely new sterile instruments were used.
3. 3. Prosthesis reimplantation: After pulsed lavage again, vancomycin powder was sprinkled into the femoral and tibial medullary canals. Bone cement was mixed to fill the bone defects, and cement was spread inside the prostheses; a tibial prosthesis with a stem and a femoral prosthesis with augments and a stem were implanted, and a tibial insert was placed in the tibiofemoral joint space. After the bone cement had set, pulsed lavage was performed, and the wound was irrigated with normal saline, dilute povidone-iodine, and medical chitosan biological glue solution, with the bone defects filled with bone cement. A drainage tube was placed, the tourniquet was released, and bleeding at the wound surface was thoroughly controlled with hemostatic membrane. After the sponges and instruments were counted and confirmed to be correct, the joint capsule was closed with the knee flexed at 60°, and the incision was closed layer by layer.

Two-stage revision

1. 1. Debridement, irrigation, and spacer implantation: After general anesthesia, the patient was placed in the supine position; after surface marking of the affected knee, disinfection and draping were performed for the infected incision. The abscess at the lower end of the knee was first excised and explored to confirm communication with the joint cavity; the skin edges were necrotic, so the skin edges were thoroughly excised, necrotic tissue and pus were cleared, and repeated irrigation was

performed with hydrogen peroxide, dilute povidone-iodine, and normal saline. The skin, adipose tissue, and joint capsule were incised along the original surgical incision, and a large amount of turbid pus drained from the joint cavity and the distal femur, surrounded by abundant necrotic tissue; the pus and necrotic tissue were thoroughly removed to achieve a "bare" appearance. Exploration revealed partial loosening of the tibial and femoral prostheses; the bone cement between the prosthesis and bone was removed with an osteotome, the prostheses were extracted, and the bone cement and necrotic tissue within the medullary canal were thoroughly cleared. The wound was again repeatedly irrigated with hydrogen peroxide, dilute povidone-iodine, and normal saline, with an irrigation volume > 8000 mL, and the joint cavity was soaked in concentrated povidone-iodine for 15 minutes. After confirming that the instrument and sponge counts were correct, vancomycin and bone cement were mixed at a 1: 4 mass ratio to fabricate antibiotic-loaded cement temporary spacers for the femoral condyle and tibial plateau; after implantation, the joint space appeared normal, and the remaining vancomycin powder was placed in the joint cavity and deep within the medullary canal. Two drainage tubes were placed, and hemostasis was thoroughly achieved with hemostatic membrane. The joint capsule was closed with the knee flexed at 30°, the incision was closed layer by layer, and after thorough excision of the necrotic skin at the lower end of the knee, a sterile dressing was applied.

2. 2. Antibiotic therapy and monitoring during the spacer interval: Postoperatively, intravenous antibiotics combined with intra-articular antibiotic injection were administered for 2–3 weeks, after which oral antibiotics were given for approximately 5 weeks according to clinical symptoms and infection-related inflammatory markers. ESR and CRP were monitored twice weekly. After infectious symptoms resolved and inflammatory markers had decreased markedly, a 6–8-week observation period was undertaken, and the timing of the second-stage revision was determined according to the status of infection control.
3. 3. Prosthesis reimplantation: After general anesthesia, the patient was placed in the supine position, and a pneumatic tourniquet was applied at the root of the thigh of the affected limb (pressure 35 kPa, duration 90 minutes). After surface marking, routine disinfection and draping were performed, and an approximately 16-cm incision was made along the original surgical incision; the skin, subcutaneous tissue, and deep fascia were sequentially divided, the joint capsule was incised, and clear fluid drained from the joint cavity, which was collected for bacterial culture. The spacer was removed, and the synovial tissue around the knee joint was thoroughly cleared; the wound was repeatedly irrigated 3 times with povidone-iodine, hydrogen peroxide, and normal saline. The patient was re-draped and the knee was irrigated again. Because the joint space was enlarged and the bone defect was large and could not be filled by a conventional prosthesis, a constrained prosthesis was used. After measurement with a tibial extramedullary alignment rod, an opening was made on the osteotomy surface with a triangular file, and augments (2 pieces) were placed to fill the proximal tibial bone defect; the flexion and extension osteotomy gaps were measured and found to be appropriate, and the tibial prosthesis size was measured. A tibial insert and knee trial components were implanted, and movement of the affected knee showed good flexion and extension with medial and lateral stability. The trial components were removed, pulsed lavage was performed, and

vancomycin powder was sprinkled into the femoral and tibial medullary canals. Bone cement was mixed and spread inside the tibial prosthesis; a tibial prosthesis with a stem and a femoral prosthesis with a stem were implanted, and a tibial insert was placed in the tibiofemoral joint space. After the sponges and instruments were counted and confirmed to be correct, the wound was irrigated with a pulsed lavage system and chitosan biological quaternary ammonium salt colloid, and a drainage tube was placed. The joint capsule was closed with the knee flexed at 60°, the incision was closed layer by layer, and a wound dressing was applied.

Postoperative management

On the basis of preoperative and intraoperative culture results, an antibiotic regimen comprising two phases—during hospitalization and after discharge—was implemented. One-stage treatment pathway: during hospitalization, intravenous antibiotics combined with intra-articular antibiotic injection were administered for 2–3 weeks, after which oral antibiotics were given after discharge for approximately 5 weeks according to clinical symptoms and infection-related inflammatory markers. Infection markers were closely monitored to evaluate efficacy and safety. Two-stage treatment pathway: during hospitalization, intravenous antibiotics combined with intra-articular antibiotic injection were administered for 2–3 weeks; the evaluation and post-discharge regimen were the same as for the one-stage pathway, followed by a 6–8-week antibiotic-free observation period; therefore, the interval between the two stages was approximately 13–16 weeks. ESR and CRP were monitored twice weekly. The second stage was performed only after clinical symptoms of infection had resolved and ESR and CRP had decreased to normal or near-normal levels; at reimplantation, synovial fluid cultures were newly obtained in all patients, and all 52 patients had negative cultures before reimplantation. No patient died during the spacer interval or follow-up, and there was no spacer dislocation or fracture and no premature spacer removal due to spacer-related complications. The microbiological findings and postoperative medications are shown in Table 2.

Table 2
Microbiological findings and postoperative medications

Microorganism	One-stage (n = 56)	Two-stage (n = 52)	P value	Initial intravenous antibiotics	Intra-articular antibiotic infusion	Sequential oral antibiotics
Gram-positive bacteria	33	31				
Staphylococcus aureus	20	19	0.929b	VAN	VAN	LVFX + RFP
Staphylococcus epidermidis	5	4	0.816b	VAN	VAN	LVFX + RFP
Staphylococcus simulans	4	4	0.913b	VAN	VAN	LVFX + RFP
Staphylococcus lugdunensis	2	3	0.587b	VAN	VAN	LVFX + RFP
Enterococcus faecalis	2	1	0.602b	CAR + SUL	VAN	AMX + RFP
Gram-negative bacteria	10	8				
Escherichia coli	5	4	0.816b	SUL	VAN + MER	LVFX
Klebsiella pneumoniae	4	3	0.772b	SUL	VAN + MER	LVFX
Pseudomonas aeruginosa	1	1	0.958b	MER	MER	CIP
Polymicrobial infection	11	12				
Escherichia coli, Bacillus pumilus	2	3	0.587b	VAN + MER	VAN + MER	LVFX + RFP
Staphylococcus epidermidis, Staphylococcus warneri	2	2	0.940b	VAN	VAN	LVFX + RFP
Proteus mirabilis, Staphylococcus hominis	2	1	0.602b	VAN + MER	VAN + MER	LVFX + RFP
Staphylococcus aureus, Staphylococcus haemolyticus	5	6	0.654b	VAN	VAN	LVFX + RFP
Fungi	2	1				

Microorganism	One-stage (n = 56)	Two-stage (n = 52)	P value	Initial intravenous antibiotics	Intra-articular antibiotic infusion	Sequential oral antibiotics
Candida albicans	2	1	0.602b	VAN + FLU	FLU	LVFX + RFP + FLU
Total	56	52				

b Chi-square test. Because the P values for comparisons at the species level ranged from 0.67 to 1.00 under Fisher exact test, the P values in this column are for reference only and were not used for inference. VAN, vancomycin; LVFX, levofloxacin; RFP, rifampin; CAR, carbenicillin; SUL, sulbactam; AMX, amoxicillin; MER, meropenem; CIP, ciprofloxacin; FLU, fluconazole.

Follow-up

Follow-up assessments were performed by independent evaluators. Follow-up began on the day of the definitive operation (the day of one-stage revision in the one-stage group and the day of second-stage reimplantation in the two-stage group) and ended at the last documented follow-up (outpatient review or telephone interview); the measured follow-up range in this cohort was 23.0–32.0 months (28.11 ± 1.76 months in the one-stage group and 28.30 ± 1.81 months in the two-stage group). Data collected included pathogens, antibiotic regimens, and recurrence rates. To evaluate infection control and knee recovery, the following parameters were compared: serum infection markers (ESR, CRP, IL-6, PCT) before surgery and on postoperative days 3, 7, and 14 and at 1 month; and VAS score, knee ROM, and KSS before surgery and at postoperative day 14, 3 months after surgery, and the final follow-up.

Statistical analysis

Statistical analysis was performed with SPSS 27.0 software. Normality was tested with the Shapiro-Wilk test; normally distributed continuous variables were expressed as mean ± standard deviation and compared between groups with the independent-samples t test. Non-normally distributed continuous variables were expressed as median (interquartile range) and compared between groups with the Mann-Whitney U test. Categorical variables were expressed as frequencies (percentages) and compared between groups with the chi-square test or Fisher exact test. $P < 0.05$ was considered statistically significant. Because only 4 infection recurrence events were observed (such models would be overfitted and unstable when the number of events is too small), no multivariable regression model or propensity score matching was performed in this study; between-group comparisons of the recurrence group were therefore presented descriptively. For the primary outcome, the absolute risk difference and the relative risk with their 95% confidence intervals were calculated. Because the follow-up data were repeated measurements from the same patients, between-group comparisons at each time point should be regarded as exploratory analyses.

Results

Infection control rate

Both groups showed high infection control rates. The mean follow-up duration was 28.11 ± 1.76 months in the one-stage revision group and 28.3 ± 1.81 months in the two-stage revision group. With regard to the primary outcome, 2 infection recurrences were observed in the one-stage revision group, giving an infection control rate of 96.4% (54/56); 2 infection recurrences were observed in the two-stage revision group, giving an infection control rate of 96.2% (50/52). The infection control rates did not differ significantly between the two groups (P = 0.981) (Fig. 1). The relative risk for two-stage versus one-stage revision was 1.08 (95% CI, 0.15–7.96), equivalently 0.93 (95% CI, 0.14–6.36) for one-stage versus two-stage; the absolute risk difference was − 0.3% (95% CI, -8.7% to 8.0%), so the risk of the event cannot be considered different between the two groups. With only 2 recurrence events in each group, all 4 patients with infection recurrence (2 in each group) underwent repeat surgery, and no other repeat surgery was recorded during follow-up (repeat surgery rate 3.5% in the one-stage group and 3.8% in the two-stage group; both patients in the one-stage group underwent two-stage revision, whereas 1 patient in the two-stage group underwent two-stage revision and 1 underwent knee arthrodesis). No patient death or serious antibiotic-related adverse event was recorded during the study period. All 4 patients with recurrence developed surgical site infection, sinus tract, bone defect, and joint stiffness, and all had extensor mechanism problems (quadriceps weakness and knee pain); their pathogens, repeat surgical procedures, and complications are summarized in Table 3. Subgroup analysis stratified by sinus tract status showed that the infection control rate was 94.3% (33/35) in one-stage revision patients with a sinus tract and 100% (21/21) in those without a sinus tract, and 93.3% (28/30) in two-stage revision patients with a sinus tract and 100% (22/22) in those without a sinus tract; all 4 recurrences occurred in patients with a sinus tract, and among patients with a sinus tract the two strategies did not differ significantly (P = 1.000).

Table 3
Data of patients with infection recurrence

Item	One-stage (n = 2)	Two-stage (n = 2)
Repeat surgery rate	3.5%	3.8%
Repeat surgical procedure		
Two-stage revision	2	1
Knee arthrodesis	0	1
Microorganism		
Staphylococcus aureus, Staphylococcus haemolyticus	1	0
Pseudomonas aeruginosa	0	1
Candida albicans	1	1
Complications		
Surgical site infection	2	2
Sinus tract	2	2
Bone defect	2	2
Stiffness	2	2
Extensor mechanism problem		
Quadriceps weakness	2	2
Knee pain	2	2
Preoperative VAS (median)	8.1 (7.8–8.4)	8.0 (7.4–8.6)
Preoperative KSS (median)	36 (33–39)	34 (31–37)
Preoperative ROM (median)	67 (65–69)	64 (62–66)

Infection markers

Comparison of the dynamic changes in infection-related biomarkers after one-stage versus two-stage revision showed that CRP, ESR, and IL-6 levels in both groups declined continuously from before surgery to postoperative day 30 and tended to return toward normal (Table 4). Pairwise between-group comparisons confirmed that infection markers did not differ significantly between the one-stage and two-stage groups at most time points ($P > 0.05$). Specifically, CRP, ESR, and IL-6 did not differ significantly between the two groups before surgery or on postoperative days 3, 7, 14, and 30. PCT was at a borderline level on postoperative day 14 ($P = 0.050$), and a statistically significant between-group difference was found only on postoperative day 30 ($P = 0.003$); PCT levels did not differ significantly between the two groups at the remaining time points ($P > 0.05$). In Fig. 2, the curves for infection-related

markers in the two groups essentially overlapped, and the recovery trends were basically consistent, suggesting that both revision strategies effectively controlled and improved the postoperative infectious status, with no significant between-group difference in the recovery of the systemic inflammatory response.

Table 4
Infection markers

Marker	One-stage	Two-stage	P value
CRP (mg/dl)			
Before surgery	4.6 (3.4, 6.1)	4.7 (4.1, 5.7)	0.603c
Postoperative day 3	4.0 (3.0, 5.0)	4.1 (3.1, 5.3)	0.978c
Postoperative day 7	2.3 (1.7, 3.4)	2.5 (1.7, 3.3)	0.758c
Postoperative day 14	1.1 (0.7, 1.6)	1.1 (0.7, 1.5)	0.740c
Postoperative day 30	0.3 (0.2, 0.5)	0.4 (0.3, 0.6)	0.185c
ESR (mm/h)			
Before surgery	55.5 (45.3, 67.6)	55.5 (45.3, 65.5)	0.563c
Postoperative day 3	43.4 (35.1, 51.5)	44.7 (39.8, 51.1)	0.705c
Postoperative day 7	27.9 (22.3, 34.0)	30.5 (26.8, 33.8)	0.058c
Postoperative day 14	19.5 (12.6, 24.4)	19.5 (16.2, 23.4)	0.446c
Postoperative day 30	9.0 (5.6, 12.8)	9.2 (7.2, 11.2)	0.856c
PCT (ng/ml)			
Before surgery	0.094 (0.052, 0.112)	0.095 (0.074, 0.129)	0.061c
Postoperative day 3	0.068 (0.037, 0.095)	0.069 (0.055, 0.082)	0.726c
Postoperative day 7	0.045 (0.028, 0.080)	0.049 (0.034, 0.062)	0.919c
Postoperative day 14	0.037 (0.019, 0.070)	0.032 (0.017, 0.047)	0.050c
Postoperative day 30	0.027 (0.017, 0.038)	0.021 (0.009, 0.029)	0.003c
IL-6 (pg/ml)			
Before surgery	21.8 (16.7, 35.6)	23.3 (19.8, 28.8)	0.830c
Postoperative day 3	18.8 (11.6, 23.9)	18.0 (15.1, 21.5)	0.768c
Postoperative day 7	11.9 (6.9, 19.9)	12.4 (10.1, 14.8)	0.565c
Postoperative day 14	5.1 (3.2, 7.4)	5.6 (4.5, 6.8)	0.398c
Postoperative day 30	2.2 (1.5, 3.5)	2.3 (1.8, 3.1)	0.485c

c Mann-Whitney U test.

Functional outcomes

Joint function improved significantly after surgery in both groups, and pain, range of motion, and knee function scores improved steadily over time at each time point. Before surgery, the VAS score was 8.0 (7.6, 8.4) in the one-stage revision group and 8.2 (7.4, 8.8) in the two-stage group. By postoperative day 14, the scores had decreased rapidly to 3.1 (2.6, 3.4) and 3.6 (3.1, 4.0), respectively. At this time point, pain control in the one-stage group was significantly better than in the two-stage group ($P < 0.01$). At 3 months after surgery, the VAS score had decreased to 2.1 in both groups, and at the final follow-up it was recorded as 0.0 in both (between-group $P = 1.00$). With regard to KSS, the score was 33.5 ± 5.8 before surgery in the one-stage revision group and 33.8 ± 5.2 in the two-stage group; on postoperative day 14, the scores were 64.0 ± 4.4 and 62.7 ± 5.4, respectively; at 3 months after surgery, they had risen to 78.8 ± 5.7 and 79.3 ± 5.4, respectively; and at the final follow-up, they were 88.2 ± 5.0 and 87.5 ± 3.9, respectively. KSS did not differ significantly between the two groups at any time point throughout follow-up (all $P > 0.05$). With regard to ROM, it was 63.9 ± 4.9° before surgery in the one-stage revision group and 63.0 ± 5.7° in the two-stage group; it increased to 83.3 ± 4.9° and 81.9 ± 5.4°, respectively, on postoperative day 14; and it improved further to 105.8 ± 4.8° and 103.3 ± 6.5°, respectively, at 3 months after surgery. At this time point, ROM recovery in the one-stage group was significantly better than in the two-stage group ($P = 0.026$). Taken together, the one-stage revision group showed a certain advantage in early postoperative pain relief and ROM recovery at 3 months after surgery, which did not recur at other time points, and its clinical significance remains uncertain; however, both groups achieved satisfactory functional outcomes at the final follow-up, with no significant difference between groups. The detailed data and trends are shown in Table 5 and Fig. 3.

Table 5
Functional outcomes

Measure	One-stage	Two-stage	P value
VAS			
Before surgery	8.0 (7.6, 8.4)	8.2 (7.4, 8.8)	0.444c
Postoperative day 14	3.1 (2.6, 3.4)	3.6 (3.1, 4.0)	< 0.01c
Postoperative month 3	2.1 (1.8, 2.4)	2.1 (1.4, 2.5)	0.574c
Final follow-up	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	1.00c
KSS			
Before surgery	33.5 ± 5.8	33.8 ± 5.2	0.840a
Postoperative day 14	64.0 ± 4.4	62.7 ± 5.4	0.177a
Postoperative month 3	78.8 ± 5.7	79.3 ± 5.4	0.642a
Final follow-up	88.2 ± 5.0	87.5 ± 3.9	0.426a
Knee ROM (°)			
Before surgery	63.9 ± 4.9	63.0 ± 5.7	0.373a
Postoperative day 14	83.3 ± 4.9	81.9 ± 5.4	0.147a
Postoperative month 3	105.8 ± 4.8	103.3 ± 6.5	0.026a
Final follow-up	121.3 ± 5.3	120.1 ± 4.9	0.225a

a Independent-samples t test; c Mann-Whitney U test.

Discussion

The case data in this study show that the infection control rates of one-stage and two-stage revision at mid- to short-term follow-up were 96.4% and 96.2%, respectively (P = 0.981). The prospective, randomized controlled trial conducted by Fehring et al. [9] clearly confirmed that, under strict adherence to a standardized surgical protocol, the 2-year success rate of one-stage revision was 97%, showing a trend toward superiority over two-stage revision (91%). Meanwhile, the systematic review by Bosco et al. [21], which included 881 patients, reported a reinfection rate of 12.2% after one-stage revision, higher than the 3.6% in our cohort; this discrepancy may be related to case selection, follow-up duration, and differences between centers, and it also suggests that the infection control rate in our cohort lies at the better end of the range reported in the literature. The study by Huang et al. [22], based on a longer follow-up period, also showed no statistically significant difference in long-term infection control rates at 5 years after surgery among different surgical strategies. Taken together, these data suggest that, when

indications are appropriate and intraoperative execution is rigorous, one-stage revision can achieve an infection control rate comparable to that reported in the literature for two-stage revision.

In addition to infection control, functional recovery is also a key indicator for evaluating revision surgery. This study showed that, although the one-stage revision group had better early postoperative pain relief (for example, at 14 days) and better ROM recovery at 3 months after surgery, both groups achieved an ideal, nearly pain-free state at the final follow-up, with no significant differences in KSS or ROM. Although the differences between the two groups in VAS at postoperative day 14 (3.1 vs 3.6) and ROM at 3 months after surgery (105.8° vs 103.3°) reached statistical significance, the absolute differences were small (0.5 points and 2.5°, respectively), below the minimal clinically important difference thresholds commonly used for knee arthroplasty outcomes, and they did not occur at any other time point; their clinical significance is therefore uncertain. The cross-sectional study by Zhang et al. [23], based on the SF-36 and the McGill Pain Questionnaire, also confirmed that overall quality of life after revision for PJI is generally satisfactory and that one-stage revision is superior to two-stage revision in improving the physical health domain. Wang et al. [24] also pointed out that one-stage revision has greater advantages in the magnitude of improvement in joint function scores at 2 years after surgery. Prolonged immobilization caused by spacer retention in two-stage revision is an important reason for limited early recovery and often leads to joint stiffness, muscle atrophy, and bone loss [6]. Therefore, on the premise of ensuring effective infection control, one-stage revision can address both infection and reconstruction in a single operation, significantly shortening the patient's functional rehabilitation period and improving early quality of life. From the perspective of health economics, the total hospitalization cost in the one-stage group was significantly lower than in the two-stage group ($P < 0.01$), which has clear practical significance. The model constructed by Alt et al. [3] based on European health system data suggested that the medical insurance payment burden of hip and knee PJI is extremely heavy and that two-stage revision is a core cost driver. Aftab et al. [4] also emphasized that the cost of PJI treatment is 3–5.6 times that of primary joint arthroplasty and that repeated revisions after failure not only further increase costs but are also associated with extremely high mortality. Clearly, compared with two-stage revision, which requires two hospitalizations and a lengthy interval, one-stage revision has an economic advantage in reducing direct medical expenditure and avoiding waste of resources.

For "sinus tract" cases, which have traditionally been regarded as a contraindication to one-stage revision, our team's previously published cohort of patients with a sinus tract who underwent one-stage exchange achieved an infection-free survival rate of 95.7% (22/23) [25]. The key lies in adhering to an extremely rigorous standardized debridement protocol. The core obstacle in infection is biofilm formation, which effectively resists the host immune response and limits antibiotic penetration [26, 27]. We therefore adopted thorough mechanical debridement (including sinus tract excision, synovectomy, and medullary canal clearance), high-volume pulsed irrigation (> 10000 mL for one-stage revision and > 8000 mL for two-stage revision), and sequential chemical debridement with hydrogen peroxide combined with dilute povidone-iodine, supplemented intraoperatively with high-concentration local antibiotics (such as intracavitary injection of vancomycin powder into the medullary canal), to compensate for the inadequacy of physical debridement alone in removing mature biofilms. In

postoperative antibiotic management, the regimen strictly followed preoperative and intraoperative drug susceptibility results, using intravenous antibiotics combined with intra-articular antibiotics. The experimental and clinical studies by Wei et al. [28] suggested that local vancomycin combined with systemic administration facilitates biofilm eradication. To guide antimicrobial therapy precisely, we relied heavily on accurate microbiological feedback, which in this study was provided by conventional culture with prolonged incubation. Zhu et al. [29] observed a high positive rate of mNGS in a population with infection after total hip arthroplasty, suggesting that it may serve as a supplementary means of pathogen identification in the future; however, that result should not be directly extrapolated to knee PJI without dedicated study. mNGS was not used in this study, nor is it regarded as the "gold standard" for the diagnosis of PJI. The study by Lucas et al. [30] also emphasized the key role of rifampin-containing regimens in antibiotic therapy targeting staphylococcal biofilms, and the intraosseous regional administration proposed by Arthur et al. [31] represents an effective approach to achieving high local antibiotic concentrations in the future.

Indications are the core issue in this type of surgery. Traditional international consensus (such as the ICM) regarded "sinus tract formation" as an absolute contraindication to one-stage revision. Our observations are consistent with the views of some European centers (such as the ENDO-Klinik), namely that, when strict prerequisites are met, a sinus tract itself does not necessarily preclude one-stage revision [6]. We emphasize, however, that the ICM consensus still regards a sinus tract as a relatively high-risk factor rather than a generally accepted indication for one-stage exchange; the findings of this study derive from a single-center retrospective cohort with a limited number of events, so clinical application therefore requires caution. Kheir et al. [32], in a retrospective analysis, found that only about 12%–13% of patients with chronic PJI met the ICM criteria for one-stage revision, and that meeting these criteria did not significantly predict the success or failure of two-stage revision. This suggests that the current consensus criteria may be too strict, causing many patients who could have benefited from one-stage revision to miss the opportunity. However, the indications for one-stage revision must never be blindly broadened; a high degree of vigilance must be maintained for infections caused by atypical pathogens or highly virulent drug-resistant bacteria. Singla et al. [33] reported PJI caused by Achromobacter species (a biofilm-forming, multidrug-resistant gram-negative bacillus); in such cases the DAIR failure rate is often high, and two-stage revision is the more prudent choice. The multicenter study by Famada Arboix et al. [34] on gram-negative PJI also confirmed that the success rate of two-stage revision (94.8%) was superior to that of one-stage revision (88%). Therefore, meticulous preoperative pathogen screening (which in this study relied on prolonged conventional culture rather than mNGS) can support the safe application of one-stage revision, and mNGS may serve as a supplementary means in the future. Notably, both strategies were available at our center during the study period, and two-stage revision was not a fallback adopted because eligible patients could not receive one-stage revision.

Perioperative management was a focus of our study. Gomez-Barrena et al. [35], on the basis of a Delphi consensus among European orthopedic surgeons, clearly stated that multidisciplinary team (MDT) collaboration and optimization of preoperative risk factors (such as obesity, smoking, and glycemic

control) are core elements in the prevention and treatment of PJI. The specialized center model at our institution is likewise built on this multidisciplinary principle [35]. With regard to follow-up strategy, we used a standardized follow-up schedule (outpatient review at 1, 3, 6, 12, and 24 months after surgery, with telephone follow-up thereafter) and emphasized rigorous dynamic monitoring of infection-related biomarkers such as ESR, CRP, IL-6, and PCT, with discontinuation of antibiotics considered only after these markers had returned to normal. Notably, although two-stage revision has long been regarded as the ultimate solution for refractory infection, the systematic review by Puetzler et al. [36] pointed out that a long waiting time to reimplantation (long TTR) during revision did not confer additional infection control benefit and was instead associated with a higher risk of complications. This supports the potential value of shortening the interval between operations from another perspective; the broader positioning of the role of one-stage revision still awaits definition by prospective trials. As to whether extended postoperative oral antibiotics are needed to prevent reinfection, the meta-analysis by Kao et al. [37] showed that extended oral antibiotics after two-stage revision reduced the risk of reinfection, but its applicability to one-stage revision still requires further verification in prospective clinical trials.

This study has several limitations. First, as a retrospective, non-randomized, single-center study, treatment allocation was based on the institutional clinical criteria described above rather than randomization, so selection bias and residual confounding cannot be excluded. Because only 4 recurrence events were observed, no propensity score matching or multivariable adjustment was performed in this study (such models would be overfitted and unstable), and the comparison of infection control rates should be interpreted with caution. Second, the sample size was relatively limited (108 patients), with only 2 recurrences in each group. Third, the mid- to short-term follow-up (mean approximately 28 months) cannot accurately assess late aseptic loosening of the revision prosthesis or very late infection recurrence; in this regard, the follow-up reported by Huang et al. [22] showed that long-term outcomes tended to converge across different strategies, which provides a rationale for our continued follow-up. Fourth, all operations were performed by the same senior surgeon, and the intraoperative antibiotic regimen and the intensity of debridement remained highly influenced by the operator's subjective experience, which may limit the generalizability of the results. Fifth, the inflammatory markers and functional outcomes were repeated measurements from the same patients, and each time point was tested separately in this study; the above comparisons are therefore exploratory. Large-sample, multicenter, prospective randomized controlled trials that include more comprehensive primary and secondary outcome measures are still needed to provide the highest level of evidence-based medical evidence for clinical decision-making.

Conclusion

This single-center retrospective cohort study found that, in the treatment of chronic TKA-PJI, one-stage revision achieved an infection control rate at a mean follow-up of approximately 28 months that did not differ statistically significantly from that of two-stage revision (96.4% vs 96.2%). One-stage revision had statistically significant but clinically modest advantages in early pain and ROM, similar functional outcomes at the final follow-up, and significantly lower total hospitalization costs. Provided that the

preoperative pathogen is identified with confirmed antibiotic susceptibility, debridement is strictly standardized and thorough, and soft tissue conditions permit primary closure, a sinus tract was amenable to one-stage revision in our experience. In summary, one-stage revision can serve as one of the treatment options for chronic TKA-PJI, but its long-term efficacy still requires confirmation by prospective multicenter studies.

Abbreviations

AMX amoxicillin

ASA American Society of Anesthesiologists physical status classification system

BMI body mass index

CAR carbenicillin

CCI Charlson comorbidity index

CI confidence interval

CIP ciprofloxacin

CRP C-reactive protein

DAIR debridement, antibiotics, and implant retention

ESR erythrocyte sedimentation rate

FLU fluconazole

ICM International Consensus Meeting

IL-6 interleukin-6

KSS Knee Society Score

LVFX levofloxacin

MDR/XDR multidrug-resistant/extensively drug-resistant

MDT multidisciplinary team

MER meropenem

MSIS Musculoskeletal Infection Society

PCT procalcitonin

PJI periprosthetic joint infection

PMN% polymorphonuclear neutrophil percentage

Q1/Q3 first quartile/third quartile

RFP rifampin

ROM range of motion

SF-36 36-item Short Form Health Survey

SPSS Statistical Package for the Social Sciences

SUL sulbactam

TKA total knee arthroplasty

TKA-PJI chronic periprosthetic joint infection following total knee arthroplasty

TTR time to reimplantation

VAN vancomycin

VAS visual analog scale

WBC white blood cell

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Ethics Committee of the 940th Hospital of Joint Logistics Support Force of the Chinese People's Liberation Army (Approval No. 2026KYLL049). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Owing to the retrospective nature of the study, the requirement for written informed consent was waived by the Ethics Committee.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available because they contain patient-level clinical information and their disclosure is restricted by the institutional policy on the protection of medical records, but they are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

JPW and ZHL conceived and designed the study, and JPW drafted the manuscript. JPW, ZHL, XHW, QFS, JAS, SJZ, and QHB contributed to the acquisition, collection, and curation of the clinical data. JPW, XHW, and YJQ performed the statistical analysis and interpreted the data. SHZ and YJQ supervised the study and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

Acknowledgements

Not applicable.

References

1. Grupkovic J, Ceculovic M, Dabetic U, et al. Infection in Joint Arthroplasty: Diagnosis, Prevention, and Treatment Strategies—A. Compr Narrative Review[J/OL] Life. 2025;15(12):1853. 10.3390/life15121853.
2. Feng W, Zhang Z, Pu R, et al. Research progress on debridement, antibiotics, and implant retention (DAIR) for the treatment of periprosthetic joint infection after artificial joint replacement[J/OL]. Arch Orthop Trauma Surg. 2026;146(1):245. 10.1007/s00402-026-06368-3.
3. Alt V, Szymski D, Rupp M, et al. The health-economic burden of hip and knee periprosthetic joint infections in Europe[J/OL]. Bone Joint Open. 2025;6(3):298–311. 10.1302/2633-1462.63.BJO-2024-0225.R1.
4. Aftab MHS, Joseph T, Almeida R et al. Periprosthetic Joint Infection: A Multifaceted Burden Undermining Arthroplasty Success[J/OL]. Orthop Rev, 17: 138205. 10.52965/001c.138205
5. Mass A, Sajo M, Silverstein E. Six-Week Protocol for Two-Stage Exchange Arthroplasty in a High-Risk Population[J/OL]. Arthroplasty Today. 2026;38:101987. 10.1016/j.artd.2026.101987.

6. Nguyen M, Sukeik M, Zahar A, et al. One-stage Exchange Arthroplasty for Periprosthetic Hip and Knee Joint Infections[J/OL]. Open Orthop J. 2016;10:646–53. 10.2174/1874325001610010646.
7. Epley R, Stoops TK, Deckard ER et al. Kidney Injury and Mortality Are Minimal Following Two-Stage Treatment of Periprosthetic Joint Infection[J/OL]. The Journal of arthroplasty, 2026-06-16: S0883-5403(26)00647-9. 10.1016/j.arth.2026.06.027
8. Boyer B, Cazorla C, Carricajo A, et al. Single-stage surgery with antibiotic-loaded hydrogel-coated implants versus two-stage surgery for chronic periprosthetic hip joint infection in French tertiary referral hospitals: the SINBIOSE-H non-inferiority, randomised, controlled trial study protocol[J/OL]. BMJ Open. 2025;15(2):e085146. 10.1136/bmjopen-2024-085146.
9. Fehring TK, Otero JE, Fehring KA, et al. One-Stage Versus Two-Stage Exchange Arthroplasty for Periprosthetic Joint Infection[J/OL]. J Bone Joint Surg Am Volume. 2026;108(14):1070–82. 10.2106/JBJS.25.00713.
10. Lai Y-H, Xu H, Li X-Y, et al. Outcomes of culture-negative or -positive periprosthetic joint infections: A systematic review and meta-analysis[J/OL]. Joint Dis Relat Surg. 2023;35(1):231–41. 10.52312/jdrs.2023.1437.
11. Sabater-Martos M, Morata L, Segur JM, et al. One-stage knee replacement shows similar healing rates in patients with negative or positive preoperative cultures: a retrospective cohort study[J/OL]. J Bone Joint Infect. 2025;10(4):237–41. 10.5194/jbji-10-237-2025.
12. Sandu E-C, Cursaru A, Serban B et al. Is the Presence of Sinus Tract in Periprosthetic Joint Infection Still One of the Main Deciding Factors for Septic Revision?[J/OL]. Cureus, 16 (12): e75379. 10.7759/cureus.75379
13. Auñon Á, Gabardo S, Álvaro C, et al. Rifampin resistance and multidrug resistance or extensive drug resistance (MDR/XDR) predict failure in monomicrobial Staphylococcus epidermidis periprosthetic joint infection (PJI) – a 15-year single-center cohort study[J/OL]. J Bone Joint Infect. 2026;11(2):237–46. 10.5194/jbji-11-237-2026.
14. Harrabi H, Mamona-Kilu C, Meyer E, et al. Treatment Duration in Bacterial Prosthetic Joint Infections: A Narrative Review of Current Evidence[J/OL]. Antibiotics. 2025;14(11):1066. 10.3390/antibiotics14111066.
15. Shannon MF, Rothenberger SD, Drummond EF, et al. Treatment Failure Rates Decrease Significantly at Approximately One Year Following Two-Stage Exchange Arthroplasty for Periprosthetic Joint Infection[J/OL]. J Arthroplast. 2026. 10.1016/j.arth.2026.02.009. https://www.sciencedirect.com/science/article/pii/S0883540326001208. -02-06.
16. Ji B, Li Y, Yan X, et al. Intra-articular antibiotic infusions versus intravenous antibiotic administration for infected knee arthroplasty: a study protocol for a randomized multicenter clinical trial[J/OL]. Trials. 2025;27:50. 10.1186/s13063-025-09319-2.
17. McPherson EJ, Chowdhry M, Lin A, et al. Antimicrobial Brachytherapy Protocol for Chronic Periprosthetic Joint Infection in Total Knee Arthroplasty: A Preliminary Case Series with 2-Year Results[J/OL]. J Clin Med. 2026;15(11):4070. 10.3390/jcm15114070.

18. Sina J, Schrednitzki D, Ting A, et al. Comparable reinfection rates between one-stage and two-stage revision total knee arthroplasty with gastrocnemius flap reconstruction for periprosthetic joint infection: A systematic review and meta-analysis[J/OL]. J Experimental Orthop. 2026;13(2):e70738. 10.1002/jeo2.70738.
19. Saracco M, Ciriello V, Levita DM, et al. Are free flaps a reliable solution to treat massive soft tissue defects in patients with knee periprosthetic joint infection? A systematic review and meta-analysis[J/OL]. EFORT Open Reviews. 2026;11(7):737–47. 10.1530/EOR-2025-0161.
20. Pioger C, Marmor S, Bouché P-A, et al. One-stage exchange strategy with extensive debridement for chronic periprosthetic joint infection following total knee arthroplasty is associated with a low relapse rate in non-selected patients: a prospective single-center analysis[J/OL]. Volume 111. Orthopaedics & Traumatology: Surgery & Research; 2025. p. 104019. 110.1016/j.otsr.2024.104019.
21. Bosco F, Cacciola G, Giustra F, et al. Characterizing recurrent infections after one-stage revision for periprosthetic joint infection of the knee: a systematic review of the literature[J/OL]. Eur J Orthop Surg Traumatol. 2023;33(7):2703–15. 10.1007/s00590-023-03480-7.
22. Huang C, Lin L, Liu X et al. Reinfection and re-revision rates of periprosthetic knee infection under four different surgical strategies: a single centre retrospective observational study[J/OL]. Front Cell Infect Microbiol, 16: 1769101. 10.3389/fcimb.2026.1769101
23. Zhang C, Liu Z, Lin Y, et al. Patient-Reported Outcome on Quality of Life and Pain after Revision Arthroplasty for Periprosthetic Joint Infection: A Cross-Sectional Study[J/OL]. J Clin Med. 2022;11(23):7182. 10.3390/jcm11237182.
24. Wang Q, Lu Z, Huang J et al. Reevaluation of surgical strategies for chronic periprosthetic joint infection: a comparison of short-term outcomes between one-stage and two-stage revision[J/OL]. Front Cell Infect Microbiol, 16: 1776770. 10.3389/fcimb.2026.1776770
25. Qiao Y, Song Q, Song X, et al. One-stage exchange arthroplasty for periprosthetic joint infection following total knee arthroplasty with sinus tract: a mid-to short-term follow-up study[J/OL]. BMC Musculoskelet Disord. 2026;27:265. 10.1186/s12891-026-09648-6.
26. Boyle KK, Wood S, Tarity TD. Low-Virulence Organisms and Periprosthetic Joint Infection—Biofilm Considerations of These Organisms[J/OL]. Curr Rev Musculoskelet Med. 2018;11(3):409–19. 10.1007/s12178-018-9503-2.
27. Shannon MF, Wong VR, Osifo SE, et al. Frontiers in the Management of Orthopaedic Periprosthetic Joint Infection[J/OL]. J Orthop Res. 2026;44(2):e70087. 10.1002/jor.70087.
28. Wei J, Wen Y, Tong K et al. Local Application of Vancomycin in One-Stage Revision of Prosthetic Joint Infection Caused by Methicillin-Resistant Staphylococcus aureus[J/OL]. Antimicrob Agents Chemother, 65 (9): e00303–21. 10.1128/AAC.00303-21
29. Zhu J, Xia T, Wang L et al. Investigating the benefits of metagenomic next-generation sequencing for patients experiencing infections after total hip replacement surgery: a retrospective cohort study with a minimum of one year of follow-up[J/OL]. Front Cell Infect Microbiol, 16: 1735867. 10.3389/fcimb.2026.1735867

30. Lucas J, Queirós J, Soares D, et al. The Impact of Antibiotic Therapy Options and Multidisciplinary Approach in Prosthetic Joint Infections[J/OL]. Microorganisms. 2025;13(10):2241. 10.3390/microorganisms13102241.
31. Arthur JR, Bingham JS, Clarke HD et al. Intraosseous Regional Administration of Antibiotic Prophylaxis in Total Knee Arthroplasty[J/OL]. JBJS Essential Surgical Techniques, 2020, 10 (4): e20.00001. 10.2106/JBJS.ST.20.00001
32. Kheir MM, Anderson CG, Chiu Y-F, et al. Do one-stage indications predict success following two-stage arthroplasty for chronic periprosthetic joint infection?[J/OL]. J Bone Joint Infect. 2024;9(1):75–85. 10.5194/jbji-9-75-2024.
33. Singla R, Vatsya P, Malhotra V, et al. Successful Management of Achromobacter-Associated Periprosthetic Joint Infections After Total Knee Arthroplasty: A Case Series of Ten Knees in Six Patients[J/OL]. Arthroplasty Today. 2026;39:102055. 10.1016/j.artd.2026.102055.
34. Famada Arboix E, Fischbacher A, Ferrari MCM, et al. Gram-negative prosthetic joint infections: a retrospective multicentre European study of incidence, risk factors, and treatment outcomes[J/OL]. J Bone Joint Infect. 2026;11(3):355–61. 10.5194/jbji-11-355-2026.
35. Gómez-Barrena E, Warren T, Walker I, et al. Prevention of Periprosthetic Joint Infection in Total Hip and Knee Replacement: One European Consensus[J/OL]. J Clin Med. 2022;11(2):381. 10.3390/jcm11020381.
36. Puetzler J, Schulze M, Gosheger G, et al. Is long time to reimplantation a risk factor for reinfection in two-stage revision for periprosthetic infection? A systematic review of the literature[J/OL]. Front Surg. 2023;10:1113006. 10.3389/fsurg.2023.1113006.
37. Kao P-E, Hsu C-W, Hsu AHS, et al. The effect of extended postoperative oral antibiotic prophylaxis on the reinfection risk following two-stage exchange arthroplasty for hip and knee periprosthetic joint infection: a systematic review and meta-analysis[J/OL]. BMC Musculoskelet Disord. 2026;27:101. 10.1186/s12891-025-09410-4.

Figures

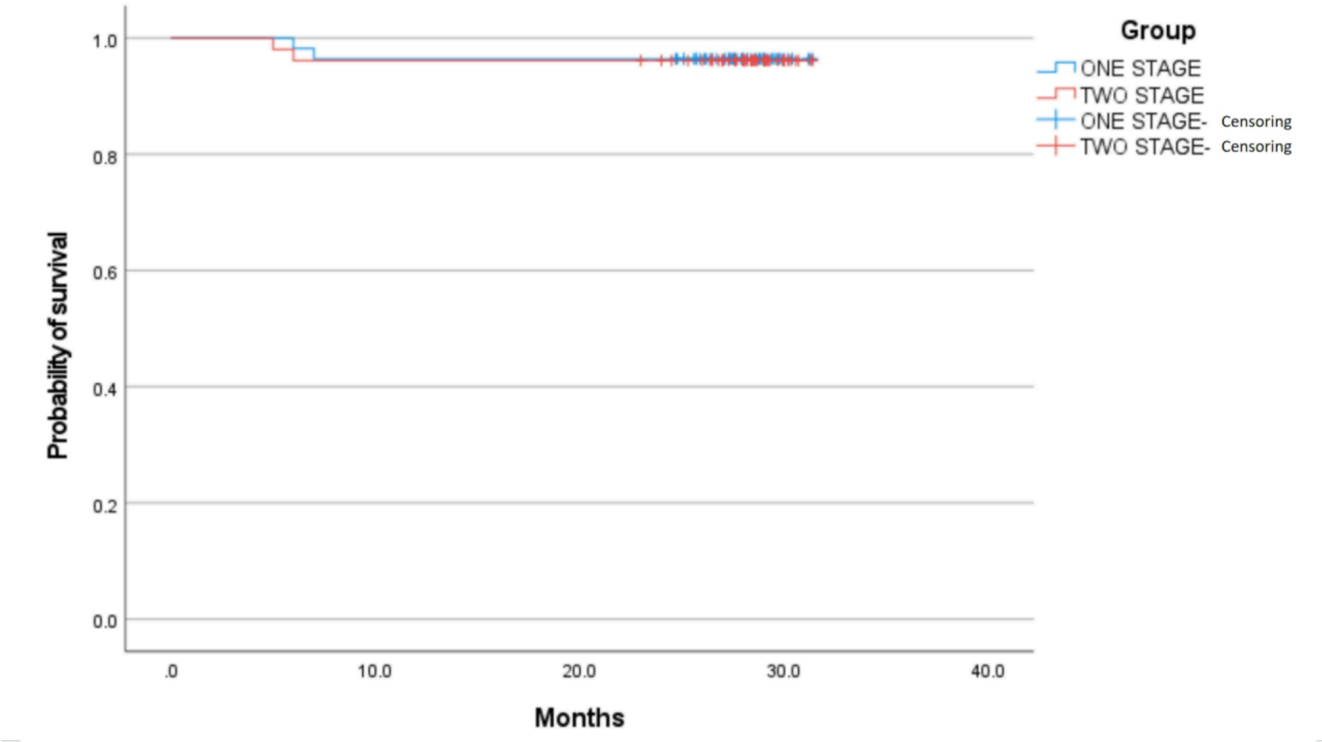


Figure 1

Survival curves after one-stage versus two-stage revision for chronic TKA-PJI.

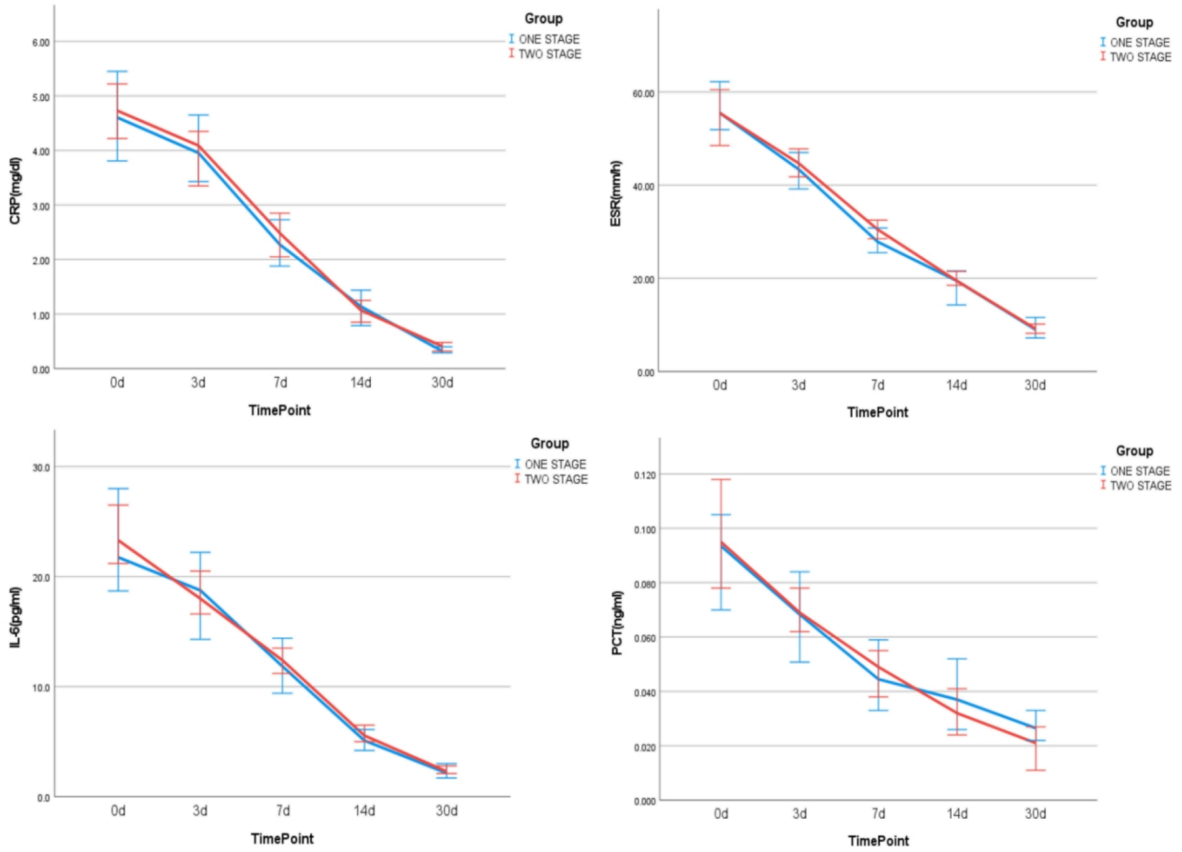


Figure 2

Dynamic changes in infection-related biomarkers after one-stage versus two-stage revision.

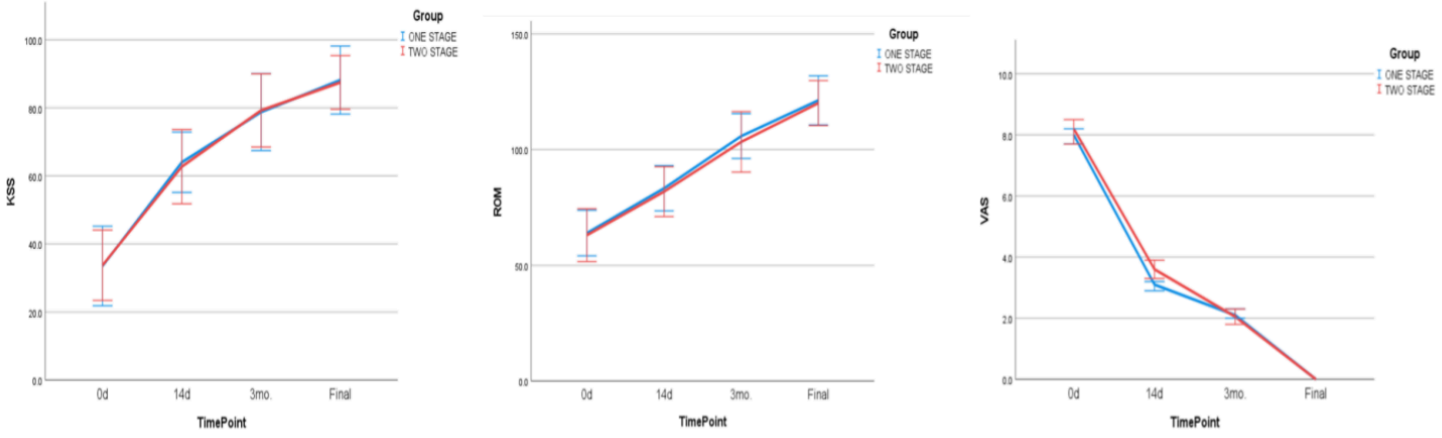


Figure 3

Trends over time in functional recovery indicators in the one-stage and two-stage revision groups.

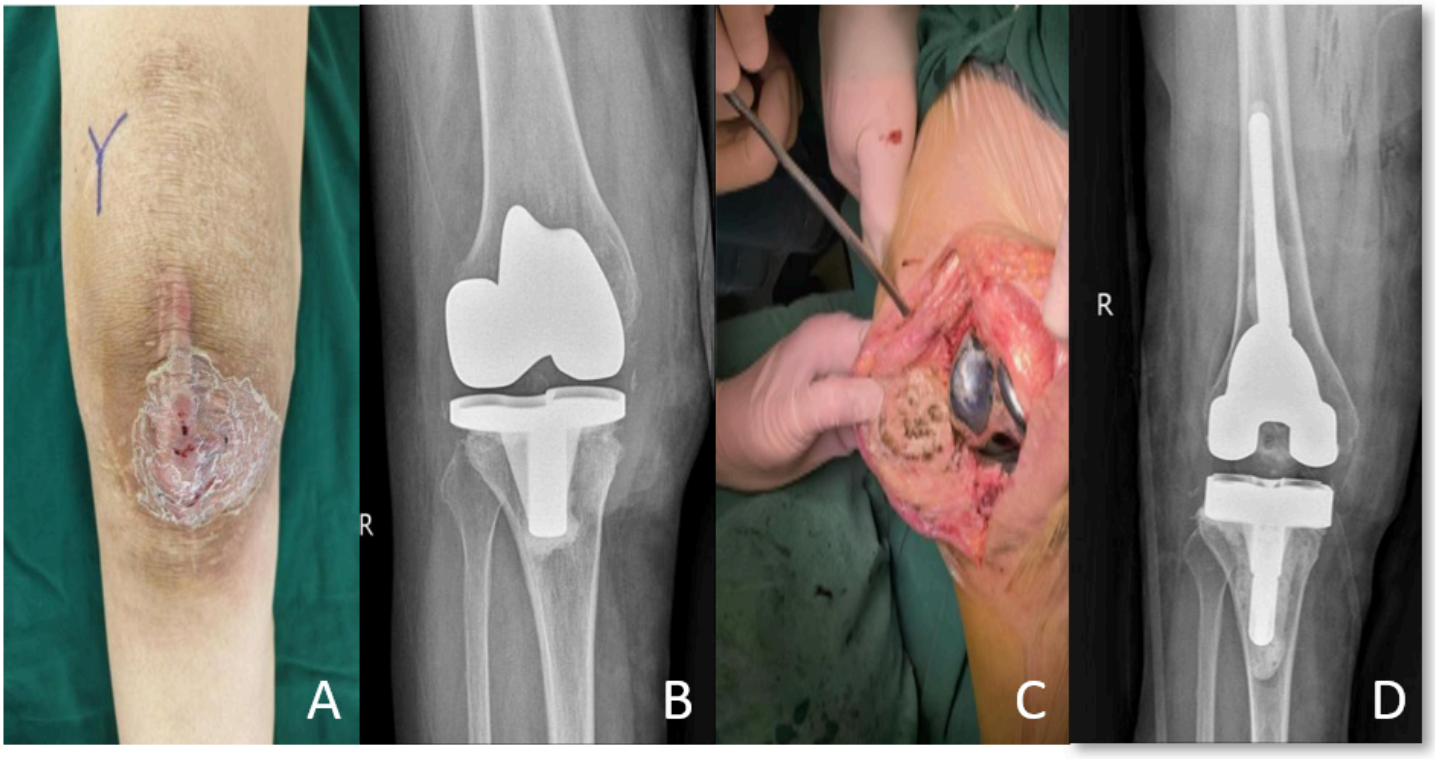


Figure 4

Preoperative, intraoperative, and postoperative documentation of a patient with periprosthetic joint infection (PJI) and a sinus tract following total knee arthroplasty, treated with one-stage revision arthroplasty.A: external sinus tract and local skin condition; B: radiographic assessment; C: intraoperative view; D: postoperative outcome.

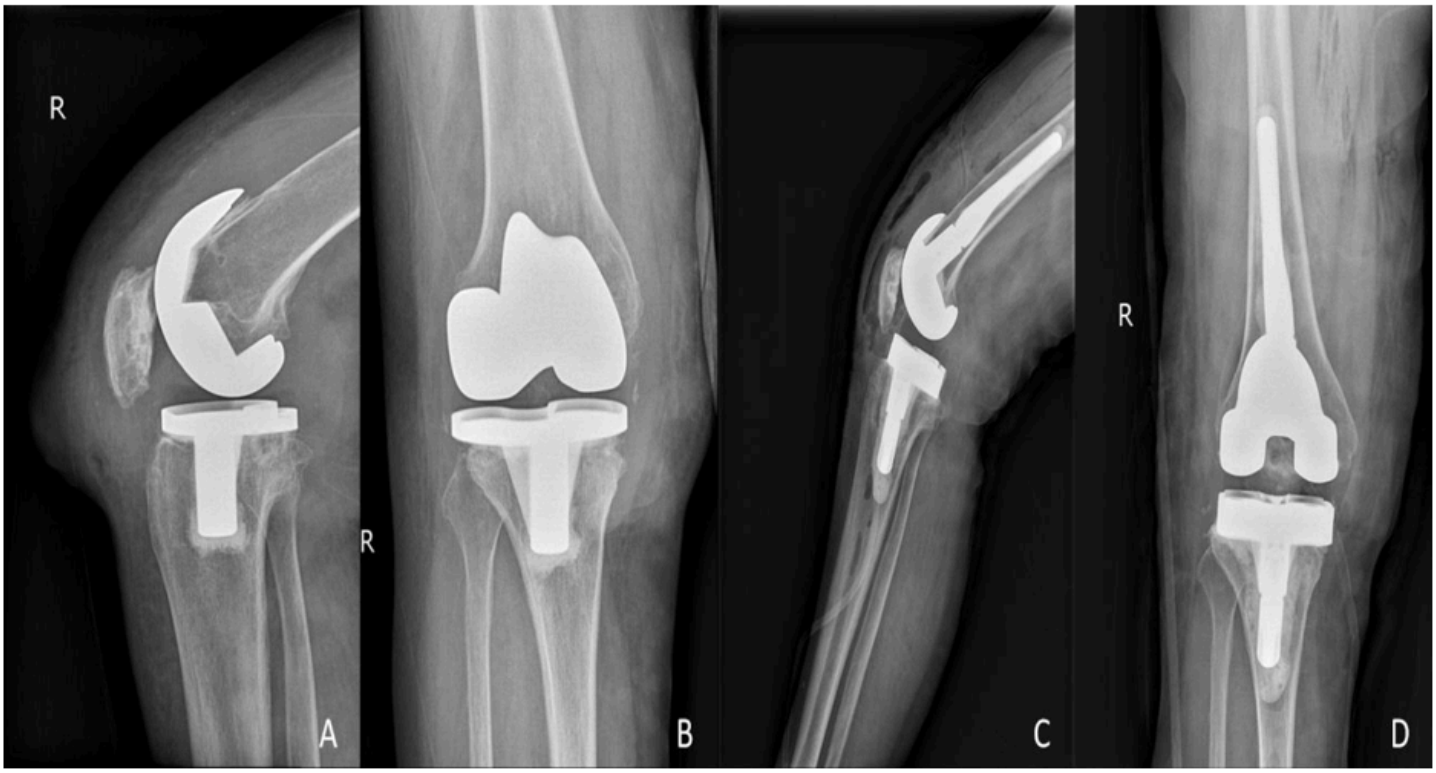


Figure 5

Preoperative and postoperative radiographs of a patient with chronic TKA-PJI treated with one-stage revision. A, B: Preoperative radiographs; C, D: Postoperative radiographs.



Figure 6

Preoperative and postoperative radiographs of a patient with chronic TKA-PJI treated with two-stage revision. A, B: Preoperative radiographs before the first-stage resection arthroplasty; C, D: Postoperative radiographs after the first-stage resection arthroplasty; E, F: Preoperative radiographs before the second-stage prosthesis reimplantation; G, H: Postoperative radiographs after the second-stage prosthesis reimplantation.

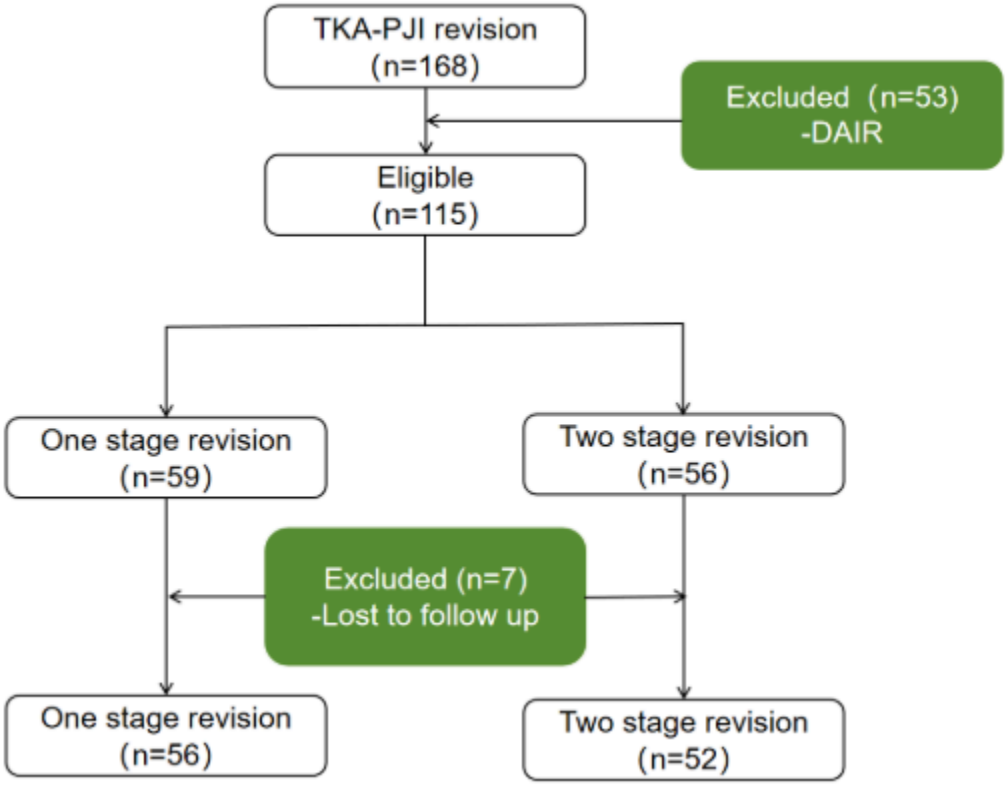


Figure 7

Unnumbered image in the Materials & Methods section.