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# Static vs Articulating Spacers for Two-Stage Revision Total Knee Arthroplasty: Minimum Five-Year Review

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ABSTRACT

*Background:* The gold standard treatment for infected total knee arthroplasty (TKA) is two-stage revision. The first stage involves a temporary antibiotic spacer, which can be static or articulating; it remains unclear which is best. We aimed to compare 5-year outcomes between static and dynamic spacers.

*Methods:* One hundred and seventy-six patients with infected TKA requiring two-stage revision were enrolled. Patients were organized based on the type of spacer used during the first-stage revision. One hundred and four patients received articulating spacers, and 72 received static spacers. At 5 years, postoperative range of motion (ROM), Short Form 12 (SF-12), Knee Society Score (KSS), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores were recorded. Reinfection and revisions were also tracked.

*Results:* Eradication of infection was similar in both groups, with 83.7% in the articulating group and 86.1% in the nonarticulating spacer group ($P = .234$). Articulating spacers resulted in significantly improved ROM (111 vs 82 degrees, $P < .001$), SF-12 physical component score (35.2 vs 31.0, $P = .01$), KSS (145.2 vs 113.7, $P < .001$), and WOMAC function scores (60.1 vs 51.1, $P = .03$) as compared to the static spacer group.

*Conclusions:* Treatment with an articulating spacer as opposed to a static spacer resulted in improved ROM, SF-12 physical component score, KSS, and WOMAC function scores at the final follow-up visit. There was no significant difference in reinfection rates. Patients requiring staged revision for infected TKA may benefit from an articulating spacer.



## Introduction

Infection is a devastating complication that can occur after total knee arthroplasty (TKA), with an incidence of 0.7%-2.0% [1-4]. Infections can be challenging to treat for both patients and surgeons. The gold standard treatment for an infected TKA is a two-stage revision procedure [2,5,6]. This involves removal of the original implants, debridement, implantation of a temporary antibiotic-impregnated spacer, and intravenous antibiotics. This is then followed by definitive revision surgery once the infection has been eradicated.

Options for the first-stage implant include a static or articulating antibiotic-impregnated spacer. Static spacers immobilize the knee while articulating, or dynamic, spacers allow for range of motion [7]. Proponents of static spacers believe that restricting motion of soft tissues allows for superior infection control [7]. Furthermore, static spacers are less costly than their articulating counterparts [7-10]. Proponents of articulating spacers cite improvements in long-term function scores, higher patient satisfaction, and greater final range of motion [7,11-14].

This study was granted approval by our Health Sciences Research Ethics Board, which is available upon request. Patients were appropriately consented for being included in the database used for this study.

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Results in the literature, however, remain unclear as to which spacer option is superior [2]. Most existing studies are retrospective in nature, with a small sample size and mixed findings [2,7]. Of the four systematic reviews in the literature comparing static vs dynamic spacers, three found no difference in reinfection rate while one found a significantly lower reinfection rate with the use of articulating spacers [11-14]. Similarly, although all four systematic reviews reported significantly improved range of motion with articulating spacers, only one showed increased functional outcome scores in the articulating group [11-14]. Recently, the first randomized control trial comparing the two spacer types was also published and demonstrated improved range of motion and functional scores in the articulating spacer group [7].

Thus, there remains no clear consensus on whether articulating or static spacers are best. Static spacers are generally indicated in cases with poor soft tissues, extensor mechanism dysfunction, and significant bone loss [2]. We aimed to add to the existing body of literature through a large, long-term study. The purpose of our study was to investigate the minimum 5-year outcomes of articulating spacers, for two-stage revision knee arthroplasty for infection, and to compare these to those of patients treated with static spacers. We hypothesized that articulating spacers would result in improved patient outcomes and range of motion as compared to static spacers.

## Material and methods

This study was a retrospective review of a prospectively collected database. One hundred and seventy-six patients with an infected TKA requiring two-stage revision were prospectively enrolled. This study was approved by our Institutional Health Sciences Research Ethics Board, and the single institution database was searched for all two-stage revisions performed before 2014. Infection was diagnosed using the 2018 Musculoskeletal Infection Society (MSIS) criteria [15]. Inclusion criteria included any adult patient requiring two-stage revision for infected TKA with a minimum of 5 years of clinical follow-up. The duration of clinical follow-up was determined based on the most recent clinic visit with the treating surgeon. This initial search returned 333 cases. Of these, cases were excluded if they underwent single-stage revision, had a prior revision surgery of the affected knee, had the first-stage procedure performed at an outside institution, where the type of spacer implanted was unclear, or did not meet the minimum 5-year follow-up requirement. One hundred and seventy-six patients met these criteria. One hundred and four patients were treated with an articulating spacer, and seventy-two were treated with a non-articulating static spacer. Patients were followed up for a minimum of 5 years.

All surgeons followed a similar protocol. Seven fellowship-trained surgeons contributed patients to this study. An aspirate was obtained preoperatively. The first-stage procedure included obtaining intraoperative cultures, removal of the infected TKA, thorough removal of all debris, and extensive irrigation and debridement of the infected soft tissue. There was some variability in the exact method in which irrigation and debridement was carried out. The typical protocol consisted of 9 liters of normal saline with 3 liters of bacitracin added, as well as a 1 liter of 50/50 povidone-iodine/normal saline mix. Once the debridement was completed, an antibiotic-impregnated spacer was inserted. The choice of static or articulating spacer was at the discretion of the treating surgeon, with static spacers often used in cases with poor soft tissues, bone stock, or extensor mechanism compromise. Static spacers at our institution typically consist of antibiotic cement fashioned around a tibial nail, which has been passed into the tibial and femoral canals through the knee. The type of articulating spacer used was also dependent on the treating surgeon. The antibiotic-impregnated articulating spacers were either custom-made, Prostalac, Biomet, or Exactech spacers. All spacers were cemented using antibiotic cement that was then mixed with vancomycin and either additional tobramycin or gentamicin. The exact dose of antibiotic used was surgeon dependent. The typical protocol at our institution is to add 2 grams of vancomycin and 2.4 grams of tobramycin/gentamicin per 40 grams of Simplex (Stryker, Inc., Kalamazoo, MI) bone cement. Postoperative radiographs were obtained. Patients were permitted to weight bear as tolerated with a walking aid (walker or crutches). Range of motion as tolerated was also allowed.

The postoperative treatment protocol at our institution consisted of 6 weeks of intravenous antibiotics tailored to the sensitivity of the cultured organisms in conjunction with the infectious disease specialists. Two weeks after completing the antibiotic therapy, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and white blood cell count were taken, and an aspirate of the knee was typically performed. Once the infectious symptoms subsided, the ESR and CRP normalized (ESR < 30 mm/h, CRP < 10 mg/L), and the aspirate was negative (cell count < 1100 cells/μl with negative cultures), plans were made to proceed to a second-stage revision. This was generally performed at approximately 3 months after the first stage. In cases in which bloodwork did not normalize and/or a positive aspirate was obtained, a repeat first-stage procedure was performed.

Outcomes after surgical treatment of prosthetic joint infection were stratified according to the MSIS definition of successful infection control [16]. Successful treatment was defined as not meeting the MSIS criteria for a prosthetic joint infection and not having any additional need for surgery.

The data were prospectively collected on each patient. Demographic data were collected, as well as patient-reported outcome scores consisting of the Knee Society Score (KSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Short Form 12 (SF-12) (mental and physical) at the annual clinical follow-up visits. Outcome score measurements were performed by the treating surgeon, fellow, or orthopedic resident. SF-12 scores were broken down into the physical component score (PCS) and mental component score (MCS) and reported as Z-scores [17]. WOMAC scores were divided into pain, stiffness, and function components and reported on a scale of 0 (worst) to 100 (best) [18]. WOMAC total scores were also reported using a similar 0 (worst) to 100 (best) scale [19]. The KSS was divided into function and knee components and also reported on a scale of 0 (worst) to 100 (best) [20]. The total KSS was calculated by taking the sum of the function and knee components. Any complication and need for subsequent revision surgery were documented.

A statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, Version 23.0.; IBM Corp., Armonk, NY). Independent student t tests were used to compare outcomes between groups.

As this was a retrospective study, a post hoc power analysis was performed for ROM using an alpha value of 0.05, which showed 100% power. However, this should be carefully interpreted given post hoc power analyses in retrospective studies can be flawed and analytically misleading [21].

## Results

The mean age of the patients in the articulating spacer group at the time of surgery was 68.6 (±10.6) years, and mean BMI was 33.2 (±8.23). Forty-four (42%) were female, and 49 (47%) had an infection in their left knee. In the static spacer group, the mean age was 69.4 (±10.0) years, and the mean BMI was 31.3 (±7.5). The static

group consisted of 41 (57%) females and 36 (50%) left knees. There were no statistically significant differences in age ($P = .64$), BMI ($P = .12$), or sex ($P = .084$) between groups (Table 1). There was also no significant difference in preoperative SF-12 MCS ($P = .39$), SF-12 PCS ($P = .29$), WOMAC ($P = .99$), ROM ($P = .31$), or KSS ($P = .10$) between groups. Final mean follow-up was 19.0 ± 6.3 years for the nonarticulating group and 10.0 ± 4.1 years for the articulating group. Mean time to revision was 3.65 years (range 3 months to 14 years) in the articulating spacer group and 4.28 years (range 3 months to 10 years) in the static spacer group.

Infection was successfully eradicated in 149 of 176 (84.7%) patients after a single first-stage revision. Articulating (87/104 [83.7%]) and nonarticulating (62/72 [86.1%]) spacers resulted in similar rates of infection eradication ($P = .234$). Seventeen of 104 patients in the articulating spacer group (16.3%) required revision for infection, and four (3.8%) underwent revision for aseptic reasons (2 for fracture, 1 for loosening, and 1 for instability and loosening). In the nonarticulating group, ten of the 72 patients (13.9%) required revision for infection, and eleven (15.2%) required revision for aseptic reasons (4 for instability, 4 for loosening, 1 for extensor mechanism failure, 1 for pain, and 1 for an allergy). Seven patients in the articulating spacer group and four patients in the static spacer group required repeat first-stage procedures. There were no statistically significant differences between the survivorship in knees treated with articulating and nonarticulating spacers.

Range of motion (full flexion minus full extension) was significantly greater in the articulating spacer group at the most recent follow-up visit. Final mean ROM in the articulating spacer group was 110.6 (±13.5) degrees, and final ROM in the nonarticulating group was 82.1 (±25.4) degrees ($P < .001$). Final ROM was reported instead of the change from preoperative to postoperative values given the similar preoperative ROM between groups (69.5 ± 26.5 degrees articulating spacer group vs 64.2 ± 29.5 degrees static spacer group; $P = .31$) and nonrandomized study design.

Both the articulating and nonarticulating groups had clinical improvement when comparing preoperative to postoperative scores. When compared to the nonarticulating group, at the most recent follow-up visit, the articulating spacer patients showed statistically significant improvements in WOMAC functional component scores (articulating = 60.1 ± 24.1, nonarticulating = 51.1 ± 21.4; $P = .03$), SF-12 PCS (articulating = 35.2 ± 9.8, nonarticulating = 31.0 ± 9.8; $P = .01$), KSS function score (articulating = 57.7 ± 32.3, nonarticulating = 43.1 ± 30.3; $P = .04$), KSS Knee score (articulating = 86.8 ± 13.6, nonarticulating 72.0 ± 23.3; $P < .001$), and KSS total outcome scores (articulating = 145.2 ± 34.9; nonarticulating = 113.7 ± 45.6; $P < .001$). There was no significant difference between groups with regard to postoperative SF-12 MCS ($P = .37$), WOMAC pain score ($P = .13$), WOMAC stiffness score ($P = .08$), and total WOMAC score ($P = .06$). Postoperative outcome data are summarized in Table 2.

## Discussion

Chronically infected TKAs are challenging clinical problems. The goals of the treating surgeon are to eradicate the infection while maximizing long-term function and quality of life. Two-stage revision TKA is considered the gold standard in achieving these goals. The options for implants during the period between infected component removal and implantation of a definitive arthroplasty include a static or articulating spacer.

There remains no clear consensus on whether an articulating or static spacer is best [2]. Guild et al. performed a systematic review of 47 articles and found that articulating spacers had superior range of motion (100.1 vs 82.9 degrees, $P < .003$), lower reinfection rate (7.5% vs 13.6%, $P < .0031$), decreased complexity of reimplantation ($P < .0011$), and decreased incidence of bone loss during the interim period ($P < .0001$) [12]. Voleti et al. also published a systemic review comparing the two spacer types and found no significant difference in reinfection rate (7% for articulating, 12% for static, $P = .2$) or functional scores [14]. They did find improved range of motion in the articulating group (101 vs 91 degrees, $P = .0002$) [14]. Similarly, in the systematic review of 48 studies by Pivec et al., they reported higher range of motion in the articulating spacer group (100 vs 92 degrees, $P = .001$), but no difference in reinfection rates or functional outcome scores [13]. Finally, Ding et al. also performed a meta-analysis of ten studies comparing spacer types and found improved range of motion, Hospital for Special Surgery score, and KSS function score in the articulating group ($P < .00,001$) [11]. However, they found no difference in reinfection rate ($P = .28$) or KSS pain score ($P = .11$) [11]. Recently, the first RCT comparing static and articulating spacers was also published and reported increased range of motion in the articulating group (113.0 vs 100.2 degrees, $P = .001$), as well as higher KSS (79.4 vs 69.8, $P = .043$) [7]. However, they found no difference in reinfection rate.

In our series of 176 patients, infection was successfully eradicated in 84.7% of patients. Articulating and nonarticulating spacers resulted in similar success rates of treatment. There were no differences between the survivorship in knees treated with articulating and nonarticulating spacers, which is consistent with other reports in literature reporting eradication rates of 85%-95% and similar survivorship rates between groups [5,22,23]. Reinfection was the most common cause of failure, and there was no difference in reinfection rates between spacer types. The infection eradication rate in our cohort was similar to that published for single-stage revisions, which ranges from 67% to 100% with an average rate of 87.1% in a recent systematic review [24].

The use of articulating spacers improved final range of motion by nearly 30 degrees on average, as compared to the static spacer group. Clinical outcome scores were also improved, as the articulating spacer group was found to have significantly higher postoperative SF-12 PCS, WOMAC function, and KSS total scores than the static group. WOMAC stiffness and total scores also approached

**Table 1**
Overview of the demographic data.

| Demographic | Articulating group | Nonarticulating group |
|---|---|---|
| Age | 68.6 ± 10.6 | 69.4 ± 10.0 |
| BMI | 33.2 ± 8.23 | 31.3 ± 7.5 |
| Sex (% female) | 42 | 57 |
| Side (% left) | 47 | 50 |

**Table 2**
Postoperative outcome scores for the articulating and nonarticulating spacer groups.

| Outcome | Articulating group | Nonarticulating group | *P* value (significant if $P < .05$) |
|---|---|---|---|
| Postop ROM | 110.6 ± 13.5 | 82.1 ± 25.4 | **<0.001** |
| Postop SF-12 PCS | 35.2 ± 9.8 | 31.0 ± 9.8 | **0.01** |
| Postop SF-12 MCS | 47.8 ± 11.4 | 49.5 ± 11.3 | 0.37 |
| Postop WOMAC pain score | 67.1 ± 25.1 | 60.4 ± 26.2 | 0.13 |
| Postop WOMAC stiffness score | 61.8 ± 24.3 | 54.4 ± 24.1 | 0.08 |
| Postop WOMAC function score | 60.1 ± 24.1 | 51.1 ± 21.4 | **0.03** |
| Postop WOMAC total score | 63.2 ± 22.5 | 55.8 ± 20.9 | 0.06 |
| Postop KSS function score | 57.7 ± 32.3 | 43.1 ± 30.3 | **0.004** |
| Postop KSS knee score | 86.8 ± 13.6 | 72.0 ± 23.3 | **<0.001** |
| Postop KSS total score | 145.2 ± 34.9 | 113.7 ± 45.6 | **<0.001** |

Significant values ($P < 0.05$) are indicated in bold.

statistical significance favoring the articulating spacer group ($P = .08$ and $P = .06$, respectively), which is important to note as perhaps a larger study with better control of variables may have shown a difference. This is similar to the other reports in the literature showing improved range of motion and functional outcome scores with articulating spacers [5,7,11,22,25-27].

Outcome scores in our cohort were similar to those published for single-stage revisions, which have published KSS scores ranging from 63.8 to 86.0 [24]. With regard to range of motion, our articulating spacer group had slightly higher ROM than values published for single-stage revisions, which range from 76 to 100 degrees with an average of 91.4 degrees in a recent systematic review [24].

To our knowledge, this is the largest series reporting on the outcomes of static vs articulating spacers in two-stage revision arthroplasty. As there is still debate over the cost-effectiveness of using articulating spacers because of their similar rates of infection eradication, the use of dynamic spacers is often questioned. As two-stage revision remains the gold standard for treating a chronically infected TKA, our results indicate that these patients may benefit from an articulating spacer.

Our study did have some notable limitations. The surgical technique and postoperative management of patients, although similar, did vary across surgeons. Furthermore, this was a retrospective examination of a prospectively collected database. Finally, there could have been a selection bias; in situations where reinfection leads to massive bone loss, poor soft-tissue condition, and/or extensor mechanism insufficiency, surgeons may prefer to use a static spacer [28-30]. As such, static spacers may have been more likely to be implanted in complicated cases at higher risk for poor outcomes. No specific criteria were used to determine bone loss before revision. The type of implant being revised and the implant used at the second stage were also not tracked, which may have affected results. We also were not able to do a subgroup analysis to determine if there were any variables in the articulating group that improved outcomes, such as spacer design, organism, or specific surgeon. In addition, we did not track the infecting organisms, patient comorbidities, incidence of extensor mechanism insufficiency, or if any cases required plastic surgery support for soft-tissue coverage. These would be interesting considerations for future studies.

## Conclusions

Articulating antibiotic spacers may benefit patients in the treatment of infected TKA with two-stage revision. Compared to static spacers, articulating spacers showed superior range of motion, SF-12 PCS, WOMAC function, and KSS scores at 5 years postoperatively. There was no significant difference in reinfection rate between the two groups.

## Conflicts of interests

B. Lanting is a paid consultant for Stryker, DePuy, Intellijoint, Smith & Nephew; has stock or stock options in PersaFix Spacer Solutions; and receives research support from Stryker, Smith & Nephew, and DePuy. E. Vasarhelyi is a paid consultant for DePuy and Hip Innovation Technology; receives research support from DePuy; and receives other financial and material support from DePuy, Smith & Nephew, Stryker, and Zimmer Biomet. D. Naudie receives royalties from, is in the speakers' bureau of, and is a paid consultant for Smith & Nephew; receives institutional and reserach support from Stryker, Smith & Nephew, and DePuy; is the chair of Membership Committee of The Knee Society. J. Howard is in the speakers' bureau of/gave paid presentations for Stryker, Smith & Nephew, and DePuy; is a paid consultant for Stryker, Smith & Nephew, Intellijoint, and DePuy; has stock or stock options in PersaFix Technologies Inc, receives research support from DePuy; and receives other financial and material support from Stryker, Smith & Nephew, Zimmer, Microport, and DePuy.

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