Use of Static or Articulating Spacers for Infection Following Total Knee Arthroplasty

A Systematic Literature Review

Pramod B. Voleti, MD, Keith D. Baldwin, MD, MSPT, MPH, and Gwo-Chin Lee, MD

Investigation performed at the Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania

Background: The so-called gold standard for treatment of periprosthetic joint infection following total knee arthroplasty is two-stage reimplantation. However, it is unclear whether use of static or articulating antibiotic-impregnated spacers during the interim period between these two stages is superior. The purpose of this study was to compare the outcomes of static and articulating spacers in the treatment of infection following total knee arthroplasty.

Methods: A systematic review of the peer-reviewed literature indexed by MEDLINE and Embase was performed to identify studies reporting the outcomes of antibiotic spacers in the treatment of infection following total knee arthroplasty. Seven Level-III comparative studies and thirty-two Level-IV case series remained following the screening process. The data in these studies were extracted and aggregated to compare the reinfection rate, range of knee motion, functional scores, and complication rates between static and articulating spacers.

Results: The two types of spacers demonstrated similar reinfection rates (7% for articulating and 12% for static, $p = 0.2$). However, the articulating spacers resulted in significantly greater range of knee motion after reimplantation (101° for articulating and 91° for static, $p = 0.0002$). Despite this difference in ultimate knee motion, functional scores in the treatment groups were similar. Rates of wound-related and spacer-related complications were similarly low with both types of spacers.

Conclusions: Our review failed to identify a significant difference in the ability of static or articulating spacers to eradicate periprosthetic infection following total knee arthroplasty. Compared with static spacers, articulating spacers provided improved knee motion following reimplantation, although functional scores were similar in the two treatment groups. We encourage arthroplasty surgeons to consider both static and articulating spacers in the treatment of infection following total knee arthroplasty and to tailor treatment on the basis of patient-related factors.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Reported rates of periprosthetic joint infection following primary total knee arthroplasty range from 0.4% to 2.5%[1-5]. This catastrophic complication results in substantial morbidity, is associated with a mortality rate approaching 2.5%, and costs approximately $50,000 per episode (exclusive of lost wages)[6].

The so-called gold standard for treatment of subacute and chronic periprosthetic infection following total knee arthroplasty is two-stage reimplantation[6-11]. In the first stage, a resection arthroplasty is performed with placement of an antibiotic spacer. The antibiotic spacer provides local delivery of antibiotics, and systemic intravenous antibiotics are administered simultaneously. The goals of spacer use are to maintain alignment, prevent contracture, increase patient comfort, enhance soft-tissue healing, and deliver antibiotics[12]. Controversy exists regarding whether static or articulating antibiotic spacers are superior in the treatment of infection following total knee arthroplasty.

Proponents of the use of static spacers during the interim period between resection arthroplasty and reimplantation maintain that static spacers are more effective than articulating spacers at delivering antibiotics and thus controlling the periprosthetic joint infection[13]. However, critics argue that articulating spacers provide better function during the interim period,

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

TABLE I Characteristics of the Seven Included Level-III Comparative Studies

Study	No. of Patients			Follow-up *(mo)*		
	Overall	Static Spacers	Articulating Spacers	Overall	Static Spacers	Articulating Spacers
Fehring, 2000[18]	40	25	15	33	36	27
Emerson, 2002[14]	48	26	22	70	90	46
Jämsen, 2006[19]	30	8	22	31	49	25
Freeman, 2007[13]	114	38	76	70	87	62
Hsu, 2007[15]	28	7	21	69	101	58
Park, 2010[16]	36	20	16	33	36	29
Chiang, 2011[17]	45	22	23	41	40	41
Total	341	146	195			
Mean				54	63	48

superior knee motion and functional outcomes following reimplantation, and decreased bone loss resulting from spacer migration[14-17]. Despite the multitude of studies comparing static and articulating spacers, the question still remains: are static or articulating spacers superior in the treatment of periprosthetic joint infection following total knee arthroplasty?

The purpose of this study was to analyze the peer-reviewed literature in order to compare the outcomes (reinfection rate, range of knee motion and functional scores following reimplantation, and complication rate) of static spacers with those of articulating spacers in the treatment of infection following total knee arthroplasty.

Materials and Methods

We performed a systematic query of both the MEDLINE and Embase computerized literature databases to identify articles containing the keyword terms "total knee arthroplasty" and "spacer." The search was performed on May 1, 2012, and all studies published prior to that date were considered. In addition to this primary search, we performed a secondary search by scrutinizing all references cited in the articles retrieved from the primary search and identifying additional studies of interest. Each of the three authors independently reviewed all articles retrieved from the primary and secondary searches with use of the systematic strategy outlined below. Each author was blinded with regard to the determinations of the other two authors.

Studies were included if they (1) described patients treated with static and/or articulating spacers for periprosthetic infection following primary total knee arthroplasty; (2) reported reinfection rates, knee motion after reimplantation, functional scores after reimplantation, and/or complication rates; and (3) followed patients for at least two years. Review articles, technique descriptions, and editorials were excluded.

The initial combined MEDLINE and Embase search with use of the aforementioned keyword terms yielded 259 unique articles. The titles of these articles were reviewed independently by all three authors. Articles whose titles indicated that they were clearly irrelevant to the topic in question (118) were eliminated. The abstracts of the remaining 141 articles were then scrutinized independently by all three authors. Articles that clearly did not meet the inclusion criteria on the basis of the information contained in the abstract (ninety-three) were eliminated. The abstracts of the remaining forty-eight articles were determined to meet the inclusion criteria by at least one author, and the corresponding full text was therefore reviewed independently by all three authors. After review of the full text, sixteen of these articles were eliminated unanimously by all three authors because they failed to meet the inclusion criteria. The remaining thirty-two articles from the primary search were retained. At each phase of review, if one or more authors selected an article, it moved on to the next phase. In the final (full text) phase of review, there was no disagreement regarding which articles should ultimately be included.

All references cited in the articles retrieved in the initial query were then compiled for the secondary search. These references were screened in the same manner as the articles from the primary search (title review, then abstract review, then full text review). Seven of the additional articles identified in the secondary search met the inclusion criteria and were retained. Therefore, a total of thirty-nine articles underwent the data retrieval process (Fig. 1); seven of

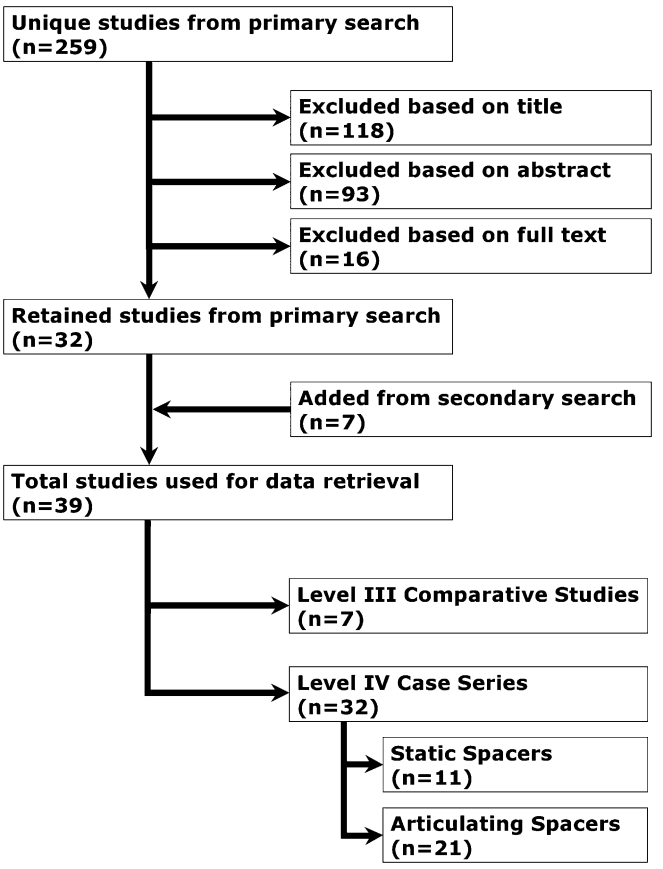

Fig. 1
Flow diagram outlining the systematic search utilized in this study.

TABLE II Reinfection Rates Reported in the Included Level-III Comparative Studies

Study	Reinfection Rate (%)		
	Overall	Static Spacers	Articulating Spacers
Fehring[18]	10	12	7
Emerson[14]	8	8	9
Jämsen[19]	13	25	9
Freeman[13]	6	8	5
Hsu[15]	11	14	10
Park[16]	11	15	6
Chiang[17]	11	14	9
Mean	9	12	7

these represented Level-III comparative studies that described both static and articulating spacer treatment groups[13-19], and thirty-two represented Level-IV case series that described either patients treated with static spacers (eleven studies, references 23 through 33 in the Appendix) or patients treated with articulating spacers (twenty-one studies, references 34 through 54 in the Appendix).

The data published in these articles were meticulously extracted and compiled. The data obtained from the seven Level-III comparative studies were used to generate a random-effects meta-analysis model to compare reinfection rates and frequency-weighted mean knee motion after reimplantation. The meta-analysis was performed with MIX meta-analysis software (version 1.7 for Windows; BiostatXL). The data obtained from the thirty-nine Level-III and Level-IV studies were used to calculate frequency-weighted means and groupwise variance for the reinfection rate, range of motion after reimplantation, and functional scores after reimplantation as well as to compare complication rates between the treatment groups.

Source of Funding

No external funding sources were utilized for this investigation.

Results

The seven Level-III comparative studies included a total of 341 patients, 146 treated with static spacers and 195 treated with articulating spacers (Table I). The population sizes for the individual studies ranged from twenty-eight to 114 patients. Of note, the frequency-weighted mean duration of follow-up was greater for static spacers (sixty-three months) than for articulating spacers (forty-eight months). This was because the authors of four of these studies[13-15,18] initially used static spacers exclusively and then transitioned gradually to using articulating spacers more frequently.

Six of the seven Level-III studies[13,15-19] demonstrated a greater reinfection rate in the static spacer group than in the articulating spacer group (Table II). However, because of the overall paucity of reinfections, none of these individual studies demonstrated a significant difference between the reinfection rates in the two treatment groups. Aggregation of the reinfection rate data with use of the random-effects meta-analysis model revealed a frequency-weighted mean reinfection rate of 12% for static spacers and 7% for articulating spacers (Fig. 2). This difference was again not significant ($p = 0.2$). The antibiotic concentration within the spacer cement was identical in the two spacer groups in five of the studies[13-16,18], greater in the static spacer group than in the articulating spacer group in one study[17], and not reported in one study[19] (see Appendix).

All six Level-III comparative studies that included data on the range of knee motion after reimplantation[14-19] indicated that articulating spacers resulted in greater range of motion after reimplantation than did static spacers (Table III). This difference reached significance in four of the six studies[14-17]. The remaining two studies[18,19] were likely underpowered with regard to this variable, although no power analysis was reported.

The results of the combined analysis of the thirty-nine Level-III and Level-IV studies are shown in Table IV. These studies included a total of 1526 patients, 654 treated with static spacers and 872 treated with articulating spacers. The frequency-weighted mean duration of follow-up was similar in the two treatment groups (fifty-seven months for static spacers and fifty-two months for articulating spacers, $p = 0.4$). The mean reinfection rate was again greater, but not significantly so, in the static spacer group (12%) than in the articulating spacer group (8%, $p = 0.1$). Importantly, there was a significant difference between the groups with regard to knee motion after reimplantation (91° for static spacers and 101° for articulating spacers, $p = 0.0002$). Despite this difference in range of motion, the treatment groups demonstrated similar functional outcomes ($p = 0.5$ for the HSS [Hospital for Special Surgery] score and $p = 0.7$ for the Knee Society score). Wound-related

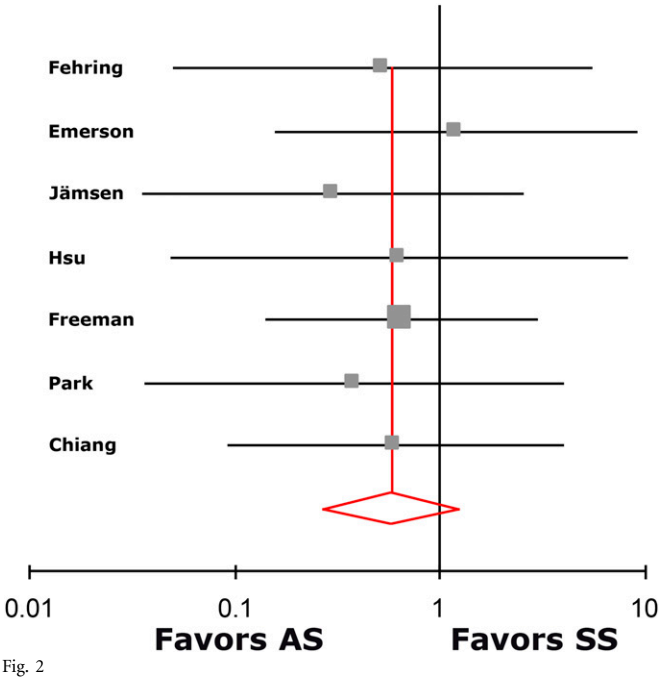

Fig. 2

Forest plot showing the meta-analysis of reinfection rates. The diamond indicates the pooled estimate of the ratio between the infection rates in the two treatment groups, the horizontal bars and the width of the diamond indicate the 95% confidence intervals, and the box sizes indicate the relative weighting of each study. AS = articulating spacers, and SS = static spacers.

TABLE III Range of Motion After Reimplantation Reported in the Included Level-III Comparative Studies*

Study	Range of Motion *(deg)*			Reported P Value
	Overall	Static Spacers	Articulating Spacers	
Fehring[18]	101	98	105	0.14
Emerson[14]	100	94	108	0.01†
Jämsen[19]	101	92	104	0.143
Freeman[13]	NR	NR	NR	NR
Hsu[15]	91	78	95	0.019†
Park[16]	99	92	108	0.04†
Chiang[17]	99	85	113	<0.05†
Mean	99	92	105	

*NR = not reported. †Significant ($p < 0.05$).

TABLE IV Clinical Data Reported in the Thirty-nine Included Level-III and Level-IV Studies*

Variable	Overall	Static Spacers	Articulating Spacers	P Value
No. of patients	1526	654	872	NC
Follow-up *(mo)*	54	57	52	0.4
Reinfection rate	10%	12%	8%	0.1
Postop. range of motion	97°	91°	101°	0.0002†
HSS score	82	81	83	0.5
Knee Society score	78	77	80	0.7
Wound complication rate	4%	8%	2%	NC
Spacer complication rate	2%	1%	3%	NC

*NC = not calculated. †Significant ($p < 0.05$).

complications occurred in 8% of patients treated with static spacers compared with 2% of patients treated with articulating spacers, and spacer-related complications occurred in 1% of patients treated with static spacers compared with 3% of patients treated with articulating spacers. Given the infrequency of these complications, the present study was underpowered to demonstrate a significant difference between these complication rates.

Discussion

Periprosthetic joint infection following total knee arthroplasty is a catastrophic complication that results in substantial pain, disability, and health-care costs. Even after successful eradication of the infection, the patient may experience long-term residual pain and continued disability[20]. These poor functional results may be attributed to multiple causes, including (but not limited to) patient comorbidities, wound-healing complications, bone loss, and residual infection. Therefore, optimizing the outcomes of these patients by determining the ideal type of antibiotic spacer is of critical importance.

Concerns that have been raised regarding static spacers include bone erosion, spacer subluxations and dislocations, spacer fractures, knee stiffness, and increased difficulty of exposure during reimplantation. Additionally, patient function during the interim period between resection arthroplasty and reimplantation is limited if static spacers are used, as the patient is required to keep the affected lower extremity extended. Articulating spacers have gained in popularity because they are thought to allow limited motion, decrease stiffness, increase the range of knee motion after reimplantation, reduce surgical exposure time during reimplantation, and result in improved functional outcomes. However, some concerns have been raised regarding whether articulating spacers deliver antibiotics as well as static spacers do.

We failed to identify a significant difference in the ability of static or articulating spacers to eradicate periprosthetic infection following total knee arthroplasty. Our meta-analysis of Level-III comparative studies demonstrated a reinfection rate of 12% for static spacers and 7% for articulating spacers ($p = 0.2$). The combined analysis of Level-III and Level-IV studies also demonstrated similar reinfection rates in the two treatment groups (12% for static spacers and 8% for articulating spacers, $p = 0.1$). Therefore, the currently available evidence suggests that the two types of spacers are similarly effective at

controlling infection in patients undergoing two-stage reimplantation for periprosthetic infection following total knee arthroplasty.

Knee stiffness is a frequent complication of periprosthetic infection following total knee arthroplasty, even after eradication of the infection[20]. Factors that contribute to knee stiffness include relative immobility during the interval between the two stages of the revision procedure, multiple surgical procedures, and scar tissue formation. According to our analysis, articulating spacers resulted in significantly greater post-reimplantation range of knee motion compared with static spacers. All six Level-III comparative studies in which the final range of motion was reported demonstrated greater knee motion for patients treated with articulating spacers compared with static spacers. The frequency-weighted mean range of motion after reimplantation was 105° for articulating spacers and 92° for static spacers. Additionally, the combined analysis of the Level-III and Level-IV studies demonstrated a similar difference in ultimate range of motion (101° for articulating spacers and 91° for static spacers, $p = 0.0002$). The difference in mean flexion appears small, but the greater ultimate range of motion in patients treated with articulating spacers may actually result in a difference in the ability to perform activities of daily living, such as stair climbing and rising from a chair[21].

Despite the difference in ultimate range of motion, patients in the two treatment groups had similar clinical and functional outcomes. We found no significant difference between the groups with regard to the HSS score ($p = 0.5$) or the Knee Society score ($p = 0.7$). The reason for this lack of difference in function is unknown. One possible explanation involves the fact that the range of knee motion accounts for only a small proportion of these two functional scores (18 out of 100 total points in the HSS score and 25 out of 100 total points in the Knee Society score). Other components of the HSS and Knee Society scores include pain, ability to perform activities of daily living (walking, stairs, and transfers), muscle strength, alignment, and stability. Therefore, although patients treated with articulating spacers experienced improved range of motion after reimplantation compared with patients treated with static spacers, the contribution of residual pain and diminished activity level to these scores may have led to statistically insignificant improvements in overall knee function.

Finally, the rates of complications—both wound-related and spacer-related—appeared similar between the treatment groups. The most common wound-related complications were wound dehiscence and superficial infection, and the most common spacer-related complications were spacer migration and bone loss. Of note, these complications were so uncommon that statistical comparisons could not be performed even after aggregating all available data. Consequently, it appears that either articulating or static spacers, when placed in well-selected patients with use of an appropriate surgical technique, can yield similarly low complication rates.

The present study has some important limitations. As with all systematic reviews and meta-analyses, this investigation is limited by the inherent weaknesses of the component studies (which were all Level-III comparative studies and Level-IV case series characterized by retrospective study designs, limited population sizes, and medium-term follow-up durations). There was also notable heterogeneity among the component studies with regard to surgical technique, spacer preparation method, spacer antibiotic selection and concentration, duration of intravenous antibiotic treatment, and duration of spacer use. Furthermore, our analysis did not control for confounding variables (such as medical comorbidities, body mass index, the extent of bone loss, skin quality, or surgical history) and it did not directly evaluate certain important outcomes (such as spacer-related bone erosion and operative time). Our ability to take such confounding variables and additional outcomes into account was unfortunately hindered by inconsistent reporting of this information in the component retrospective studies. In addition, the included studies were nonrandomized, and our analysis was therefore likely affected by selection bias as the authors of the component studies may have tailored the treatment on the basis of patient-related variables (such as medical comorbidities, body mass index, the extent of bone loss, skin quality, and the surgical history). For example, static spacers may have been employed preferentially in patients with more severe bone loss. Pooling data from nonrandomized comparative and observational studies is controversial and does have important statistical limitations that may impact the results of the review. However, some research questions, such as the ones addressed in this investigation, are not amenable to randomized trials; in such cases, the Cochrane Collaboration notes that authors of reviews are justified in including nonrandomized studies[22].

Despite its limitations, the present systematic literature review does make important comparisons between static and articulating spacers with regard to reinfection rates, knee motion and functional outcomes following reimplantation, and complication rates. Given the similar reinfection and complication rates in the two treatment groups, we encourage arthroplasty surgeons to consider both static and articulating spacers in the treatment of periprosthetic infection following total knee arthroplasty and to tailor treatment on the basis of patient-related factors (such as comorbidities, bone deficiency, the soft-tissue envelope, skin quality, and the infecting microorganism).

Evidence-based medicine dictates that medical decisions should be guided by sound evidence in the literature. One of the most important findings of the present study is that the currently available literature comparing static with articulating antibiotic spacers in the treatment of infection following total knee arthroplasty is extremely limited. We encourage the initiation of large, multicenter, prospective, randomized controlled trials to further elucidate the best treatment protocols for periprosthetic joint infection following total knee arthroplasty.

Appendix

eA A table listing the antibiotic concentrations in the seven included Level-III comparative studies as well as references for the thirty-two Level-IV case series are available with the online version of this article as a data supplement at jbjs.org. ■

Pramod B. Voleti, MD
Keith D. Baldwin, MD, MSPT, MPH
Gwo-Chin Lee, MD
Department of Orthopaedic Surgery,
Hospital of the University of Pennsylvania,
3400 Spruce Street,
2 Silverstein, Philadelphia, PA 19104.
E-mail address for G.-C. Lee: Gwo-Chin.Lee@uphs.upenn.edu

References

1. Blom AW, Brown J, Taylor AH, Pattison G, Whitehouse S, Bannister GC. Infection after total knee arthroplasty. J Bone Joint Surg Br. 2004 Jul;86(5):688-91.

2. Hanssen AD, Rand JA. Evaluation and treatment of infection at the site of a total hip or knee arthroplasty. Instr Course Lect. 1999;48:111-22.

3. Peersman G, Laskin R, Davis J, Peterson M. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. Clin Orthop Relat Res. 2001 Nov;392:15-23.

4. SooHoo NF, Lieberman JR, Ko CY, Zingmond DS. Factors predicting complication rates following total knee replacement. J Bone Joint Surg Am. 2006 Mar;88(3):480-5.

5. Phillips JE, Crane TP, Noy M, Elliott TS, Grimer RJ. The incidence of deep prosthetic infections in a specialist orthopaedic hospital: a 15-year prospective survey. J Bone Joint Surg Br. 2006 Jul;88(7):943-8.

6. Lentino JR. Prosthetic joint infections: bane of orthopedists, challenge for infectious disease specialists. Clin Infect Dis. 2003 May 1;36(9):1157-61. Epub 2003 Apr 14.

7. Teeny SM, Dorr L, Murata G, Conaty P. Treatment of infected total knee arthroplasty. Irrigation and debridement versus two-stage reimplantation. J Arthroplasty. 1990 Mar;5(1):35-9.

8. Goldman RT, Scuderi GR, Insall JN. 2-stage reimplantation for infected total knee replacement. Clin Orthop Relat Res. 1996 Oct;331:118-24.

9. Wilde AH, Ruth JT. Two-stage reimplantation in infected total knee arthroplasty. Clin Orthop Relat Res. 1988 Nov;236:23-35.

10. Haleem AA, Berry DJ, Hanssen AD. Mid-term to long-term followup of two-stage reimplantation for infected total knee arthroplasty. Clin Orthop Relat Res. 2004 Nov;428:35-9.

11. Hirakawa K, Stulberg BN, Wilde AH, Bauer TW, Secic M. Results of 2-stage reimplantation for infected total knee arthroplasty. J Arthroplasty. 1998 Jan;13(1):22-8.

12. Booth RE Jr, Lotke PA. The results of spacer block technique in revision of infected total knee arthroplasty. Clin Orthop Relat Res. 1989 Nov;248:57-60.

13. Freeman MG, Fehring TK, Odum SM, Fehring K, Griffin WL, Mason JB. Functional advantage of articulating versus static spacers in 2-stage revision for total knee arthroplasty infection. J Arthroplasty. 2007 Dec;22(8):1116-21.

14. 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 Nov;404:132-8.

15. Hsu YC, Cheng HC, Ng TP, Chiu KY. Antibiotic-loaded cement articulating spacer for 2-stage reimplantation in infected total knee arthroplasty: a simple and economic method. J Arthroplasty. 2007 Oct;22(7):1060-6.

16. Park SJ, Song EK, Seon JK, Yoon TR, Park GH. Comparison of static and mobile antibiotic-impregnated cement spacers for the treatment of infected total knee arthroplasty. Int Orthop. 2010 Dec;34(8):1181-6. Epub 2009 Nov 21.

17. Chiang ER, Su YP, Chen TH, Chiu FY, Chen WM. Comparison of articulating and static spacers regarding infection with resistant organisms in total knee arthroplasty. Acta Orthop. 2011 Aug;82(4):460-4.

18. 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 Nov;380:9-16.

19. Jämsen E, Sheng P, Halonen P, Lehto MU, Moilanen T, Pajamäki J, Puolakka T, Konttinen YT. Spacer prostheses in two-stage revision of infected knee arthroplasty. Int Orthop. 2006 Aug;30(4):257-61. Epub 2006 Mar 25.

20. Kim TW, Makani A, Choudhury R, Kamath AF, Lee GC. Patient-reported activity levels after successful treatment of infected total knee arthroplasty. J Arthroplasty. 2012 Sep;27(8)(Suppl):81-5. Epub 2012 May 23.

21. Chiu KY, Ng TP, Tang WM, Yau WP. Review article: knee flexion after total knee arthroplasty. J Orthop Surg (Hong Kong). 2002 Dec;10(2):194-202.

22. Reeves BC, Deeks JJ, Higgins JPT, Wells GA. Including non-randomized studies. In: Cochrane handbook for systematic reviews of interventions. Version 5.1.0. The Cochrane Collaboration; March 2011. http://handbook.cochrane.org. Accessed 2013 Mar 14.