Articulating Antibiotic-Impregnated PMMA Spacer for Staged Reconstruction of Infected Total Knee Arthroplasty

L. Pearce McCarty, III MD, Wolfgang Fitz, MD

Department of Orthopaedics, Brigham and Women's Hospital, Boston MA

INTRODUCTION

Infection is a devastating complication of total knee arthroplasty, affecting up to 2% of primary knee arthroplasties and up to 5.6% of revision knee arthroplasties. [1] Two-staged reconstruction --with thorough debridement of all nonviable tissue including pseudomembrane, removal of components and cement, and long-term parenteral antibiotics followed by reimplantation-- has become the standard of care in treating these infections and has met with a high rate of success.[2-4] With dual goals of eradicating infection and optimizing function, various technical modifications of the staged reconstruction process have evolved. One such technical modification, now in use for over a decade, is the utilization of a temporary intra-articular spacer fashioned out of antibiotic-impregnated bone cement. Such a spacer helps to maintain an appropriate soft tissue envelope and permits local delivery of high doses of antibiotic without systemic toxicity.[5] Traditionally, spacers have been static, consisting of a single block of cement positioned between the distal femur and proximal tibia (Figure 1). Recently, dynamic spacers have been introduced, comprising of separate femoral and tibial components that permit limited articulation with or without the combination of resterilized femoral components and thin polyethylene tibial components. A variety of techniques for making these articulating spacers appears in the literature.[6-11] However, it is unclear whether static cement spacers are superior to articulating spacers.[12] We present a simple, inexpensive method for the intra-operative manufacture of a custom-fit, all-cement articulating spacer, and review the relevant literature.

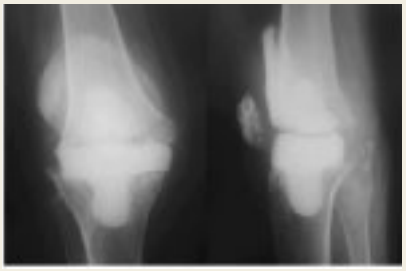

Figure 1. AP and lateral of traditional static spacer block.

Figure 2. Aluminum templates used for molding femoral and tibial articulating spacer components.

SURGICAL TECHNIQUE

The initial surgical treatment of the total knee arthroplasty with suspected or confirmed sepsis is approached in standard fashion. Adequate exposure for thorough debridement and removal of components is attained. Multiple tissue samples for deep cultures are taken prior to administration of intraoperative antibiotics. The knee is then irrigated copiously utilizing pulsatile lavage. A set of templates is then used to help fashion the separate femoral and tibial components of the articulating spacer.

Templates for the distal femur and proximal tibia are prepared in advance from 0.7 mm thick aluminum sheeting (Figure 2) and autoclaved for sterility. The same set of templates may be used for multiple cases. The femoral template is elongated, which permits one to fashion an anterior flange to fill the suprapatellar pouch. The appropriate curvature for the distal femoral spacer is created by bending the template around a trial component that matches the general size and curvature of the patient's extracted femoral component. Alternatively, the extracted femoral component—once autoclaved—may be used as a model for molding. Flexion and extension gaps are checked to gain an idea of the thickness of the cement needed. Strict balancing of flexion and extension gaps is not necessary, but tightness in flexion should be avoided.

Antibiotic-impregnated polymethylmethacrylate (PMMA)

L. Pearce McCarty, III MD is a Resident, Harvard Combined Orthopaedic Residency Program, Boston, MA

Wolfgang Fitz, MD, is an Instructor of Orthopedic Surgery, Harvard Medical School Attending Physician, Department of Orthopaedic Surgery, Brigham and Women's Hospital

Address correspondence to:

Wolfgang Fitz, MD
Brigham and Women's Hospital
Department of Orthopaedic Surgery
75 Francis St.
Boston, MA 02115
Office: 617-732-5401
Email: wfitz@partners.org

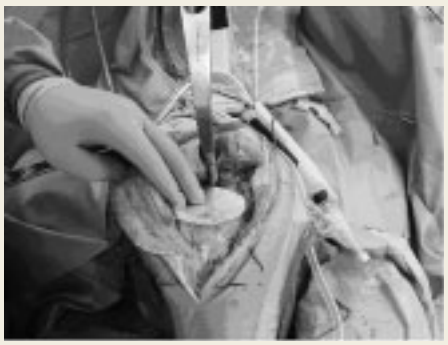

Figure 3. Molding tibial component in-situ.

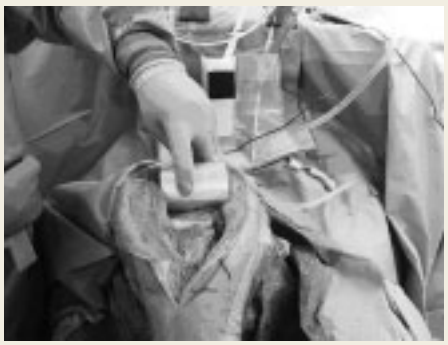

Figure 4. Molding femoral component in-situ.

Figure 5. Intraoperative image of femoral and tibial articulating spacer components.

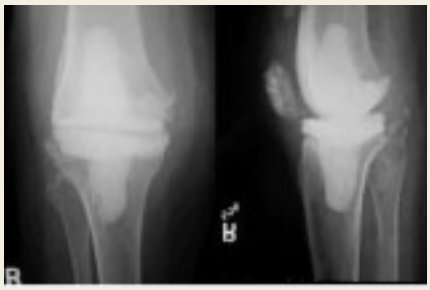

Figure 6. AP and lateral of articulating spacer.

bone cement is then prepared by mixing 3.6 grams of tobramycin and 1 gram of vancomycin per 40-gram packet of Simplex-P polymethylmethacrylate cement (Stryker Howmedica, Rutherford, NJ). Tobramycin and vancomycin act synergistically when eluted from bone cement, and elution is optimized with the doses described here.[13,14] If the sensitivities of the infectious organism are known, antibiotics are tailored accordingly. Hand-mixing is preferred over vacuum-assisted mixing due to the higher porosity of cement achieved when mixing by hand. Three to four bags of cement typically suffice, depending upon the size of the patient's distal femur and proximal tibia.

Both femoral and tibial templates are coated with sterile mineral oil to prevent adherence of cement. Once the cement has reached a doughy consistency, it is applied to both the femoral and tibial templates. The cement-filled templates are placed on the distal femur and proximal tibia (Figure 3), such that during the curing process the aluminum templates face into the joint, thereby generating smooth surfaces for articulation and preventing adherence of the spacers to each other (Figure 4). Inserting the cement-filled templates at a doughy consistency minimizes interdigitation of cement into exposed cancellous bone, but allows penetration of cement into the intramedullary canal and/or bony deficiencies. Extension of cement into the medullary canal is important because it ensures intramedullary elution of antibiotic and prevents dislodgement of the spacers during motion. The thickness of applied cement should allow for wound closure.

Excess cement is removed sharply while the cement is still malleable. Care is taken to cover the tibial surface completely and attain sufficient cortical rim contact to prevent subsidence and thereby protect tibial bone stock. The anterior flange of the femoral component fills the suprapatellar pouch, helping to minimize scarring of the extensor mechanism to the anterior femur. Slight overhang of the femoral component into the medial and/or lateral gutters may help prevent the scarring that typically occurs in these areas. After cement polymerization, the templates are removed. With cement spacers in place, full extension and at least 45° of flexion should be obtained (Figures 5 and 6). Intraarticular drains are not used, as the period of maximum antibiotic elution from the implanted spacers occurs over the first few hours to days after implantation.[15]

After surgery, a knee immobilizer is used for 24 hours, after which continuous passive motion is initiated, the limits for which are determined by the range of motion achieved during surgery. Passive range of motion is followed by gradual introduction of active range of motion, quad sets and ankle pumps to minimize muscular atrophy.

DISCUSSION

The first step of a two-stage reconstruction of infected total knee arthroplasty consists of component and cement removal, thorough debridement and irrigation of the joint, and administration of a minimum of six weeks of parenteral antibiotics.[16] The second step involves reimplantation of a new prosthesis. Despite eradication of infection, soft tissue complications can compromise the results of staged reconstruction. Soft tissue contraction, scarring of the patella and quadriceps tendon to the anterior femur, and shortening of the extensor mechanism can make exposure during reimplantation problematic, cause soft tissue complications, and severely limit post-reimplantation range of motion.

Hofmann *et al.*[10] reviewed the use of an articulating spacer in a series of 26 patients who underwent two-stage reconstruction for infected total knee arthroplasty. Their spacer consisted of a composite of the extracted femoral component

(autoclaved) and a new polyethylene insert, implanted with a large amount of antibiotic-impregnated cement. There were no soft tissue complications in the series. Average range of motion after reimplantation was 5° to 106° flexion at final follow-up (minimum 13 months).

In another series, Emerson et al.[6] compared post-reimplantation range of motion and reinfection rates between a group of 26 knees treated with staged reconstruction using a static spacer and a group of 22 knees in which an articulating spacer was used. The articulating spacers were created after the fashion of Hofmann et al. A minimum follow-up of 2.8 and 2.6 years was provided, respectively. The authors reported a statistically significant improvement in range of motion in the group treated with an articulating spacer over those treated with a static spacer, with maximum flexion of 107.8° versus 93.7°, respectively. There was no difference in the rate of reinfection between the two groups.

Fehring *et al.*[7] reviewed the results of 25 patients treated with a static spacer versus 30 patients treated with an articulating spacer. Articulating spacers were all-cement in nature, fashioned out of antibiotic-impregnated PMMA using a custom cast mold. Minimum follow-up for both groups was 24 months. The authors concluded that although they could not demonstrate a significant difference in post-reimplantation ROM (maximum flexion 95º versus 105º) between the two groups, patients treated with an articulating spacer had significantly less bone loss, and the use of an articulating spacer facilitated subsequent reimplantation.

Haddad *et al.*[9] reported on the use of a commercially available PROSTALAC system for the knee (Depuy Orthopaedics, Warsaw, IN), consisting of a metal, polyethylene and PMMA-composite that articulates in a posterior-stabilized fashion. The PROSTALAC was implanted in a group of 45 patients, with a minimum follow-up of 20 months. The investigators stated that one of the most significant advantages of using an articulated spacer is pain relief. The authors also contended that the use of a PROSTALAC system facilitated reimplantation and improved functional outcome after reimplantation. One of the most notable disadvantages of this particular articulating design, however, was its high cost.

An articulating spacer offers distinct advantages over a block spacer, including optimization of extensor mechanism function and length, improved post-reimplantation range of motion, and minimization of bone loss. Furthermore, separate femoral and tibial spacer components provide an improved surface-to-volume ratio over traditional block spacers, and there is evidence that the elution characteristics of antibiotic-laden bone cement improve with increasing surface-to-volume ratio.[17]

Multiple methods for manufacturing articulating spacers have been reported in the literature. The technique presented by Hoffman *et al.* may inspire some reservation, as it entails reimplantation of the extracted, infected femoral component, albeit after autoclave sterilization. Techniques utilizing a composite spacer, comprised of metal and polyethylene in addition to antibiotic-laden cement, also raise concern over the introduction of foreign material into an infected joint. Bacterial adherence to such foreign materials is an issue when attempting to eradicate infection prior to reimplantation. Although bacterial adherence to antibiotic-laden cement alone has been demonstrated *in vitro*,[18] it is unlikely that persistent adherence, colonization and reinfection would be as likely with use of an all-PMMA articulating spacer as with use of a composite spacer incorporating metal and plastic. To date no studies have compared composite versus all-PMMA articulating spacers with respect to reinfection or surface colonization.

Methods for manufacturing all-PMMA articulating spacers also appear in the literature. The method of McPherson et al., for example, requires the use of a custom, cast mold for manufacture of the femoral component; the tibial component is handcrafted without a matching mold. Potential disadvantages include cost and availability of the mold. Goldstein et al. have coined the acronym "TAMMAS", for Temporary Articulating Methylmethacrylate Antibiotic Spacer, and present a technique for manufacturing an all-PMMA articulating spacer in which a heavy foil is applied to both the distal femur and proximal tibia following removal of infected components. Antibiotic-impregnated cement is then molded over these foil coverings. The distal femoral spacer component is contoured using a trial tibia insert, and the tibial spacer component shaped by hand. The cement is allowed to cure with the foil in place, and the foil is then removed. Potential drawbacks of this technique include difficulty filling the intramedullary canal and other cavitary bony defects. Additionally, without non-adherent surfaces interposed between the femoral and tibial spacer components, each component must be fitted and allowed to cure independently, prolonging operative time and making it more difficult to accurately gauge the cement thickness necessary to maintain appropriate flexion and extension gaps. This technique has demonstrated poor reproducibility in our hands.

SUMMARY

The use of an articulating, antibiotic-impregnated spacer offers distinct advantages over the use of a block spacer in the staged reconstruction of infected total knee arthroplasty. An all-PMMA design is less expensive, uses readily available ingredients for manufacture, and possibly decreases reinfection rate by minimizing risk of bacterial adherence to and colonization of intra-articular foreign material. The technique presented in this report permits the manufacture of an articulating, all-PMMA spacer reproducibly and without expensive molds.

References

1. **Hanssen, A.D. and Rand, J.A.:** Evaluation and treatment of infection at the site of a total hip or knee arthroplasty. *J. Bone and Joint Surg.*, 80-A: 910-922, June 1998.
2. **Borden, L.S. and Gearen, P.F.:** Infected total knee arthroplasty: a protocol for management. *J. Arthroplasty*, 2(1): 27-36, March 1987.
3. **Wilde, A.H. and Ruth, J.T.:** Two-stage reimplantation of infected total knee arthroplasty. *Clin. Orthop.*, 236: 23-35, November 1988.
4. **Windsor, R.E.; Insall, J.N.; Urs, W.K.; Miller, D.V. and Brause, B.D.:** Two-stage reimplantation for the salvage of total knee arthroplasty complicated by infection. *J. Bone and Joint Surg.*, 72-A: 272-278, February 1990.
5. **Booth, R.E. and Lotke, P.A.:** The results of spacer block technique in revision of infected total knee arthroplasty. *Clin. Orthop.*, 248: 57-60, November 1989.
6. **Emerson, R.H.: Muncie, M.; Tarbox,T.R. and Higgins, L.L.:** Comparison of a static with a mobile spacer in total knee infection. *Clin. Orthop.*, 404: 132-138, November 2002.
7. **Fehring, T.K.; Odum, S.; Calton, T.F. and Mason, J.B.:** Articulating versus static spacers in revision total knee arthroplasty for sepsis. *Clin. Orthop.* 380: 9-16, November 2000.
8. **Goldstein, W.M.; Kopplin, M.; Wall, R.; and Berland, K.:** Temporary articulating methylmethacrylate antibiotic spacer (TAMMAS). *J. Bone and Joint Surg.*, 83-A(Supp 2): 92-97, 2001.
9. **Haddad, F.S.; Masri, B.A.; Campbell, D.; McGraw, R.W.; Beauchamp, C.P. and Duncan, C.P.:** The PROSTALAC functional spacer in two-stage revision for infected knee replacements. *J. Bone and Joint Surg.*, 82-B: 807-812, August 2000.
10. **Hofmann, A.A.; Kane, K.R.; Tkach, T.K.; Plaster, R.L. and Camargo, M.P.:** Treatment of infected total knee arthroplasty using an articulating spacer. *Clin. Orthop.*, 321: 45-54, December 1995.
11. **McPherson, E.J.; Lewonowski, K. and Dorr, L.D.:** Use of an articulated PMMA spacer in the infected total knee arthroplasty. *J. Arthroplasty*, 10(1): 87-89, 1995.
12. **Hanssen, A.** Instructional Course Lecture. AAOS, 2003.
13. **Valle, A.G.D.; Bostrom, M.;Brause, B.;Harney, C. and Salvati, E.A.:** Effective bactericidal activity of tobramycin and vancomycin eluted from acrylic bone cement. *Acta Orthop. Scand.*, 72(3): 237-240, 2001.
14. **Masri, B.A.; Duncan, C.P. and Beauchamp, C.P.:** Long term elution of antibiotics from bone-cement. *J. Arthroplasty*, 13(3):331-338, 1998.
15. **Trippel, S.B.:** Antibiotic-impregnated cement in total joint arthroplasty. *J. Bone and Joint Surg.*, 68-A(8): 1297-1302, 1986.
16. **Tsukayama, D.T.; Goldberg, V.M. and Kyle, R.:** Diagnosis and management of infection after total knee arthroplasty. *J Bone Joint Surg*, 85-A: S75-S80, 2003.
17. **Masri, B.A.; Duncan, C.P.; Beauchamp, C.P.; Paris, N.J. and Arntorp, J.:** Effect of varying surface patterns on antibiotic elution from antiobiotic-loaded bone cement. *J. Arthroplasty*, 10(4): 453-459, 1995.
18. **Kendall, R.W.;Duncan, C.P.; Smith, J.A. and Ngui-Yen, J.H.:** Persistence of bacteria on antibiotic loaded acrylic deposits. *Clin. Orthop.*, 329: 273-280, 1996.

Jeff Zarin masters a DCS at the Colorado AO course