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Antibiotic-loaded bone cement spacers in two-stage management of infected total knee arthroplasty

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Abstract We reviewed the current use of spacers in the management of the infected knee prosthesis. There are two types of temporary spacers: block or non-articulating spacers and articulating or mobile spacers. Generally, spacers improve mobilisation and hasten recovery with shorter hospital stay between stages. Furthermore, spacers facilitate the second-stage procedure by maintaining joint space, and articulating spacers may also maintain range of motion. Last but not the least, the cost of spacers represents only a small fraction of the total expenses for management of infected knee arthroplasties.

Résumé Nous avons examiné l'usage courant d'espaceurs dans la gestion de la prothèse du genou infectée. Il y a deux types d'espaceurs temporaires: articulants ou non. Généralement les espaceurs améliorent la mobilisation et hâtent la récupération des malades, avec un plus court séjour d'hospitalisation entre les deux étapes. En outre, ils les facilitent le deuxième temps chirurgical en maintenant l'espace articulaire et les espaceurs articulants peuvent aussi maintenir une gamme de mouvement. Dernier avantage, et non le moindre, le coût des espaceurs représente seulement une petite fraction des dépenses totales pour la gestion des arthroplasties du genou infectées.

Introduction

The infection rate after primary total knee arthroplasty (TKA) ranges from 0.5 to 2% [1, 31] and is a serious problem despite modern technology and rigorous prophylaxis. Peersman et al. [27] reported recently a 0.43% rate of deep infection in a consecutive series of 6,439 total

knee arthroplasties performed with vertical laminar air-flow and body exhaust suits. This is encouraging; however, considering the increasing number of patients with TKA, infection is still a complication of major concern [3, 2, 28, 29, 30, 35, 37].

A variety of techniques and devices have been developed to improve the management of the infected TKA. Antibiotic-loaded bone cement spacers in the two-stage re-implantation technique allow early joint and patient mobilisation, a shorter hospital stay and potentially a reduced rate of re-infection. In this article, we have reviewed the use of joint spacers and outlined their potential benefits and drawbacks.

The infected TKA

The choice of management for patients with infected TKA depends on many factors; nevertheless, the clinical presentation of infection can be used as a guide to the treatment. Segawa et al. [33] proposed a classification based on the clinical presentation, focusing on the severity of symptoms and the temporal relationship between the index operation and the infection. The classification recognises four types of infections: (1) early post-operative infection, (2) late chronic infections, (3) acute haematogenous infections, and (4) sub-clinical infections with positive cultures.

The early post-operative infection (type 1) is defined as a wound infection (superficial or deep) developing less than 4 weeks after the index operation. The treatment for superficial infection is extra-articular soft-tissue debridement and a course of antibiotics [25]. Deep infection extends into the joint and requires aggressive treatment including debridement, exchange of the tibial polyethylene insert and intravenous administration of antibiotics. Intra-articular placement of antibiotic-loaded cement beads has also been advocated [26]. Retention of prosthesis is possible in early post-operative deep infection if the implant appears well fixed.

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Late chronic infections (type 2) develop 4 weeks or more after the index operation and have an insidious clinical presentation. These infections are most commonly treated with debridement, implant removal and placement of antibiotic-impregnated cement spacer or antibiotic-impregnated cement beads. This is followed by a course of systemic antibiotics for 6 weeks and a delayed-exchange arthroplasty (two-stage reimplantation technique).

The acute haematogenous infection (type 3) is associated with a documented or suspected antecedent bacteraemia and is characterised by an acute onset of severe pain and swelling. These infections are treated with debridement, exchange of the polyethylene insert of the tibial component, retention of prosthesis if it is well fixed and intravenous antibiotics for 6 weeks. The non-specific symptoms and signs of a sub-clinical infection (type 4) generally lead to the patient proceeding to revision surgery for presumed aseptic loosening. The patient is then treated with intravenous antibiotics for 6 weeks, often without requiring repeated revision surgery, essentially because of the wide antibiotic susceptibility of the infecting organisms.

Two-stage revision

It is widely accepted that the most reliable outcome for the treatment of late chronic infection is obtained by a two-stage technique involving implant removal followed by a 6-week course of systemic antibiotics and delayed exchange arthroplasty. The success rate has been reported at around 90% [14, 22, 32, 36, 37]. The two-stage reimplantation has become a procedure of choice to eradicate the infection and maintain a functional extremity.

The major disadvantage of this method is the period between stages, which is often associated with pain, difficult mobility and knee instability [13, 18]. Furthermore, reimplantation is often difficult because of scar formation, shortening of the extensor mechanism, and retraction of the joint capsule and ligaments. To overcome these difficulties, temporary joint spacers have been introduced [16, 24].

Spacers

Spacers have been reported successful in preserving limb length and minimising soft-tissue contracture, therefore facilitating re-implantation [7, 15, 38]. Furthermore, the insertion of an antibiotic-loaded cement spacer, in addition to the elution of high levels of antibiotic into the joint, allow ambulation, rehabilitation and earlier discharge from the hospital between stages [11]. Essentially, there are two types of temporary spacers: (1) block spacers (also known as non-articulating or static spacers), and (2) articulating spacers (also known as mobile spacers).

Block spacers

The use of block spacers was first reported in 1988 by Cohen et al. [7] and Wilde and Ruth [36]. Antibiotic-impregnated polymethylmethacrylate cement blocks are handmade in the operating room and fashioned to fit the bone stock defect left after removal of the infected prosthesis. A small cement stem can be added to the spacer block to achieve adequate fixation. The impregnated cement allows higher local concentrations of antibiotics, and the block itself maintains the articulating space and prevents retraction of the collateral ligaments. These factors facilitate easier re-implantation. Static knee spacers are a better option for knees with severe bone loss, as the mobile spacers cannot maintain stability in these settings [4, 5, 10, 12, 17].

Block spacers present several disadvantages: patients are not allowed to move the knee, they require cast immobilisation between stages and the spacer can dislodge and cause bone erosion. Moreover, second-stage surgery is still difficult due to scar formation, tissue adherence and quadriceps shortening.

Articulating knee spacers

To overcome the disadvantages of block spacers and to ease reimplantation surgery further, several authors have independently introduced articulated spacers [20, 21]. Emerson et al. [10] compared static block spacers (26 knees) with articulating spacers (22 knees) and found an improved post-operative range of motion in the articulating spacer group (108° compared with 94°) with no significant difference in the reinfection rate at 36 months (9% compared with 7.6%).

Essentially, there are three types of articulating spacers: (1) temporary prosthesis from re-sterilised components or new components (also called spacer prosthesis), (2) cement spacers moulded during operation, and (3) preformed cement spacers.

Temporary prosthesis

Scott et al. [32] described a modified technique cementing the original prosthesis between stages after re-sterilisation in autoclave. The cement was loaded with antibiotics. Additionally, antibiotic-loaded cement beads were inserted into the medullary canal of the tibia and femur and into the joint space. At 6 weeks, the final stage was performed fixing the definitive prosthesis using antibiotic-loaded bone cement according to the sensitivity profile of the infecting organism. In 1995, Hoffmann et al. [21] described a similar technique with articulating spacers, this time using the removed and sterilised femoral and tibial components, a new polyethylene tibial insert and a new all-polyethylene patellar component without pegs. The spacer was fixed using antibiotic-impregnated bone cement mixed in a ratio of 4.8 g of tobramycin to 40 g of

Fig. 1 A Post-operative antero-posterior and **B** lateral radiographs of a 75-year-old woman with total knee arthroplasty (TKA) late infection show a cemented antibiotic-loaded articulating spacer in satisfactory position

cement. Cement was applied to the bone at the end of the working phase to mould the surfaces without deep interdigitation. Partial weight bearing and range-of-motion exercises were allowed after surgery. There was no recurrence of infection in this series of 25 patients at an average follow-up of 30 months.

Emerson et al. [10] suggested the use of 3.6 g of tobramycin and 2 g of vancomycin per 40 g of cement. Haddad et al. [16] confirmed that the normal limit of antibiotic comprising 5% of the whole cement mass does not necessarily apply in temporary spacers. This does not seem to affect the mechanical properties of such constructs. Their major drawback is the presence of metallic and plastic prosthetic components between the revision stages that can, in theory, favour bacterial adhesion [14]. In many countries, current infectious-disease-control policies prohibit the use of removed and re-sterilised prosthetic implants. Moreover, the use of a new prosthesis as a spacer is an additional factor increasing the high costs of management of patients with infected TKA [19].

Cement spacers moulded during operation

McPherson et al. [24] presented the technique of using a handmade mould of a TKA made of antibiotic-loaded cement as a temporary spacer in two-stage revision. Although this allowed some knee function, stability was difficult to maintain.

Duncan et al. [8, 9] also introduced an intra-operatively moulded cement spacer. This spacer had smooth articular surfaces obtained with the utilisation of plastic moulds. The spacer is a facsimile of a TKA prosthesis made entirely of antibiotic-loaded bone cement [Prostalac (prosthesis of antibiotic-loaded acrylic cement), Smith & Nephew, USA]. Haddad et al. [15] reported the use of the Prostalac spacer in two-stage revision for infected TKA in 45 consecutive patients. The mean follow-up was 48

months. At the final review, there was no evidence of infection in 41 patients (91%); only one had a recurrent infection, with the same organism. There was improvement in the Hospital for Special Surgery knee score, and the range of movement was maintained between stages. According to the authors, complications were primarily related to the extensor mechanism, wear and stability of the knee between stages. These problems have been addressed with refinement of the design. The new generation of Prostalac has femoral and tibial components made of antibiotic-loaded bone cement with a small metal-on-polyethylene articular surface and a posterior stabilised design. Generally, patients with these spacers in situ are allowed to walk with partial weight bearing, and free knee motion is encouraged with or without a brace.

One of the advantages of the Prostalac system is the ability to add a relatively large amount of antibiotic powder to the bone cement [23]. Again, the presence of metal and plastic, although in small amounts, could in theory favour bacterial adhesion. An objection can also be made that such “custom made” cement spacers cannot warrant reproducible mechanical properties.

Preformed cement spacers

Castelli et al. [6] recently introduced a preformed articulating spacer. The spacers are manufactured with ultra-congruent condylar knee prosthesis design made exclusively of acrylic cement impregnated with gentamicin antibiotic (Spacer-K, Tecres, Italy), and no additional reinforcement device is used. Both femoral and tibial components are produced in three sizes. Experimental studies have demonstrated good mechanical properties and standardised antibiotic release of this spacer. In theory, good mechanical properties without the presence of metal or plastic are an advantage in the treatment of infected TKA. Like other articulating spacers, Spacer-K is

Fig. 2 The articulating spacer allows range-of-motion exercises between stages. The patient is mobilised with crutches and partial weight bearing

Fig. 3 Spacer in situ before removal and reimplantation of a new total knee arthroplasty. Slight signs of articulating surface wear are present after 8 weeks of function with partial weight-bearing and daily range-of-motion exercises

fixed to the bone with cement loaded with antibiotics of the surgeon's choice. It allows partial weight bearing and knee motion exercises between stages (Fig. 1, 2 and 3).

A prospective multi-centre study on Spacer-K [34] showed no recurrence of infection at a minimum follow-up of 6 months. Pre-operative range of motion remained unchanged between stages and improved after reimplantation. Neither breakage nor clinically relevant spacer wear were detected, and no complications related to the spacer were observed.

Conclusion

Infected TKA is a devastating complication, both for patient and surgeon. It causes major morbidity, and presents a difficult surgical management issue with pos-

sible unsatisfactory outcome, prolonged hospitalisation, and a period of marked limitation of mobility. Hebert et al. [19] reported that the surgical treatment of an infected TKA is three-to-four times as expensive as a primary procedure. Most of the cost was related to hospitalisation and antibiotic treatment.

Knee spacers used in the two-stage surgical management of infected TKA, at present the gold standard of treatment [11, 16, 20], can improve mobilisation and hasten recovery, with shorter hospital stay between stages. Furthermore, in addition to the local delivery of high levels of antibiotics, spacers facilitate the second-stage procedure by maintaining the joint space and, in cases of articulating devices, maintain knee range of motion. It has been shown that patients with articulating spacers, when compared with block spacers, have better mobility after re-implantation, with similar complication and infection rates in the long term [11, 20, 23]. Last but not the least, the cost of spacers represents a relatively small fraction of the total expenses for the management of the infected TKA.

References

1. Abudu A, Sivardeen KAZ, Grimer RJ, Pynsent PB, Noy M (2002) The outcome of perioperative wound infection after total hip and knee arthroplasty. *Int Orthop* 26:40–43
2. Bengtson S, Knutson K (1991) The infected knee arthroplasty. A 6-year follow-up of 357 cases. *Acta Orthop Scand* 62:301–311
3. Bengtson S, Knutson K, Lidgren L (1986) Revision of infected knee arthroplasty. *Acta Orthop Scand* 57:489–494
4. Booth R.E., Jr, Lotke PA (1989) The results of spacer block technique in revision of infected total knee arthroplasty. *Clin Orthop* 248:57–60
5. Calton TF, Fehring TK, Griffin WL (1997) Bone loss associated with the use of spacer blocks in infected total knee arthroplasty. *Clin Orthop* 345:148–154
6. Castelli C, Martinelli R, Ferrari R (2002) Preformed all-cement knee spacer in two-stage revision for infected knee replacement. *Proceedings of the SICOT XXII World Congress*, 327c

7. Cohen JC, Hozack W, Cuckler JM, Booth RE Jr (1988) Two-stage reimplantation of septic total knee arthroplasty. Report of three cases using an antibiotic-PMMA spacer block. *J Arthroplasty* 3:369–377
8. Duncan CP, Beauchamp C (1993) A temporary antibiotic-loaded joint replacement system for management of complex infections involving the hip. *Orthop Clin North Am* 24:751–759
9. Duncan CP, Beauchamp C, Masri BA (1992) The antibiotic loaded joint replacement system: a novel approach to the management of the infected knee replacement. *J Bone Joint Surg [Br]* [Suppl III] 74:296
10. Emerson RH, Jr, Muncie M., Tarbox TR, Higgins LL (2002) Comparison of a static with a mobile spacer in total knee infection. *Clin Orthop* 404:132–138
11. Fehring TK (2003) Techniques for the infected knee: Molded Acrylic Spacer. Proceedings of the Knee Society meeting, New Orleans, LA, USA, p 19
12. Fehring TK, Odum S, Calton TF, Mason JB (2000) Articulating versus static spacers in revision total knee arthroplasty for sepsis. *Clin Orthop* 380:9–16
13. Goksan SB, Freeman MA (1992) One-stage reimplantation for infected total knee arthroplasty. *J Bone Joint Surg [Br]* 74:78–82
14. Goldman RT, Scuderi GR, Insall JN (1996) 2-stage reimplantation for infected total knee replacement. *Clin Orthop* 331:118–124
15. Haddad FS, Masri BA, Campbell D, McGraw RW, Beauchamp CP, Duncan CP (2000) The Prostalac functional spacer in two-stage revision for infected knee replacements. *J Bone Joint Surg [Br]* 82:807–812
16. Haddad FS, Masri BA, Duncan CP (2001) Cement spacers in knee surgery. In: Insall JN, Scott WN (eds) *Surgery of the knee*, Churchill-Livingstone, Philadelphia 2:1891–1913
17. Hanssen AD (2003) Techniques for the infected knee: Static spacers for the infected knee replacement. Proceedings of the Knee Society meeting, New Orleans, LA, USA, p 18
18. Hanssen AD, Rand JA, Osmon DR (1994) Treatment of the infected total knee arthroplasty with insertion of another prosthesis. The effect of antibiotic-impregnated bone cement. *Clin Orthop* 309:44–55
19. Hebert CK, Williams RE, Levy RS, Barrack RL (1996) Cost of treating an infected total knee replacement. *Clin Orthop* 331:140–145
20. Hofmann AA (2003) Techniques for the infected knee: 10-year experience in the treatment of infected total knee arthroplasty using an articulating spacer. Proceedings of the Knee Society meeting, New Orleans, LA, USA p. 17
21. Hofmann AA, Kane KR, Tkach TK, Plaster RL, Camargo MP (1995) Treatment of infected total knee arthroplasty using an articulating spacer. *Clin Orthop* 321:45–54
22. Insall JN, Thompson FM, Brause BD (1983) Two-stage reimplantation for the salvage of infected total knee arthroplasty. *J Bone Joint Surg [Am]* 65:1087–1098
23. Masri BA, Duncan CP, Campbell D, McGraw RW (2000) Prostalac two-stage exchange for infected knee replacements: a prospective analysis. Proceedings of the 10th combined meeting of the orthopedic associations of the English speaking world, Auckland, NZ, *J Bone Joint Surg [Br]* [Suppl II] 82:153
24. McPherson EJ, Lewonowski K, Dorr LD (1995) Techniques in arthroplasty. Use of an articulated PMMA spacer in the infected total knee arthroplasty. *J Arthroplasty* 10:87–89
25. Mont MA, Waldman B, Banerjee C, Pacheco IH, Hungerford DS (1997) Multiple irrigation, debridement, and retention of components in infected total knee arthroplasty. *J Arthroplasty* 12:426–433
26. Nelson CL, Evans RP, Blaha JD, Calhoun J, Henry SL, Patzakis MJ (1993) A comparison of gentamicin-impregnated polymethylmethacrylate bead implantation to conventional parenteral antibiotic therapy in infected total hip and knee arthroplasty. *Clin Orthop* 295:96–101
27. Peersman G, Laskin R, Davis J, Peterson M (2002) Infection in total knee replacement: a retrospective review of 6489 total knee replacements. *Clin Orthop* 392:15–23
28. Rand JA, Fitzgerald RH Jr (1989) Diagnosis and management of the infected total knee arthroplasty. *Orthop Clin North Am* 20:201–210
29. Rand JA, Bryan RS, Morrey BF, Westholm F (1986) Management of infected total knee arthroplasty. *Clin Orthop* 205:75–85
30. Resig S, Saleh KJ, Bershadsky B (2002) The outcome of perioperative wound infection after total hip and knee arthroplasty. *Int Orthop* 26:257
31. Salvati EA, Robinson RP, Zeno SM, Koslin BL, Brause BD, Wilson PD (1982) Infection rates after 3175 total hip and total knee replacements performed with and without a horizontal unidirectional filtered air-flow system. *J Bone Joint Surg [Am]* 64:525–535
32. Scott IR, Stockley I, Getty CJ (1993) Exchange arthroplasty for infected knee replacements. A new two-stage method. *J Bone Joint Surg [Br]* 75:28–31
33. Segawa H, Tsukayama DT, Kyle RF, Becker DA, Gustilo RB (1999) Infection after total knee arthroplasty. A retrospective study of the treatment of eighty-one infections. *J Bone Joint Surg [Am]* 81:1434–1445
34. Spika IA, Castelli C, Ferrari R, Federici A, Grandizio M, Matamala PA, Asuncion MJ, Pitto RP (2004) Articulating spacers in two-stage revision of the infected total knee replacement. Proceedings of the 63rd Annual Meeting of the Australian Orthopaedic Association, *J Bone Joint Surg [Br]* [Suppl] (in press)
35. Whiteside LA (1994) Treatment of infected total knee arthroplasty. *Clin Orthop* 321:169–172
36. Wilde AH, Ruth JT (1988) Two-stage reimplantation in infected total knee arthroplasty. *Clin Orthop* 236:23–35
37. Windsor RE, Bono JV (1994) Infected Total Knee Replacements. *J Am Acad Orthop Surg* 2:44–53
38. Windsor RE, Insall JN, Urs WK, Miller DV, Brause BD (1990) Two-stage reimplantation for the salvage of total knee arthroplasty complicated by infection. Further follow-up and refinement of indications. *J Bone Joint Surg [Am]* 72:272–278