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Surgical technique

Modular Total Femur Replacement for Staged Total Femur Replacement

Tat Woon Chao, MBBS, PGDipSurgAnat [a], Yi Deng, MChD, BBiomedSc [a, b, *], Varsha Sivalingam, MD, MSc [c], D. Ashley R. Watson, MBBS, MPH, GradCertEd, FRACP [c], Alexander W.R. Burns, MBBS, FRACS, FAOrthA [a, b]

[a] Department of Orthopaedic Surgery, Canberra Hospital, Garran, ACT, Australia
[b] Trauma and Orthopaedic Research Unit, Australian National University and Canberra Hospital, Garran, ACT, Australia
[c] Department of Infectious Diseases, Canberra Hospital, Garran, ACT, Australia

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ABSTRACT

As the numbers of arthroplasties performed worldwide increase, so do complications such as prosthetic joint infection. Cases that require a two-stage revision of a total femur replacement in the femur pose an ongoing challenge to the modern orthopedic surgeon. Unlike antibiotic spacers in hip and knee arthroplasty, there lacks a commercially available cement spacer for use in total femur replacements. We describe a novel technique for the intraoperative fabrication of a total femur spacer which uses modular components. As such, our technique is unique as it is modular and, therefore, highly customisable to each individual patient. Individual components can be made by different members of the team simultaneously and then assembled to make the final construct, thereby minimizing operative time. Furthermore, the inherent stability of the spacer allows immediate partial weightbearing and functional rehabilitation while patients are waiting for their second-stage procedure.

Introduction

Total femur replacement (TFR) has classically been used for large tumor resections in the thigh; however, there are increasing indications for their use in revision hip and knee arthroplasty with massive bone loss [1]. Infection can lead to bone loss and prosthesis loosening, often requiring revision surgery. The current gold standard for treatment of a prosthetic joint infection (PJI) is a two-stage revision procedure [2]. Patients requiring a staged TFR pose a unique challenge to orthopedic surgeons. Because it is such a rare problem, there are no commercially available premade cement spacers for TFR, and many surgeons have limited prior experience in the fabrication and implantation of TFR spacers. There are only sparse reports in the literature of a staged TFR having been described to treat PJI. Traditionally, the reported techniques of a TFR spacer consisted of a mobile hip bearing but a fused knee component [3-5]. More recently, there has been a trend toward using dual-articulating prostheses to maintain the range of motion of the knee joint while waiting for the second-stage procedure [6-8]. Each technique has its own advantages and disadvantages. However, prior techniques limited the surgeons' ability to easily customize the various components — acetabulum, femoral anteversion, and femoral length. We present a novel technique for the intraoperative fabrication of a dual-articulating TFR antibiotic spacer using modular components. Our technique is unique as it involves the simultaneous fabrication of the separate parts of the spacer, thereby decreasing operative time. Furthermore, our construct is potentially stronger and more stable, thereby allowing early weightbearing for the patient.

Surgical technique

Patient background

A 73-year-old male was referred to our institution for a chronic PJI of a proximal femoral replacement and a chronic PJI of a revision

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* Corresponding author. Canberra Hospital, Yamba Drive, GARRAN, ACT 2905, Australia. Tel.: +61 02 5244 2222.
E-mail address: yi.deng@anu.edu.au

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hinged total knee replacement. The patient initially underwent primary arthroplasties of the hip and knee which were subsequently revised multiple times because of recurrent PJI. He consulted his local general practitioner when he developed a draining sinus through his lateral thigh wound associated with a C-reactive protein of 48 mg/L. He was, therefore, referred to our hospital for further investigation and management. Radiographs performed on admission demonstrated extensive bone loss and a grossly loose prostheses of the hip and knee (Fig. 1). Cultures from sinus specimens revealed *Pseudomonas aeruginosa*. After discussion with the patient and the infectious diseases team, a consensus was reached to perform a staged TFR as there were no suitable alternative surgical approaches such as a one-stage approach or "debridement and implant retention." The patient has provided verbal and written consent for their case to be published.

Surgical approach

After administration of general anesthesia, the patient was placed in a lateral decubitus position on a standard operating table. The limb was cleansed with alcohol-based surgical prep, and a free drape was applied to the extremity. Prophylactic antibiotics were withheld until after samples were taken to minimize any false negative culture results. A posterior approach to the hip joint was used and extended distally to a lateral, subvastus approach to the femur and curved anteriorly to a lateral parapatellar approach to the knee. The previous implants were removed, and the devitalized distal femur was excised. Deep tissue samples and the explanted prosthesis was sent to the microbiology team. The wound was irrigated with copious amounts of saline and Betadine (Aviro Health, Stamford, CT, USA). A custom TFR spacer was then fabricated intraoperatively.

Spacer preparation

Because of the complex acetabular defect from a previous augmented acetabular component, a constrained liner (Longevity Constrained Liner (Zimmer Biomet, Warsaw, IN, USA)) was cemented into the native acetabulum using polymethyl-methacrylate (PMMA) cement (Copal (Heraeus Medical, Hanau, Germany)) at approximately 20° anteversion and 40° abduction. For the femoral component, we used a polished tapered long stem (CPT 240 mm (Zimmer Biomet, Warsaw, IN, USA)) proximally combined with a retrograde femoral nail (T2 Supracondylar Nail (Stryker, Kalamazoo, MI, USA)) and moulded femoral spacer (Copal Knee Mold (Heraeus Medical, Hanau, Germany)) distally. The advantage of this technique is that the proximal and distal portions of the femoral component can be assembled simultaneously to minimize operative time. The proximal portion of the femoral stem was coated with PMMA cement (Copal (Heraeus Medical, Hanau, Germany)), and the distal portion of the stem left uncoated for adjustment of length and rotation (Fig. 2a). For the distal portion, a retrograde femoral nail (T2 Supracondylar Nail (Stryker, Kalamazoo, MI, USA)) with a distal locking screw is cemented to the femoral part of a moulded spacer (Copal Knee Mold (Heraeus, Medical, Hanau, Germany)) using PMMA cement (Copal (Heraeus, Medical, Hanau, Germany)). The purpose of the distal locking screw is to increase rotational stability of the prosthesis and allow easier adjustment of femoral rotation. Specifically, the spacer is held stationary on the table by the surgical assistant and a polyester fiber tape (Mersilene tape (Ethicon, Raritan, NJ, USA)) is secured temporarily with an arterial clamp (Fig. 2b and c). The retrograde femoral nail (T2 Supracondylar Nail (Stryker, Kalamazoo, MI, USA)) is held at approximately 5° valgus relative to the femoral part of the knee spacer (Copal Knee Mold (Heraeus Medical, Hanau, Germany)), and PMMA cement (Copal (Heraeus Medical, Hanau, Germany)) is used to secure the components together.

Finally, the two segments are combined using PMMA cement (Copal (Heraeus, Germany)) while adjusting for femoral length and rotation (Fig. 2c). It is important to remember that the knee spacer should be larger than the final implant to preserve the soft-tissue envelope and prevent wound closure issues during the second-stage procedure.

The tibial component is made using the tibial part of a moulded spacer (Copal Knee Mold (Heraeus Medical, Hanau, Germany)) with a 6-mm external fixator pin inserted to the keel. A polyester fiber tape (Mersilene tape (Ethicon, Raritan, NJ, USA)) is again secured in place in a similar fashion to the femoral side. The external fixator pin is then covered with PMMA cement (Copal (Heraeus Medical, Hanau, Germany)) (Fig. 2d). The femoral and tibial components are combined, and the TFR spacer is ready for implantation (Fig. 2e).

The tibial component is cemented into the tibia using PMMA cement with methylene blue added to facilitate future differentiation of cement from host bone. Then, the femoral component is inserted. The medial and lateral strands of the polyester fiber tape (Mersiline tape (Ethicon, Raritan, NJ, USA)) from the femoral and tibial sides are tied together to recreate collateral stability. The abductors were not attached to the spacer, but a captured liner was used to prevent dislocation which is otherwise common and can lead to abrasive bone loss (Fig. 3). Additional antibiotic-impregnated beads (Stimulan beads (LifeHealthcare, North Ryde, NSW, Australia)) are used to augment antibiotic delivery. The wound is closed in layers, and a surface vacuum dressing is applied.

A total of 13 bags of PMMA cement were used: 3 bags of Copal G&C (Heraeus, Medical, Hanau, Germany) (1 g gentamicin and 1 g clindamycin) and 10 bags of Copal G&V (Heraeus Medical, Hanau, Germany) (0.5 g gentamicin and 2 g vancomycin). Three grams of vancomycin mixed in with Stimulan beads (LifeHealthcare, North Ryde, NSW, Australia) was also used. This equates to a total of 8 g gentamicin, 3 g clindamycin, and 23 g vancomycin for the entire spacer.

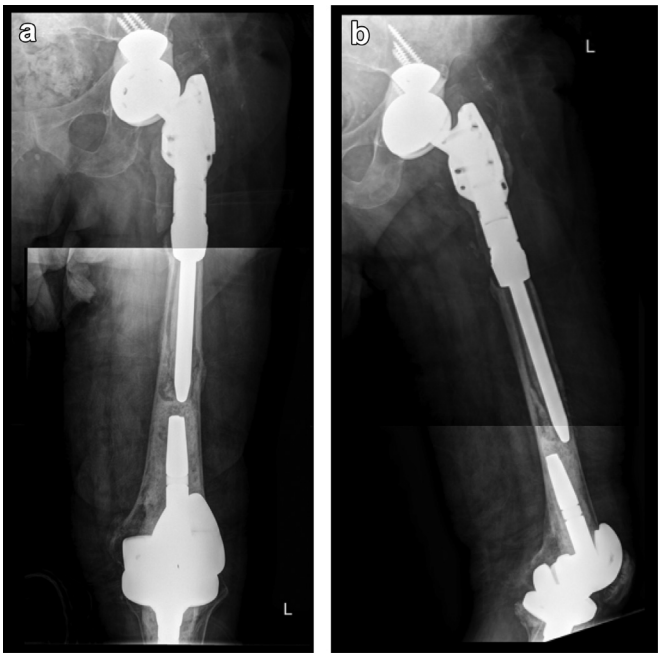

Figure 1. Preoperative anteroposterior (a) and lateral (b) radiographs demonstrating periprosthetic osteolysis and gross loosening.

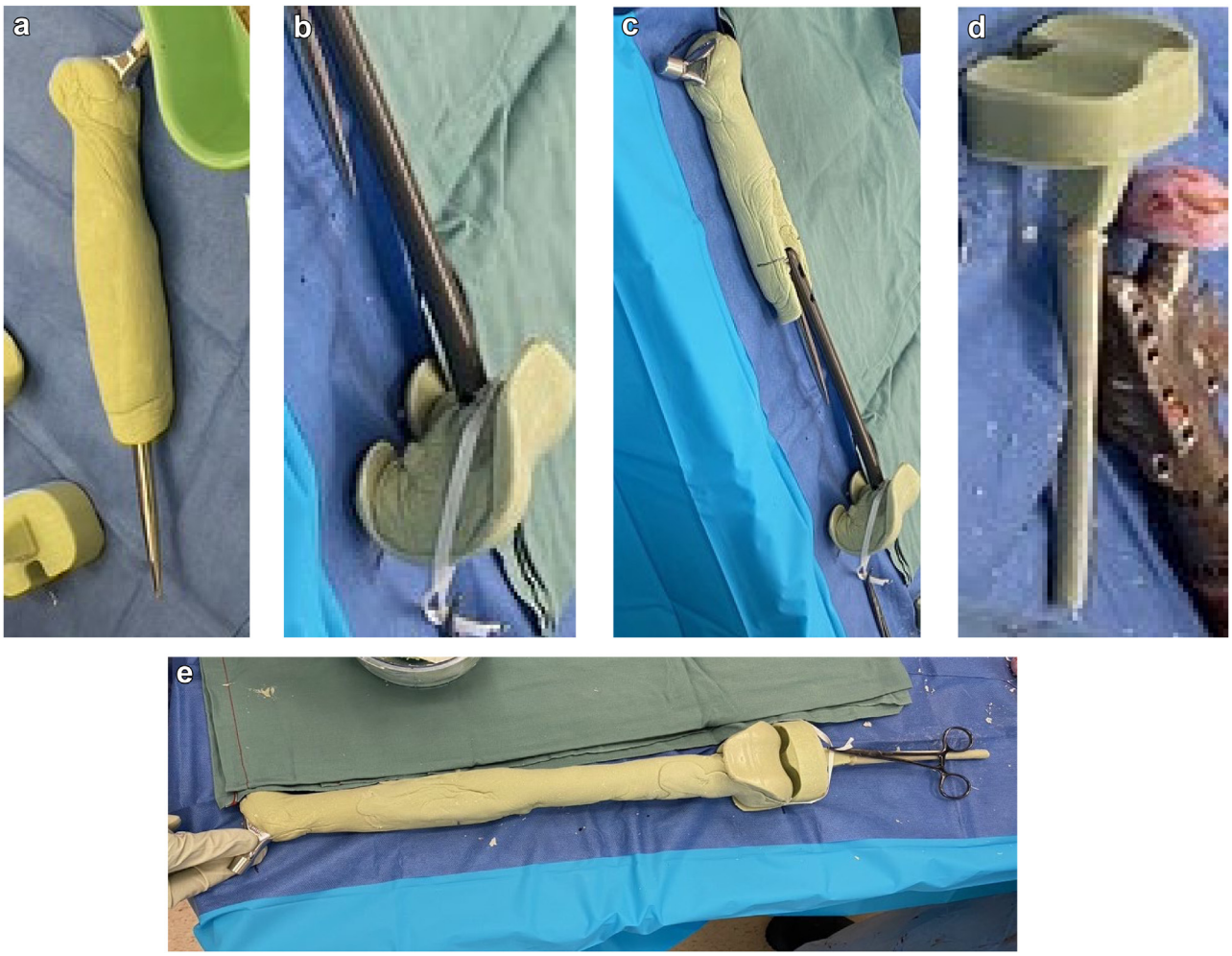

Figure 2. Preparation of TFR spacer: (a) proximal portion of femoral component (Zimmer CPT 240-mm stem with proximal cement coating); (b) distal portion of femoral component (Stryker T2 Supracondylar retrograde femoral nail and Heraeus Copal Knee Mold spacer with Mersilene tape); (c) combined femoral component; (d) tibial component (Heraeus Copal Knee Mold spacer with 6mm external fixator pin coated with cement); (e) completed TFR cement spacer.

Postoperative protocol and outcome

A hinged knee brace locked at 0-90^{o} is used to add stability to the knee and prevent dislocation. The patient is immediately allowed to mobilize with partial (50%) weightbearing on the affected limb and commence a functional physiotherapy program to maintain soft-tissue function and joint mobility while waiting for the second-stage procedure. Radiographs were performed at day 1 postoperatively (Fig. 4).

The patient was placed onto broad-spectrum antibiotics postoperatively — intravenous vancomycin and piperacillin/tazobactam. Renal function was monitored closely postoperatively which demonstrated a mild acute kidney injury (estimated glomerular filtration rate: 61 to 38 and creatinine: 103 to 152 μmol/L) which

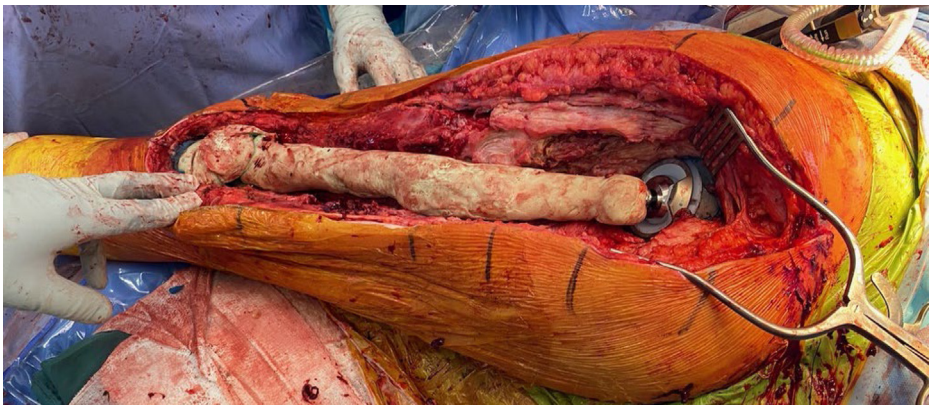

Figure 3. Implanted TFR spacer.

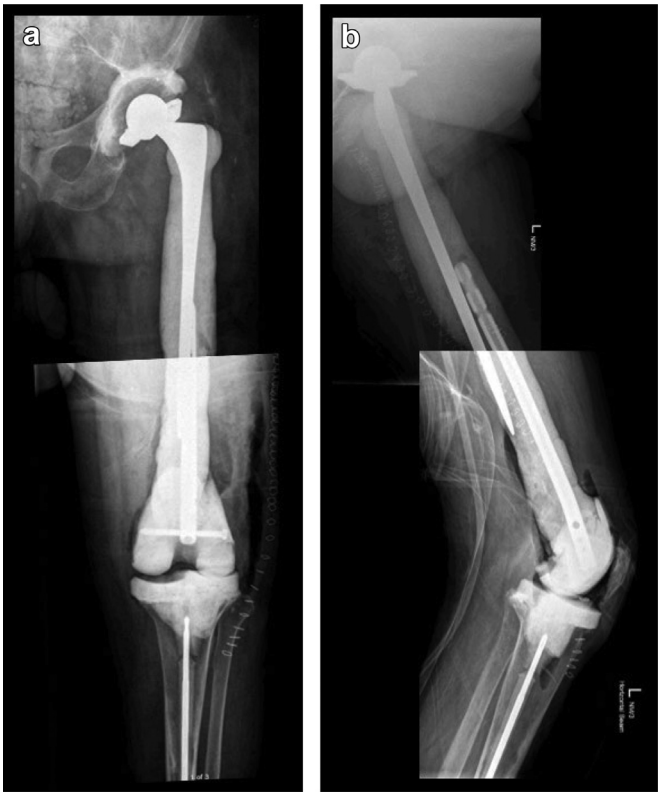

Figure 4. Postoperative anteroposterior (a) and lateral (b) radiographs demonstrating TFR cement spacer in situ.

resolved within 48 hours. Intraoperative samples were positive for *Staphylococcus epidermidis* and *Pseudomonas aeruginosa*. Subsequent antibiotics were tailored according to sensitivities and clinical response. Piperacillin-tazobactam was ceased, and intravenous ceftazidime and oral ciprofloxacin were commenced along with vancomycin. After 6 weeks of intravenous therapy, the ceftazidime and vancomycin were ceased and switched to oral trimethoprim/sulfamethoxazole. Oral ciprofloxacin and oral trimethoprim-sulfamethoxazole were continued until the second-stage procedure without an antibiotic-free period. Unfortunately, the patient was noncompliant with 50% partial weightbearing and using the hinged knee brace, which resulted in subluxation of the spacer at the level of the knee joint. This was corrected by gentle manipulation on the ward and reapplication of the knee brace. After 12 weeks, there were no clinical signs of infection, and it was deemed safe to perform a second-stage TFR. The surgical approach was identical, and a TFR (MUTARS TFR (LifeHealthcare, North Ryde, NSW, Australia)) was implanted (Fig. 5).

The patient discharged himself against medical advice after a prolonged admission and did not attend subsequent follow-up appointments.

Discussion

The use of total femur spacers for infected megaprostheses poses a unique challenge to the orthopedic surgeon. With the increase in arthroplasty procedures will also come an increase in PJI [9]. Although other techniques have been described in the literature, each has their pros and cons [3-8]. It is, therefore, vital for surgeons to have a range of techniques available to customize their treatment to the specific patient.

We believe our technique is advantageous as it enables surgeons to use several modular components to create a custom spacer, and its inherent stability allows early weightbearing. There are four separate components to the construct — the cemented liner, the proximal femoral component, the distal femoral component, and proximal tibial component. Each of these can be customized to the surgeon's requirements. Furthermore, each component can be manufactured simultaneously by separate members of the operative team, thereby minimizing the operative time. The acetabular component is a cemented liner, which can be used to fill large acetabular defects such as previous acetabular bone loss or explanted augments. We used a constrained liner in this case because the patient had a history of prosthetic hip dislocations. In patients without a significant acetabular defect or risk of dislocation, a hip hemiarthroplasty can be used. The proximal femoral component can also be customized based on the patient's native offset and surgeon preferences. The distal femoral component is again customizable based on the length of the patient's femur.

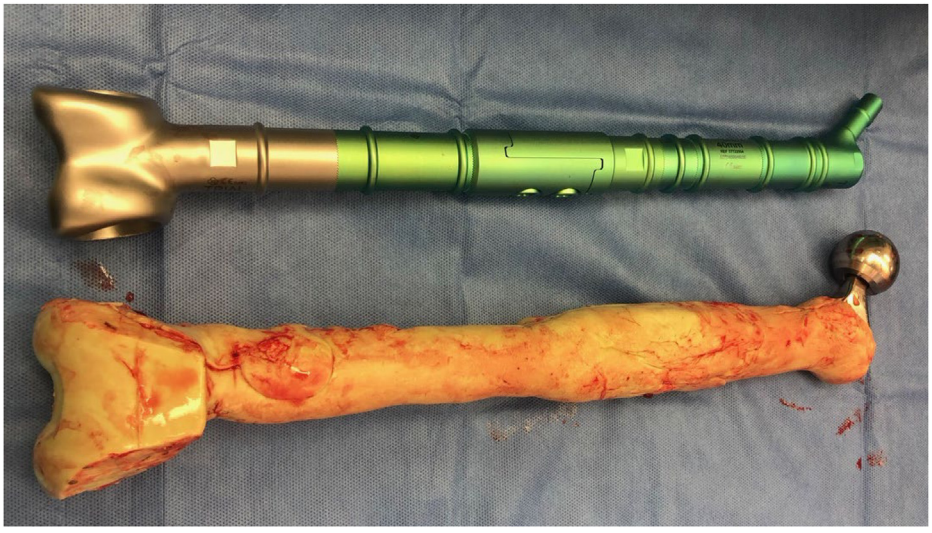

Figure 5. Total femoral replacement and spacer at the reimplantation procedure. Note the larger size of the spacer compared to the definitive prosthesis to preserve the soft-tissue envelope during closure.

Using a femoral nail has several advantages. These include the greater thickness of the nail diameter than that of rush rods and the availability of distal locking screws to add rotational stability to the final construct. Using Mersilene tape (Ethicon, Raritan, NJ, USA) adds varus-valgus stability to the knee by augmenting the collateral ligaments. The external fixator pin mounted onto the tibial spacer block adds stability to the tibial component, preventing toggling and dislocations of the spacer. Because of the inherent stability of our construct, the patient was able to partially weight-bear immediately in a hinged knee brace.

We acknowledge that no technique is perfect and our technique also has a number of pitfalls. Using definitive implants in the construction of a temporary spacer is no doubt costly. However, we believe the costs are outweighed by the modularity of the different components and the stability it provides. We found that although the polyester fiber tape (Mersiline tape (Ethicon, Raritan, NJ, USA)) provided some varus/valgus stability to the knee, it was not enough; therefore, we applied a hinged knee brace postoperatively. In retrospect, perhaps a stronger ligament substitute such as Ligament Augmentation Reconstruction System (Corin, Cirencester, United Kingdom) could have been used instead to increase stability and negate the need for a hinged knee brace. Another limitation is the potential of a stress-riser at the junction between the proximal and distal components in the midshaft region of the femur, increasing the risk of an implant fracture. The strength of this construct can be reinforced by adding two cables which would then be covered with antibiotic cement.

The antimicrobial principles of management of infected megaprosthesis are similar to those of other PJIs. Success is based on implant, host, and microbiological characteristics. The mainstay of treatment is largely dependent on extensive surgical debridement with removal of infected hardware containing biofilm. In addition to systemic antibiotics, local antibiotic application has been integrated into revision surgeries in the form of antimicrobial impregnated bone cement, spacers, and beads. It is used as a means to achieve high local drug concentrations while minimizing systemic effects which is important in the context of devitalized tissue [10].

A frequently used antibiotic combination in cement is vancomycin together with aminoglycosides, with the PRO-IMPLANT guidelines being a commonly used resource for recommended proportions [11]. The antimicrobials used can be tailored based on these guidelines to the relevant microbiology [2]. Various factors influence the elution kinetics from bone cement in vivo, but mainly the type and porosity of cement together with ratio and class of antibiotic. Powdered antibiotics are preferred as liquid antibiotics can significantly impair the mechanical stability of bone cement [12]. To avoid nonresorbable carriers being colonized by bacteria, bioabsorbable carriers such as antibiotic-loaded calcium sulfate beads are preferred over PMMA beads [2]. The exact pharmacokinetics of elution is uncertain but postulated that it is biphasic with an initial rapid release followed by a slow exponential release into the surrounding tissue that can last several months for some antibiotics [10].

One additional consideration in megaprosthesis is that the use of a silver-coated implant has been shown to reduce primary PJIs and reinfections, especially in the high-risk patient. These implants are thought to have stronger antibiofilm properties but also have antimicrobial activity as they are able to interrupt bacterial transcription and translational processes [13].

Summary

The use of TFR spacers is an important issue for the arthroplasty surgeon. We present a novel technique using modular components as a solution to a complex surgical problem. Our technique permits early weightbearing and knee motion for the patient, and the modular nature of the components allows for greater customisability of the implant.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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