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Surgical technique

Balanced, Stemmed, and Augmented Articulating Total Knee Spacer Technique

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ABSTRACT

Explantation and placement of an antibiotic spacer is a well-recognized treatment for periprosthetic infection after total knee replacement. Although static spacers may be occasionally indicated, many patients benefit from an articulating spacer that preserves the function and range of motion. However, many articulating spacer techniques provide an imbalanced cement-on-cement articulating knee that cannot tolerate full weight-bearing or provide adequate stability for daily function. A more durable articulating spacer may be ideal by permitting unrestricted weight-bearing, a functional range of motion, and potentially delayed reimplantation for medically complex patients. We present our evolved and reproducible technique for gap-balanced articulating spacers using cement augments and dowel stems. The result is a stable construct that permits full weight-bearing and a functional range of motion.

Introduction

Total joint arthroplasties of the hip and knee are 2 of the most common surgical procedures performed today [1]. Recent reports measuring patient-reported outcomes support improved quality of life after these procedures [2,3]. The success of primary total joint arthroplasties in an aging population has led to increased arthroplasty utilization [4]. Reflecting this increase, the absolute number of periprosthetic joint infections (PJIs) continues to rise [5]. PJI affects 0.6% to 2.5% of primary total joint arthroplasties and is responsible for 14% to 25% of early reoperations [5-7]. PJI results in additional medical expenses for the patient while also increasing the burden on the health-care system and society as a whole. A recent report by Kapadia et al [8] demonstrated a 3.5 times greater cost for episodes of primary total hip arthroplasty in patients who developed deep infections. It is estimated that the cost to treat PJI in the United States alone will approach $1.62 billion in 2020 [5].

While there is growing evidence from select European centers that one-stage treatment of PJI in total knee arthroplasty (TKA) may produce comparable results, the current standard of care in the United States is a two-stage revision [9,10]. The first stage has historically used a static spacer consisting of a block of antibiotic-impregnated cement [11]. Over time, the routine use of static spacers has diminished in favor of articulating spacers that allow a range of motion. Several studies have shown similar rates of eradication of infection between static and articulating spacers, while the latter provides easier surgical approaches and a trend toward a better range of motion after the second stage [12-15].

Currently in the stage one marketplace, there are silicone molds available for cement-on-cement articulating spacers and premade all-cement articulating spacers [16-20]. However, the premade systems provide limited antibiotic delivery and flexibility because of the prefabricated design [21]. These also have issues with cement-on-cement wear, cement fracture, and questionable function [20,22,23]. Hofmann et al [24] were the first to describe the use of a femoral component with an all-poly tibia augmented with cement. Multiple authors have shown that metal-on-polyethylene spacers are equally effective in the treatment of infection when compared with cement-on-cement articulating spacers [25,26]. More recently, Haddad et al [27] reported on the knee PROSTALAC (DePuy Synthes, Warsaw, IN) system, although this has not gained widespread use as seen in hip arthroplasty.

We have modified the Hofmann technique to construct a well-balanced articulating spacer using a cruciate-retaining (CR)

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femoral component and an anterior-stabilized tibial bearing, preferably an all-polyethylene tibial component. This has been coupled with cement augments to facilitate gap balancing and cement dowels for increased antibiotic elution and added component fixation. This technique yields a balanced, stable, and reasonably durable articulating antibiotic spacer. In our practices, it has granted patients a well-functioning knee with the freedom of full weight-bearing and activity without feeling compelled to return to the operating room for prompt reimplantation in indicated cases.

Surgical technique

The revision gap-balancing tensioner

For the past several years, we have modified our revision TKA technique to attempt to perform revisions like we do gap-balanced primary TKAs. This started with the utilization of spacer blocks and laminar spreaders, which were cumbersome and had a high degree of operator variability. During this process, we began using a Howmedica gap tensioner (Fig. 1). With the use of the tensioner and magnetic augments (Fig. 2), we were able to more reliably balance our revision knees similar to primary TKAs.

Step 1: prepare the joint

As in all infected cases, the revision begins with a complete synovectomy, restoration of the medial and lateral gutters, and implant removal. Attempts are made to spare as much host bone as possible, but a thorough debridement of all contaminated tissues is imperative for success. As part of the debridement, we ream the tibial and femoral canals noting the final diameters of each.

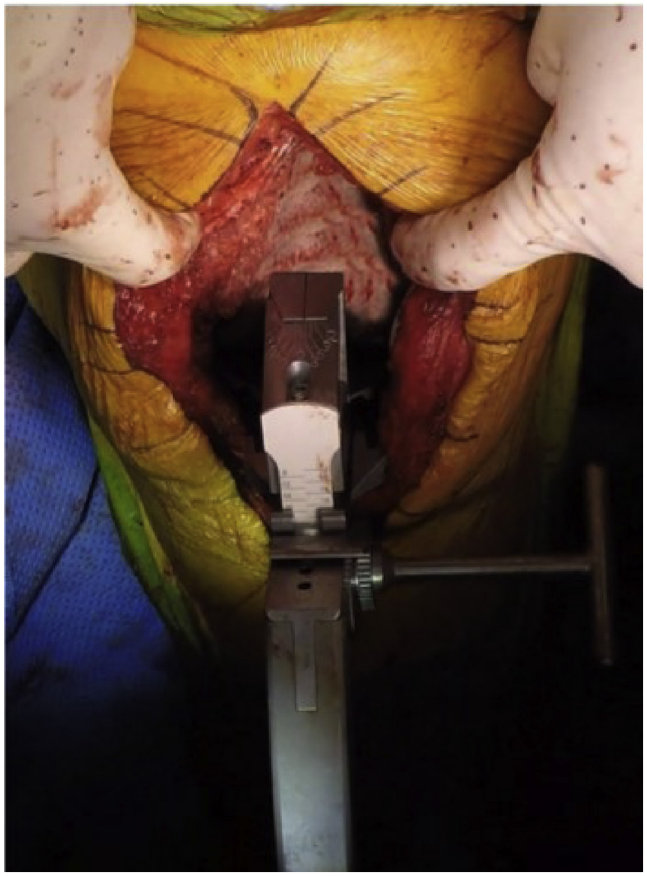

Figure 1. Gap balancer placement for assessment of the extension gap.

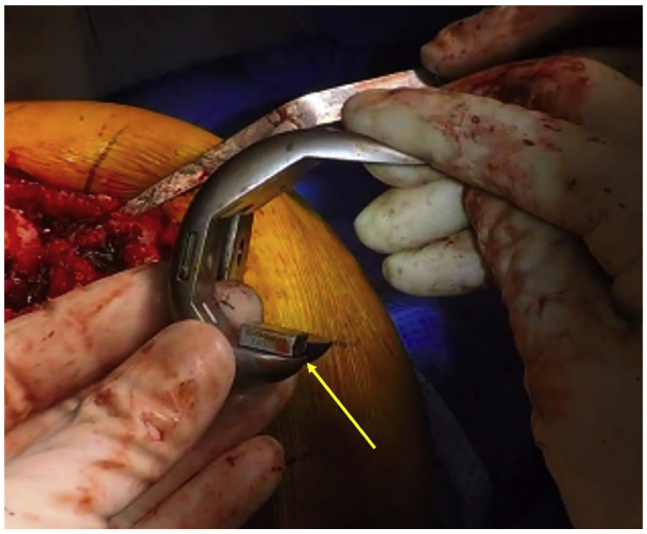

Figure 2. Magnetic augment (single-sided arrow) used to balance the extension and flexion gaps in the setting of local bone loss.

Step 2: restore a stable tibial platform

The spacer reconstruction begins at the tibial plateau. We use a standard extramedullary primary tibial cutting jig as it tends to be less bulky than the revision jig and is not affected by bowing of the tibial diaphysis. We pin the cutting guide to remove approximately 1-2 mm of the bone, restoring a bony platform that is perpendicular to the mechanical axis. We then check the tibial alignment of this cut using a drop rod. The tibia is then sized for appropriate fit using a lollipop sizer.

Step 3: restore the distal femoral cut

An intramedullary rod is then placed up the femoral canal, and a distal femoral cutting jig is set at the angle between the femoral anatomic and mechanical axes that we templated from preoperative long-standing films (usually 5 or 6 degrees). We then set the depth of resection to 1 mm and slide the paddles onto the distal femoral bony surfaces. We make note of any large bony defects on the medial or lateral side where the paddles do not come into contact with the bone. In these locations, we will need to use differential distal femoral augments to make up for bone loss. A clean-up cut is then performed on the distal femur to provide a flat bony surface at the appropriate distal femoral valgus angle. We then remove the cutting guide, release scarred and adhered posterior capsule, and examine the posterior condyles. Using a rongeur, we remove any remaining osteophytes to establish reliable posterior condylar surfaces on which the balancer paddles can rest. This occasionally requires the use of a saw to flatten the posterior condyle cuts.

Step 4: size the femur and assess the gaps using the revision gap balancer

We size the femur from anterior to posterior by placing trial CR femoral components over the distal femoral bone. If differential distal femoral augments were determined to be necessary based on the distal femoral cuts, then magnetic augments of an appropriate

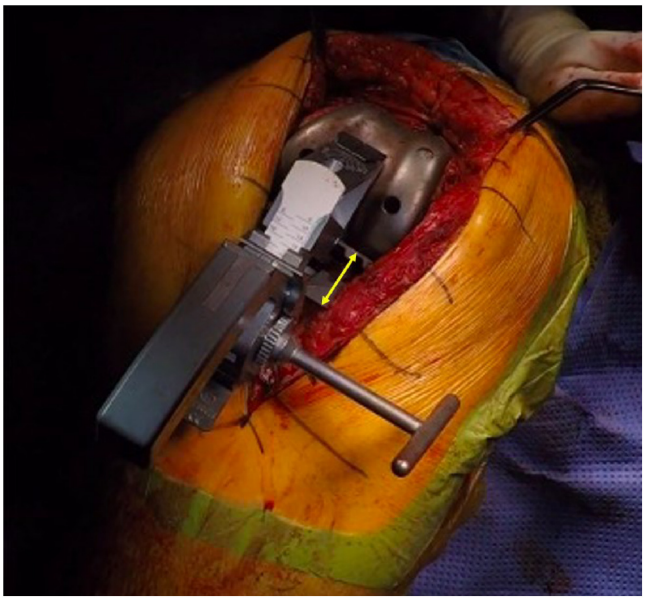

Figure 3. Thickness of the gap (double-sided arrow) that determines the necessary thickness of the tibial component polyethylene plus cement buildup.

size are placed on the trial CR femoral component. The component is placed on the distal femur, and we proceed to gap balancing.

We place the balancer in the gap with the knee in extension to assess the extension gap (Fig. 1).

The balancer is tensioned, providing the surgeon with 2 pieces of information—the thickness of the gap and the angle between the distal femoral and the proximal tibial surfaces. Ideally, the extension gap is at an angle of 0 degrees, that is, the coveted rectangular gap. Unlike in the flexion space, augments cannot be used to fix extension gap asymmetry as this would lead to limb malalignment. In cases of asymmetry, we attempt to balance the extension gap through standard soft-tissue releases. We also check again to remove any osteophytes that may be impacting the extension space balance. Usually, with a small amount of work, the extension space can be reasonably well balanced as long as the collateral ligaments are intact.

The knee is then flexed to 90 degrees, and the gap balancer is again tensioned, revealing the flexion gap thickness and angle.

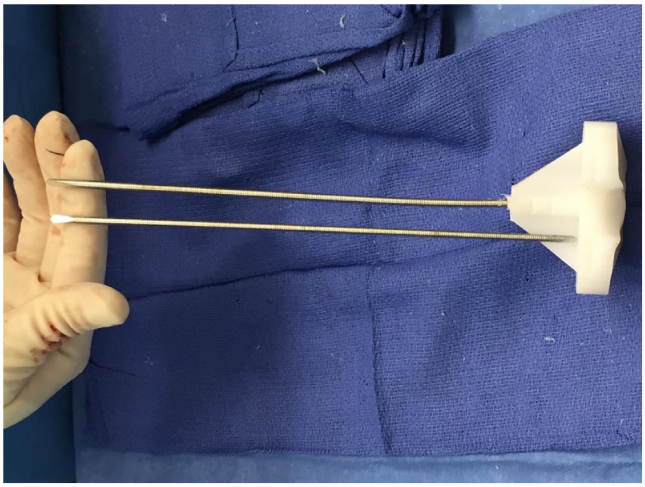

Figure 4. Steinman pin placement into the all-polyethylene tibial component.

Figure 5. Completed components before final implantation—femoral dowel, the femoral component with a cement augment matching the trial spacer (single-sided arrow) and the tibial component with a combined polyethylene and cement buildup that equals the measured gap thickness (double-sided arrow).

Here, we assess the flexion space symmetry by evaluating the angle between the posterior condyles and the tibial surface. The angles provided on the balancer are in 3-degree increments. We have found that in most knees, 3 degrees can be corrected with a 5-mm augment on the large side of the gap, 6 degrees with 10-mm augment, and so on. If there is a 4- or 5-degree gap, then we recut 1-2 mm off of the posterior condyle, converting it into a 6-degree differential and then augment with a 10-mm magnet. If posterior augmentation is needed to either convert a trapezoidal gap to a rectangular gap or to balance the size of the extension and flexion gaps, and then magnetic augments are placed on the posterior flanges of the CR trial femur (Fig. 2). Of note, posterior augmentation may require upsizing of the femoral component to allow anterior-to-posterior fit on the distal femur.

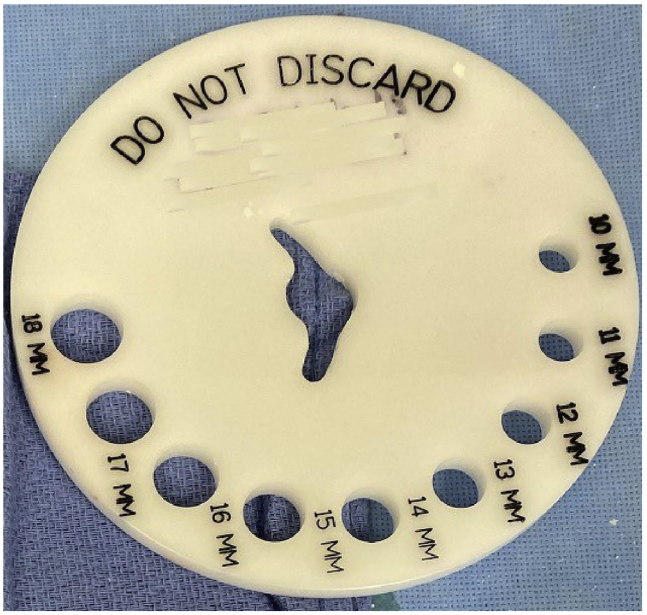

Figure 6. Custom block with cutouts for preparing the tibial keel and dowels.

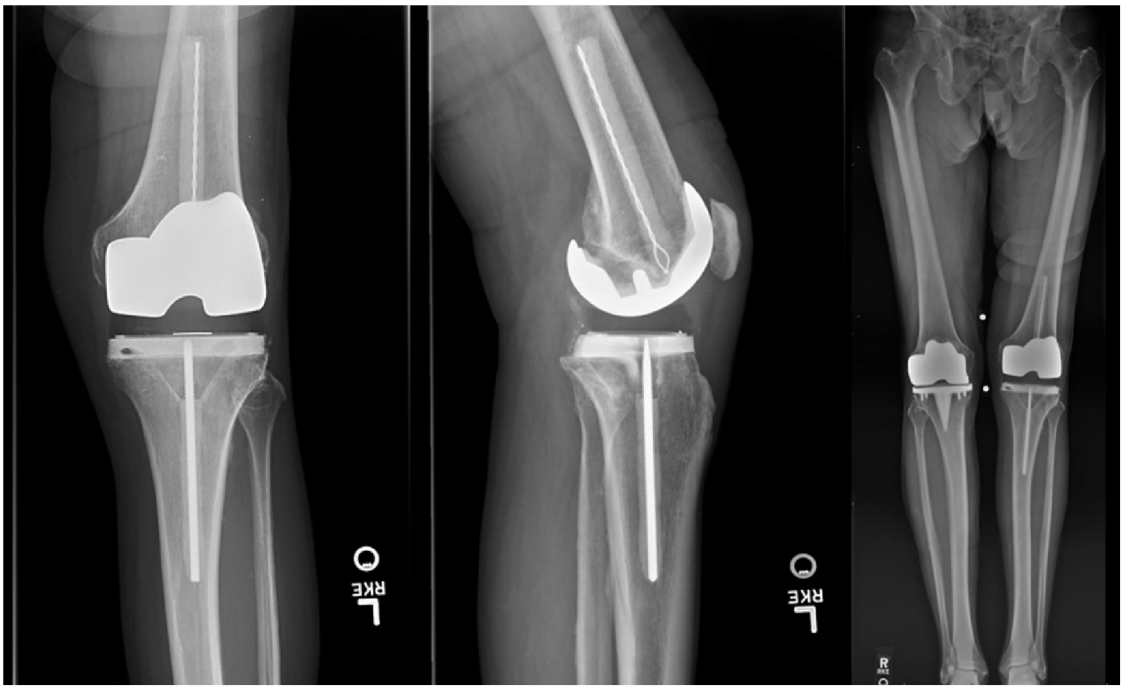

Figure 7. AP, lateral, and long-standing radiographs with the articulating spacer in place. AP, anteroposterior.

Step 5: determine the final thickness of the required tibial cement construct

With the trial augmented CR femoral component in place, we use the balancer to recheck the extension and flexion spaces to assure rectangular spaces and balance of the thickness of both spaces. We record the thickness of the gap, and this thickness is the necessary thickness of the tibial component (Fig. 3).

Ideally, we actually prefer the flexion gap to be 1-2 mm tighter than the extension gap as we have found anecdotally that this decreases the risk of flexion instability. For example, with the augmented CR femoral component in place, if our extension gap was rectangular and 21 mm, and the flexion gap was rectangular and 20 mm, then we would aim for a tibial component with an overall thickness of 21 mm. The overall thickness needed for the tibial construct equals the all-polyethylene tibial component plus the cement buildup.

Step 6: final irrigation and implantation of final spacer parts

All trials are removed, and the tourniquet is released. A thorough irrigation is performed with normal saline pulse-lavage followed by chemical debridement as per the surgeon's discretion. While this irrigation and chemical debridement is taking place, the CR femoral component and the 9-mm all-polyethylene tibia are prepared with cement augments on a separate clean back table. We predrill the stem portion of the all-polyethylene tibia with a $^{1}/_{4}$" drill and then tap a 9/64 fully threaded Steinman pin into the component ending just below to the surface of the tibial tray (Fig. 4). Placing the pin to this depth allows the tibial keel to be cut off during subsequent removal procedures without hitting the pin.

We then prepare 2 batches of cement mixed with the appropriate amount of bacteria-specific antibiotics. This cement is used to make the following components (Fig. 5):

1.) Femoral and tibia dowels of appropriate diameters and lengths based on the reamers used for debridement, molded around Luque wires or threaded Steinmann pins to provide an internal metal structure.
2.) Femoral augments of appropriate size molded onto the CR femoral component, flattened to the appropriate dimensions using an osteotome and a ruler, and allowed to harden in place.
3.) Tibial buildup needed to yield a balanced knee determined by the gap thickness with the balancer and CR femoral trial in place, flattened to the appropriate thickness with the aid of a ruler and osteotomes or a custom block with a cutout for the tibial keel (Fig. 6).

Once the dowels and augments are hard, we prepare 2 additional batches of cement with antibiotics. The tibia is delivered and cemented into position. The femur is delivered using an industrial retractor, and the femoral dowel is placed into the canal. The augmented femoral component is then cemented into place. If there is femoral metaphyseal bone loss, we fill it with additional cement unitizing the femoral dowel to the femoral component, thus adding further construct stability and fixation. We also cement on a new patellar component as we have seen multiple patellar complications with unresurfaced techniques for articulating spacers including instability, wear, and fracture (Fig. 7).

Discussion

Our practice has evolved from cement-on-cement articulating spacers to the routine use of metal-on-polyethylene spacers in all cases except for those with substantial bone loss, severe soft-tissue defects, or extensor mechanism disruption. In these cases, we use static all-cement spacers. Anecdotally, the results of our articulating spacers using the described technique are promising. In fact, a substantial number of our patients have elected not to proceed

with the second stage because of satisfaction with the function and stability of the first-stage construct. This provides an enticing option in high-risk populations including the frail and elderly patients with renal and liver transplant who are at a higher risk of complications and 1-year mortality after PJI [28]. We have simultaneously transitioned to allowing patients with metal-on-polyethylene spacers to bear full weight and range the knee as tolerated as soon as soft tissues allow. This has led to anecdotally improved patient function and satisfaction.

To address PJI in total hip arthroplasty, DePuy developed the articulating metal-on-polyethylene Prostalac system. This spacer has gained widespread use for PJI of the hip, thanks to good function with high-dose antibiotic delivery [29]. For infected TKAs, our reproducible technique provides a simple option for a well-balanced, relatively durable articulating spacer with a high-dose antibiotic load. The construct is reasonably affordable costing less than commercial premade molds but more than surgeon handcrafted molds [30]. We also believe that surgeons who adopt this technique will find that the second stage is more straightforward using the same technique. During the stage-two reimplantation, we are often able to build our trials based on augment place during the stage-one procedure. This enables surgeons to gain efficiency in performing these time-costly procedures [31].

Summary

We describe a reproducible modification of the Hofmann technique using readily available implants and instruments coupled with traditional principles of a gap-balanced revision TKA to construct a well-functioning and more durable articulating antibiotic laden spacer [24]. We have found this technique to be reproducible in our hands and for trainees at our institutions. The construct is cost-effective compared with other available articulating spacer options, demonstrates good wear characteristics, and is durable with no known failures such as implant fracture or dislocation. In fact, we have several cases of this spacer functioning as a single-stage reconstruction because of patient choice or medical comorbidities preventing reimplantation. This option is made possible by the stable and well-fixed nature of the construct that permits full weight-bearing and functional range of motion.

Conflict of interests

J.M. Gililland receives royalties from OrthoGrid, is a paid consultant for OrthoGrid, Stryker, DJO, and Smith & Nephew, receives research support from Zimmer Biomet and Stryker institutional research support, is an editorial board member of the *Journal of Arthroplasty* is an AAOS Video Theater Committee Member, and is an AAHKS education committee member and program committee member; B.D. Springer receives royalties from Stryker and OsteoRemedies, is a paid consultant for Stryker, ConvaTec, and Joint purification systems (medical advisory board), is an editorial board member of *Arthroplasty Today*, and is a board/committee member of the AJRR, ICJR, and Knee Society; W.L. Griffin receives royalties from DePuy/J&J, is a member of the Speaker's bureau for DePuy/J&J, is a paid consultant for DePuy/J&J, is an unpaid consultant for Diamond Orthopedic, holds stock ownership in Hyalex, receives research support from DePuy/J&J, Zimmer Biomet, and Smith & Nephew, is an editorial board member of the *Journal of Arthroplasty* and CORR, and is a board/committee member of the Hip Society, Knee Society, AAHKS, and AAOS; V.R. Carlson and K. Fehring declare no potential conflicts of interest.

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