Novel Utilization of Revision Cones for Femoral Condyle Lysis in Revision Total Knee Arthroplasty

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ABSTRACT

Significant bone loss is a major challenge in revision total knee arthroplasties (TKAs), especially with large femoral condylar defects. Restoring the metaphyseal-diaphyseal junction and central bone loss is critical for stability and reducing risk of component loosening. We describe a novel technique that uses a helical burr to modify porous metal cones intraoperatively, creating a custom fit without impinging on the femoral component. This approach promoted reliable osseointegration and stability in two patients with femoral condyle osteolysis. Additionally, we present a review of data demonstrating the success of metal cones in achieving osseointegration and decreased instability. Early findings suggest that intraoperative cone sizing and custom modification is a reliable technique for optimizing outcomes in the setting of femoral bone loss in revision TKA.

KEYWORDS: revision total knee arthroplasty; femoral bone loss; cone augmentation; novel technique

INTRODUCTION

The number of primary total knee arthroplasties (TKA) continues to rise, and the demand for revision TKA is forecasted to grow even more rapidly.[1,2] Revision TKAs can be costly and burdensome on the patient, surgeon, and healthcare system as a whole.[3,4] The most common indications for revision TKA include aseptic loosening, infection and mechanical complications.[5] Bone defects are often classified using the Anderson Orthopaedic Research Institute (AORI) system, where smaller defects are categorized as type I and larger defects as type II or type III.[6] Further, type I defects involve cancellous bone about the joint line and do not compromise stability; type II defects involve metaphyseal condylar bone loss with posterior condylar compromise; and type III defects are described as significant metaphyseal condylar bone loss with disruption of the collateral ligaments or patellar tendon. Significant bone loss poses one of the most unique challenges of revision TKA and can make revision surgery considerably more difficult. In the setting of revision TKA, it is critical to appropriately address bone loss, as failure to do so may lead to poor component fixation, stability, and postoperative outcomes.

In the context of substantial bone loss which must be addressed during revision TKA, a present gold-standard technique has not been established. Bone grafts, metaphyseal sleeves, porous metaphyseal cones, cementation and metal or metal alloy augments are all current options. While bone grafts are relatively inexpensive and may more easily be shaped to fit bone defects than metaphyseal cones, bone grafts have inherent risk for graft resorption, integration failure, transmission of disease, and immune reaction. Multiple studies in recent years have shown porous metaphyseal cones to be an effective way to manage large metaphyseal defects in revision TKA.[7-9] The current design of porous metal cones has a low volumetric porosity, low stiffness and high coefficient of friction which allows for greater preservation of bone stock and promotes metaphyseal ingrowth.[10,11] Cones are therefore helpful in restoring the metaphyseal-diaphyseal junction and central bone loss, forming a stable foundation for revision components and allowing for improved structural and mechanical support.

We present a novel use of metaphyseal cones for revision TKA in two patients presenting with large bony defects of a femoral condyle which required special attention during reconstruction for structural support.

SURGICAL TECHNIQUE

The below described surgical technique was performed in two revision TKA cases, both for presumed aseptic loosening following a negative infectious workup. The first patient was an 81-year-old male who presented to the office with persistent right knee pain and instability with medial laxity after a primary TKA performed approximately seven years prior. Preoperative inflammatory markers including synovial fluid culture, cell count with differential, alpha defensins, ESR and CRP were within normal limits; EOS and plain radiographic imaging was without evidence of obvious osteolysis. The second patient was a 76-year-old male who presented to the office with persistent left knee pain in the setting of prior primary TKA 11 years prior. Preoperative workup including cell count with differential, and culture of synovial fluid was negative for infection; EOS, CT, and plain radiographic imaging showed evidence of osteolysis and loosening about both tibial and femoral primary components.

Both patients were indicated for revision TKA after failing conservative management and were consented for surgical intervention. In both cases a standard medial parapatellar approach was performed and once exposure was determined to be adequate, a revision TKA was performed as described. Primary femoral components were carefully explanted utilizing Depuy hp knee osteotomes. Attention was then taken to removal of polyethylene debris and bony lysis with a combination of rongeur and curet utilizing standard technique. Once explanted, the remaining femoral bone stock was assessed (**Figure 1A,B**). There was significant bony lysis of the femoral condyle centrally with a remaining rim. Attention was then turned to the tibia where we identified the cement metal interface and removed a significant amount of subsided overgrown bone from the plateau to access the tibia. We then took a series of osteotomes through the metal cement interface and worked our way medially as well as posteriorly and laterally. The knee was then subluxed and tibial baseplate was removed without issues. Using rongeurs and curet, all cement from the tibia and femur including in the canal were removed. The femur was prepared by reaming the canal to size and placing a 4 in 1 cut guide to better assess need for femoral augment and establish femoral size and rotation. In case one, we noted a central medial femoral condyle defect that was too large for distal femoral augments. Therefore, the need for additional medial femoral support was needed and central cones were trialed utilizing the intact medial rim as a reference to estimate the size of the femoral defect. We then took the central cone reamer and carefully reamed on power to prepare the bony bed for improved fit, being specifically careful not to penetrate posteriorly. The cones were re-trialed and once the size of the cones was decided, indicated implants were opened and placed on the back table. In case two, a central lateral femoral condyle defect was noted and the same sequence of steps were performed to indicate and prepare for cone utilization. The wound was copiously irrigated and dried. The revision cone used in case one was a DePuy Attune small titanium revision concentric cone (DePuy Synthes of Johnson and Johnson Inc., Raynham, Mass.). The revision cone used in case two was a Zimmer Biomet small trabecular femoral metaphyseal cone (Zimmer Biomet, Warsaw, Indiana). In both cases it was determined that implantation of the entire cone would result in impingement on the femoral box, therefore the cone was sized in approximately half utilizing a metal cutting helical burr (**Figure 2**). Once the sized cone was appropriately positioned in a satisfactory position, implants were trialed to ensure proper seating of the femoral implant and appropriate support of the femoral condyle. In standard fashion the knee was trialed for range of motion and stability. Trial implants were then removed, the cone was carefully inspected, and stability of the cone was confirmed. Final revision TKA implants were opened on the back table in usual sterile fashion and subsequently implanted, a standard arthrotomy and skin closure was performed. In the first case, the final implants included a Depuy Attune Revision femoral component and a Depuy Attune Revision tibial stem. In the second case, the final implants consisted of a Depuy Sigma TC3 femoral component and a Depuy MBT cemented tibial stem. As per usual protocol, postoperative anterior-posterior (AP) and lateral radiographic views of the knee were obtained, shown here in direct comparison to preoperative radiographs (**Figures 3,4**). At one year postoperatively, both patients exhibited good functional status, knee range of motion, and a smooth, minimally symptomatic gait.

Figure 1A, B. Intraoperative Image
Preparation of the femur demonstrating intraoperatively well-sized porous cone within the medial femoral condyle.

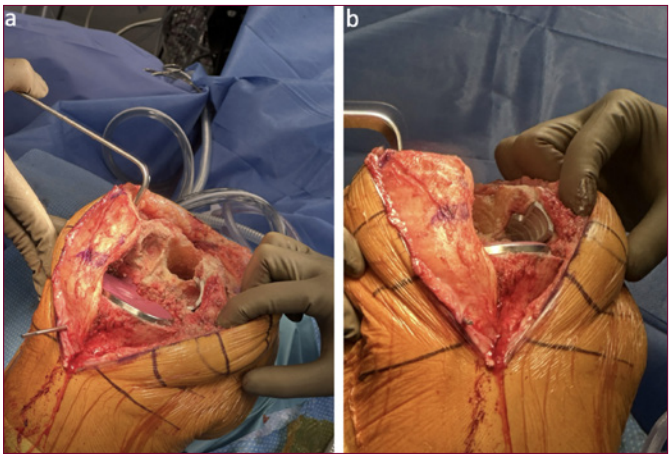


Figure 2. Intraoperative Image
Representative images of intraoperative back-table sizing of the porous cone, demonstrating use of a metal-cutting helical burr to achieve appropriate fit for reliable integration.

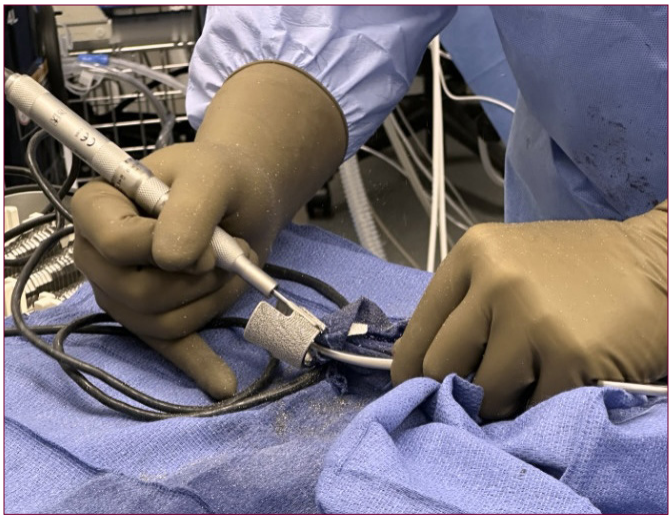


Figure 3. Case one

An 81-year-old male who presented to the office with persistent right knee pain and instability after a primary TKA performed approximately seven years prior. Preoperative inflammatory markers including ESR and CRP were within normal limits; plain radiographic imaging was without evidence of obvious osteolysis. Patient underwent revision TKA with a DePuy Attune small titanium revision concentric cone.

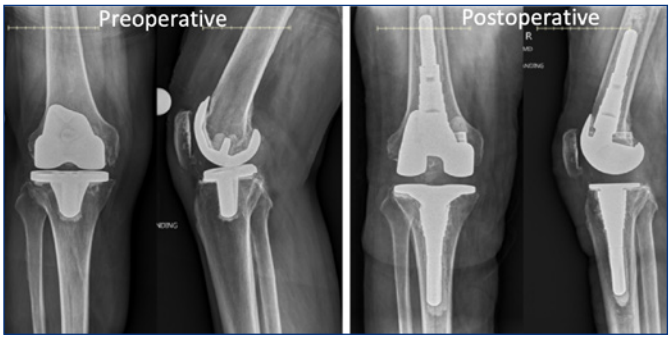
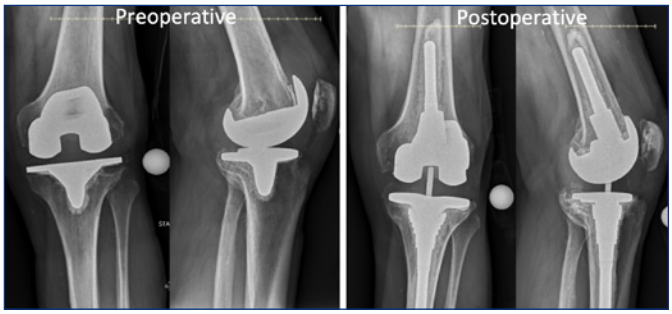


Figure 4. Case two

A 76-year-old male who presented to the office with persistent left knee pain in the setting of prior primary TKA in 2011. Preoperative workup was negative for infection; plain radiographic imaging showed evidence of osteolysis about both tibial and femoral primary components. Patient underwent revision TKA using a Zimmer Biomet small trabecular femoral metaphyseal cone.



DISCUSSION

Here we present a novel surgical technique in two cases of revision TKA in which both patients were most notably found to have significant bone loss about the femoral condyle necessitating cone augmentation for structural support. Bone loss due to aseptic and septic causes is a significant challenge in revision TKA. Traditionally, allografts have been used as they are low cost and can be easily modified intraoperatively to fit defects of various shapes and sizes. However, they come with risks such as disease transmission, integration failure, fracture, resorption, and nonunion. In retrospective outcome studies investigating structural allograft use in revision TKA, 10-year revision-free survivorship rates have been reported to range from 72 to 76%.[11,12] Metal augments therefore have been explored as an alternative to address these issues. In the last decade, there has been a rising interest in metal cones and sleeves for addressing substantial bone loss. In a systematic review comparing outcomes of structural allografts and tantalum cones in management of significant bone loss, structural allografts were found to have a significantly higher incidence of fracture, aseptic loosening, and infection.[13] Additionally, Vasso et al reported allografts were generally less stable and had shorter revision survivorship than metal augments.[14]

The porous design of modern metal cones closely mimics metaphyseal cancellous bone, which allows for and promotes bony ingrowth. Studies have consistently shown satisfactory osseointegration with modern cones, providing more reliable fixation and improved stability. Several studies involving modern metal cones have reported 100% survivorship free of revision for aseptic loosening at mid-term follow up.[15-17] Also, recent publications have shown low incidence of intraoperative fracture and immediate intraoperative complication with use of metaphyseal cones.[15,18]

To this effect, we present two patients with substantial femoral condyle bone loss, which intraoperatively was determined to be beyond structural reconstruction provided by standard allograft or metal augment. As demonstrated, this novel technique can be utilized for bony defects in either the lateral or medial femoral condyle with generic, non-company specific cones, highlighting its versatility and reproducibility. One year after surgery, both patients showed excellent functional outcomes, with a full range of motion and a smooth, nearly asymptomatic gait. To date, we are unaware of a study or prior surgical technique which has described an off-label use of porous metal cones to effectively address femoral condylar bone loss in the setting of revision TKA. However, You et al have investigated the off-label use of porous cones to address substantial tibia defects intraoperatively.[19] The authors described a case series of 17 knees where they used an off-label technique involving porous tantalum cones during primary TKA to address large tibial bone defects (AORI type IIA or IIB). In this study, posterior stabilized implants were combined with porous tibial cones that were cut in half intraoperatively to address knee defects greater than 20 mm from the surface of the tibial cut. At 3.5 years of follow-up, all knees showed stable metaphyseal cones with no radiographic evidence of osteolysis or loosening, and no patients experienced subjective instability, infection, or systemic complications. Additionally, every patient had excellent Knee Society Scores and improved range of motion.

A stacked configuration of two metal cones has been investigated as an alternative method for partial or near complete loss of the femoral condyle in revision TKA. Rajgopal et al reviewed 16 TKAs whose indications included septic loosening, giant cell tumor, periprosthetic fracture, aseptic loosening and distal femoral comminuted fracture.[9] The authors showed evidence of adequate osseointegration in all cases with no signs of radiolucency or loosening, with no complications related to the metal cones. However, the authors noted pitfalls of this technique, including increased

cost of an already costly procedure with addition of a second cone, and risk of malposition of the femoral component due to inability to use offset stems with the stack technique.

The well-documented osseointegration, survivorship without revision, and low rates of migration and complication make metal cones a reliable option for cases of severe femoral condyle bone loss. We again propose the use of a single cone as a viable and appropriate option at this time. Additionally, the success of our approach suggests that further advances in femoral cone design may be needed. Specifically, there is potential for custom porous metal cones to become a legitimate management option for patients with significant osteolysis of the femoral condyle. McNamara et al reported a successful case using a custom cone in a re-revision TKA.[20] The 55-year-old patient had severely compromised bone stock in the distal femur and proximal tibia (AORI type III) after four previous arthroplasty procedures for arthrofibrosis and periprosthetic fracture. A custom tantalum cone was used for the femur and a custom tibial stem with interlocking screws and a standard trabecular metal cone was used for the proximal tibia. At two year follow-up, the patient had well aligned, fixed components, and no pain.

Although revision arthroplasty is most commonly performed by arthroplasty-trained surgeons, we describe a reproducible, effective technique for any orthopedist who performs primary and revision arthroplasty. Additionally, patients with aseptic loosening and osteolysis often present initially to general practitioners or emergency departments. A basic understanding of management and novel treatment options is essential for conducting an initial work-up, providing informed patient counseling, and making appropriate referrals.

Future studies with larger sample sizes should be performed to further assess the safety and effectiveness of this novel surgical technique we present. By optimizing treatment for this subset of patients, we can help reduce the costly burden associated with failed revision TKAs, especially in the setting of significant bony lysis.

SUMMARY

In patients presenting for revision TKA with preoperative and intraoperatively appreciated substantial femoral condylar bone loss, we feel porous metal cones which are appropriately sized intraoperatively by the operating surgeon are an effective, reliable and reproducible technique for maintaining functional outcome. Further, we present survivorship data supporting use of porous metal cones to achieve more reliable osseointegration and decreased patient reports of instability. We hope our technique becomes a consideration for future patients presenting with substantial femoral condylar bone loss as it is critical to appreciate and appropriately address bone loss for improved postoperative outcomes in the revision TKA patient.

References

1. Sloan M, Premkumar A, Sheth NP. Projected Volume of Primary Total Joint Arthroplasty in the U.S., 2014 to 2030. J Bone Joint Surg Am. 2018 Sep 5;100(17):1455–60.
2. Klug A, Gramlich Y, Rudert M, Drees P, Hoffmann R, Weißenberger M, et al. The projected volume of primary and revision total knee arthroplasty will place an immense burden on future health care systems over the next 30 years. Knee Surg Sports Traumatol Arthrosc. 2021;29(10):3287.
3. Kallala RF, Vanhegan IS, Ibrahim MS, Sarmah S, Haddad FS. Financial analysis of revision knee surgery based on NHS tariffs and hospital costs: does it pay to provide a revision service? Bone Jt J. 2015 Feb 1;97-B(2):197–201.
4. Khan IA, Baker CM, Magnuson JA, Courtney PM, Krueger CA, Lonner JH. Surgeons Experience More Physiologic Stress and Strain During Revision Than Primary Total Joint Arthroplasty. J Arthroplasty. 2023 Jun 1;38(6):1126–30.
5. Dubin JA, Bains SS, Paulson AE, Monarrez R, Hameed D, Nace J, et al. The Current Epidemiology of Revision Total Knee Arthroplasty in the United States From 2016 to 2022. J Arthroplasty. 2024 Mar;39(3):760–5.
6. Engh GA, Ammeen DJ. Classification and preoperative radiographic evaluation: knee. Orthop Clin North Am. 1998 Apr; 29(2):205–17.
7. Kamath AF, Lewallen DG, Hanssen AD. Porous tantalum metaphyseal cones for severe tibial bone loss in revision knee arthroplasty: a five to nine-year follow-up. J Bone Joint Surg Am. 2015 Feb 4;97(3):216–23.
8. Lachiewicz PF, Bolognesi MP, Henderson RA, Soileau ES, Vail TP. Can tantalum cones provide fixation in complex revision knee arthroplasty? Clin Orthop. 2012 Jan;470(1):199–204.
9. Rajgopal A, Kumar S, Aggarwal K. Midterm Outcomes of Tantalum Metal Cones for Severe Bone Loss in Complex Primary and Revision Total Knee Arthroplasty. Arthroplasty Today. 2021 Feb;7:76–83.
10. Cohen R. A porous tantalum trabecular metal: basic science. Am J Orthop Belle Mead NJ. 2002 Apr;31(4):216–7.
11. Levine B, Sporer S, Della Valle CJ, Jacobs JJ, Paprosky W. Porous tantalum in reconstructive surgery of the knee: a review. J Knee Surg. 2007 Jul;20(3):185–94.
12. Clatworthy MG, Ballance J, Brick GW, Chandler HP, Gross AE. The Use of Structural Allograft for Uncontained Defects in Revision Total Knee Arthroplasty: A Minimum Five-Year Review. JBJS. 2001 Mar;83(3):404.
13. Beckmann NA, Mueller S, Gondan M, Jaeger S, Reiner T, Bitsch RG. Treatment of severe bone defects during revision total knee arthroplasty with structural allografts and porous metal cones-a systematic review. J Arthroplasty. 2015 Feb;30(2):249–53.
14. Vasso M, Beaufils P, Cerciello S, Schiavone Panni A. Bone loss following knee arthroplasty: potential treatment options. Arch Orthop Trauma Surg. 2014 Apr;134(4):543–53.
15. Tetreault MW, Perry KI, Pagnano MW, Hanssen AD, Abdel MP. Excellent two-year survivorship of 3D-printed metaphyseal cones in revision total knee arthroplasty. Bone Jt J. 2020 Jun;102-B(6_Supple_A):107–15.
16. Behery OA, Shing EZ, Yu Z, Springer BD, Fehring TK, Otero JE. Survivorship and Radiographic Evaluation of Metaphyseal Cones With Short Cemented Stems in Revision Total Knee Arthroplasty. J Arthroplasty. 2022 Feb;37(2):330–5.
17. Shichman I, Anil U, van Hellemondt G, Gupta S, Willems J, Deshmukh AJ, et al. Mid- term outcomes of a novel metaphyseal porous titanium cone in revision total knee arthroplasty. J Clin Orthop Trauma. 2023 Nov;46:102282.
18. Chalmers BP, Malfer CM, Mayman DJ, Westrich GH, Sculco PK, Bostrom MP, et al. Early Survivorship of Newly Designed Highly Porous Metaphyseal Tibial Cones in Revision Total Knee Arthroplasty. Arthroplasty Today. 2021 Apr 1;8:5–10.

19. You JS, Wright AR, Hasegawa I, Kobayashi B, Kawahara M, Wang J, et al. Addressing large tibial osseous defects in primary total knee arthroplasty using porous tantalum cones. The Knee. 2019 Jan;26(1):228–39.
20. McNamara CA, Gösthe RG, Patel PD, Sanders KC, Huaman G, Suarez JC. Revision total knee arthroplasty using a custom tantalum implant in a patient following multiple failed revisions. Arthroplasty Today [Internet]. 2017 Mar 1 [cited 2024 Sep 18];3. Available from: https://www.sciencedirect.com/science/article/pii/S2352344116300322

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