Addressing large tibial osseous defects in primary total knee arthroplasty using porous tantalum cones

Jae S. You [a], Anne R. Wright [a], Ian Hasegawa [a,*], Brandon Kobayashi [a], Matthew Kawahara [a], Jordan Wang [a], Cass K. Nakasone [a,b]

[a] Department of Surgery, University of Hawai'i, John A. Burns School of Medicine, Honolulu, HI 96813, United States of America
[b] Straub Clinic Bone and Joint Center, Honolulu, HI 96813, United States of America

ARTICLE INFO

ABSTRACT

Background: Tibial osseous defects can present a serious challenge in primary total knee arthroplasty. We describe a technique of using porous tantalum cones along with primary arthroplasty implants to address large tibial osseous defects in primary total knee arthroplasty and present the short-term results.
Methods: We present 17 cases (15 patients) in which primary total knee implants and porous tantalum cones were used to address large tibial bony defects. Clinical results were evaluated using Knee Society Scores, pre- and postoperative knee range of motion, and serial radiographs.
Results: At an average of 3.5 years of follow-up, all 17 knees had functioning implants with stable metaphyseal cones demonstrating radiographic evidence of osteointegration. At a minimum follow-up of two years, no patient had signs of osteolysis, instability, infection, or systemic complications. All 15 patients had excellent results with an average post-operative Knee Society Score of 94.6. Knee flexion improved by an average of 12.0° and knee extension improved to neutral in all patients.
Conclusion: Primary total knee arthroplasty with porous tantalum cone augmentation produced excellent short-term results and should be considered an effective method for addressing large tibial osseous defects in primary total knee arthroplasty.

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1. Introduction

Large uncontained tibial osseous defects can present a significant challenge for the surgeon performing a primary total knee arthroplasty (TKA). These defects may vary in size, location, and magnitude and may require augmentation in order to restore the joint line and, more importantly, provide support for implant stability [1]. A wide variety of techniques to address this problem have been described including cement and screws, metal augmentation, and bone grafting [2–4]. However, there is no gold standard fixation option for these defects and size of the defect can limit surgical options. For instance, cement and screws, as well as autografts, are often limited to smaller defects less than 10 mm [2,4].

Larger defects found in revision TKA have commonly been addressed with metal block augments or large structural allografts [5–7]. Metal block augments theoretically provide increased stability at the tibial bone–implant interface. This technique has also

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* Corresponding author at: Department of Surgery, University of Hawai'i, 1356 Lusitana Street, Sixth Floor, Honolulu, HI 96813, United States of America.
E-mail address: iangh@hawaii.edu. (I. Hasegawa).

been applied to primary TKA with satisfactory results observed in the early post-operative period [3]. A major limitation of this technique, however, is that bone stock is never restored potentially complicating future revisions. Structural allografts, on the other hand, are an efficient and cost effective method for restoring bone stock [7,8]. The disadvantage is that there is a risk of graft failure due to resorption, fracture, and nonunion [9].

Porous tantalum cones provide an excellent option and offer mechanical and osteoconductive properties that allow it to provide structural stability and host bone integration. Tantalum metal acts as a modular scaffold for osteoblast-mediated bone ingrowth and provides a porous surface for graft and cement incorporation. Additionally, it provides tremendous axial compressive support for implants [10]. It has proven to be a promising treatment for reconstructing bone loss in revision arthroplasty in terms of surgical efficacy, low infection rates, and superior radiographic results [11–14].

Advantageous properties of porous tantalum cones and its successful use in revision TKA involving severe bone loss are well described in the literature; however, to the best of our knowledge, the technique of using these implants in primary TKA with large tibial defects has not yet been described. The purpose of this study is: 1) To describe our off-label technique of using porous tantalum cones along with primary arthroplasty implants to address large tibial osseous defects and 2) to present and analyze the short-term results of this surgical technique.

2. Methods

Seventeen porous tantalum cones cut in half were implanted into 15 patients (nine men, six females) during primary TKA to address tibial osseous defects. All procedures were done by a single orthopedic surgeon who averages approximately 300 TKA per year for greater than 12 years. The average age and general demographic data of the study group is shown in Table 1. Demographic data, intraoperative data, preoperative and postoperative function, type of implant, and complications were collected from the patient charts and database.

The surgeon preoperatively assessed the plain film in order to anticipate tibial bone loss and porous tantalum cone use. Bone loss was classified using the Anderson Orthopaedic Research Institute system [15]. All 17 knees were either a 2A or 2B. The final decision to use a porous tantalum cone was made intraoperatively, with the major indication being defects greater than 20 mm measured from the surface of the tibial cut. All defects were non-traumatic and due to severe wear from long-standing osteoarthritis.

Of the nine men, one had simultaneous bilateral TKA and one had staged bilateral TKA. All knees had uncontained medial tibial plateau defects >20 mm requiring medial porous tantalum cones. All patients had osteoarthritis except for one patient with rheumatoid arthritis. Tourniquets were used in all cases except for one case where the tourniquet was not working properly and the case was done without it. Tourniquets were deflated after closure of the arthrotomy. The average tourniquet times and estimated blood loss are shown in Table 1. Three different primary total knee arthroplasty systems were used including (six) Zimmer NexGen, (six) Zimmer Persona, and (two) Ortho Development BKS. Antibiotic loaded bone cement (Palacos Gentamicin, Zimmer Orthopaedics, Warsaw, Indiana) was used in all cases. All surgeries were performed at a single private institution by a single fellowship trained orthopedic surgeon using porous tantalum cones to reconstruct tibial bone defects.

Patients routinely followed up in clinic at two weeks, six weeks, three months, six months, one year, two years, and five years following surgery. Knee Society Scores and Knee Society Function Scores were recorded at each visit except the two-week follow-up appointment and were rated as excellent, good, and fair. Knee flexion and extension were measured at each visit. Standard plain films of the knee (anteroposterior, lateral, and merchant views) were taken preoperatively and at six weeks, six months, one year, and at a minimum of two years post-operatively unless symptoms or examination indicated repeat radiographs were necessary. These films were assessed for signs of loosening, osteolysis, fracture, and implant failure at each time point. We used radiolucency at the tantalum cone–bone, tantalum cone–tibial base plate, and cement–tibial base plate interfaces, as well as implant subsidence, as radiographic signs of loosening. Additionally, AP femoral component angle, Anteroposterior (AP) tibial femoral angle, lateral femoral component angle, and tibial slope were measured on the six-week follow-up film. Tibiofemoral angle and mechanical axis were measured on hip-to-ankle plain films taken preoperatively and at six weeks following surgery. Measurements were not repeated, as there was no evidence of collapse or failure.

Table 1
Demographic and intraoperative data.

Age (years)	71 ± 12 (48–85)
Height (in.)	63 ± 6 (55–73)
Weight (lb)	194 ± 71 (105–320)
BMI (kg/m^2)	33.0 ± 7.4 (21.4–44.8)
ASA	2.7 ± 0.5 (2–3)
Tourniquet time (min)	69 ± 16 (45–107)
Estimated blood loss (cm^3)	82 ± 23 (50–100)

Figure 1. Extra-medullary tibial cutting is used to measure resection of the proximal tibia.

2.1. Surgical technique

A slightly oblique midline skin incision is made and a medial parapatellar arthrotomy is used to gain exposure of the knee. Any exposure technique can be used, as long as adequate exposure of the proximal tibia is obtained. An extra-medullary tibial cutting guide was used in all cases to perform the proximal tibial resection (Figure 1). Measurement of the thickness of tibial cut can be made based off of the lateral tibial plateau if medial tibial plateau loss is the defect being addressed. The medial tibial plateau is used for reference if a severe lateral defect is being addressed. It is not recommended to resect to the bottom of the defect, as this will remove excessive tibia (Figures 2 and 3). Once the proximal tibial cut is made, check to make sure that the tibial platform is perpendicular to the mechanical axis of the tibia or as surgically intended with the method of your choice (block and rod,

Figure 2. Preoperative templating proximal tibia resection.

Figure 3. Following resection of the proximal tibia, the medial tibial plateau defect can be assessed.

Figure 4. The porous tantalum cone size is chosen to match the defect being addressed with the trial cone sizes available.

Figure 5. Outline the planned position of the cone with a surgical pen. This will provide the template for burring the trough in which the porous tantalum cone will be impacted.

computer navigation, etc.). After selecting the tibial implant size, the proximal tibia can be prepared for the trial implants in the usual fashion according to the system of your choice. At this point, a porous tantalum cone is chosen according to the size needed to reconstruct the defect. The size of cone chosen should be large enough to support the tibial implant overlying the defect in question (Figure 4). With a surgical pen, a preliminary outline of where the surgeon plans to position the cone can be drawn on the proximal tibia (Figure 5). A high-speed burr is then used to fashion a groove in which the porous tantalum cone will be impacted. The depth of the groove will be determined by the size of the cone and defect. The goal of this process is to have the porous tantalum cone sit flush with the tibial cut and provide axial compressive support under the tibial baseplate where bone is missing (Figures 6 and 7). The porous tantalum cone is then measured, marked, and cut to the size and configuration desired with a reciprocating saw away from the surgical field. Cutting the porous tantalum cone is quick and easy, but technique dependent and should take no more than around five minutes or less. The porous tantalum cone is held firmly by two clamps, one on each side of the cut. Irrigation of the reciprocating blade with normal saline or sterile water is required to keep the

Figure 6. A high-speed burr is used to fashion a groove to accept the porous tantalum cone. Be sure to measure the depth of the cone being used and deepen the groove accordingly. Once impacted into place, the porous tantalum cone should sit flush with the proximal tibial surface.

Figure 7. Finished groove, now ready to accept the porous tantalum cone cut to fit within it.

blade cool and a very light touch is used to saw the cone. Forceful pressure will usually result in quick dulling of the blade. If this happens, turn the blade over or a new one will be required (Figure 8). Once the cone is cut to size, rinse it in sterile water or normal saline to clear debris. The cone can then be impacted into place (Figure 9). The burr may be needed to adjust the bony groove so it can accept the cone. Do not make the groove too large or deep. The adapted cone should fit snugly within the bone. The proximal tibial defect should now be fully capable of supporting axial load. If desired, bone grafting with autologous bone can be done prior to cementing in the area between the porous tantalum cone and the central portion of the tibia (Figure 10). With the tibial plateau reconstructed, trial implants can be placed and the knee can be checked for alignment and balance in the usual manner (Figure 11). A primary tibial implant can now be cemented into place, in the usual fashion, directly onto the porous tantalum cone (Figure 12). Be sure to place cement between the implant and the porous tantalum cone.

Preoperative and postoperative weight bearing radiographs are shown in Figures 13 and 14.

3. Results

Seventeen knees, 15 patients, were included in final analysis. The average length of follow-up was 3.5 years with a minimum follow-up of two years and maximum follow-up of five years. At final follow-up exams, all 17 knees had functioning implants and stable metaphyseal cones without radiographic evidence of osteolysis or loosening as evidenced by interface radiolucencies or component subsidence. In this small cohort of patients, no patient had signs of instability, infection, or any systemic complications.

Figure 8. Measure and cut the chosen porous tantalum cone with a reciprocating saw. Use a light touch with saline or sterile water to cool the blade. The cone is held firmly with clamps of your choice. With the correct technique, the cone will easily cut within one to five minutes.
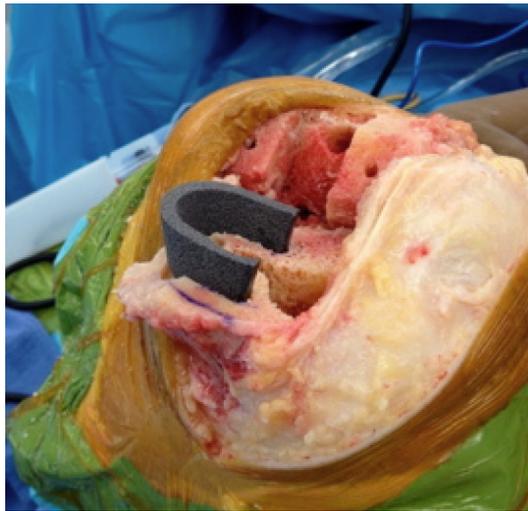
Figure 9. Porous tantalum cone cut to fit just prior to impaction.

At a minimum of two years of follow-up, there were no signs of osteolysis surrounding the porous tantalum cone augments or bone cement interfaces in any area surrounding the tibial implants.

Clinical results were rated as excellent, good, and fair according to the Knee Society Score and Knee Society Function Score. All 15 patients had excellent post-operative results with an average Knee Society Score of 94.6, improved from an average preoperative score of 19.4. Knee Society Function Scores increased from an average of 41.4 preoperatively, to 78.5 at the minimum two-year follow-up. Knee flexion improved by an average of 12.0° and knee extension improved to neutral in all patients at a minimum two-year follow-up (Table 2).

The average preoperative and postoperative tibiofemoral angle and mechanical axis as measured from hip-to-ankle films are shown in Table 3, while individual measurements are shown in Figures 15 and 16. The anteroposterior femoral component position, tibial component position, lateral femoral angle, and tibial slope as measured from standard radiographs are shown in Table 4.
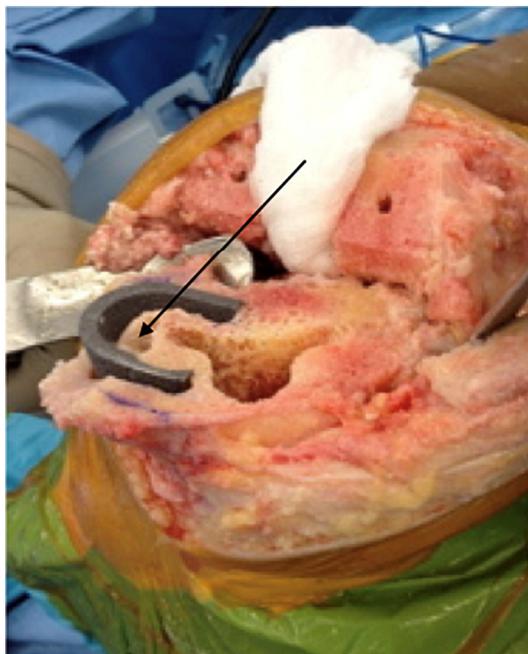

Figure 10. Fully impacted porous tantalum cone. Bone graft can be impacted into the void between the cone and host bone as indicated by the arrow shown.

Figure 11. The porous tantalum cone provides a solid foundation and trial implants can be placed to check balance and alignment of the knee prior to final cementing of implants.

4. Discussion

There are currently limited surgical options to address large uncontained tibial defects (AORI IIA and IIB) in the primary TKA setting. Techniques for addressing larger defects are often adapted from those utilized in revision TKA, including metal block augments and large structural allografts. A study by Baek et al. on 92 cases of primary TKA with a minimum two-year follow-up demonstrated the successful use of metal block augmentation with no cases of component loosening [3]. The advantages of a metal block implant are that the size and profile can be customized intraoperatively and it has superior structural properties that provide implant stability. However, Brand et al. have questioned the durability of metal augments, citing up to 25% incidence of radiolucent lines at 3.5 years post-revision TKA [6]. Additionally, a major limitation highlighted by Baek et al., is that these metal augments do not promote restoration of bone stock [3]; which may complicate future revisions.

In contrast, allograft augmentation can be used to restore bone stock in the setting of large osseous defects [7–9]. Additionally, they can be customized intraoperatively and they provide reliable structural support. Clatworthy et al. demonstrated acceptable five-year survival rates of structural allografts used for revision TKA; however, there is a potential for these grafts to fail due to resorption, graft infection, nonunion, delayed union, and fracture [7,9,16].

Studies evaluating the use of porous tantalum cones in revision TKA found improvements in Knee Society Scores, stable implants with osteointegration, and low rates of complications [1,11–13]. Compared to other methods, porous tantalum cones allow for greater biological ingrowth and substitution of bone stock due to its inherent structural properties. The higher degree of bone porosity and modulus of elasticity close to that of human bone offers the theoretical advantage of stable and long-term fixation [17,18]. These properties offer the possibility of early mechanical support without short or long-term resorption.
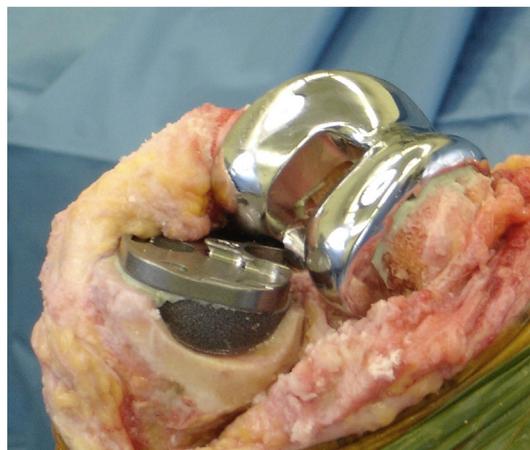

Figure 12. Final implants cemented in place. Note cement between the porous tantalum cone and tibial baseplate.
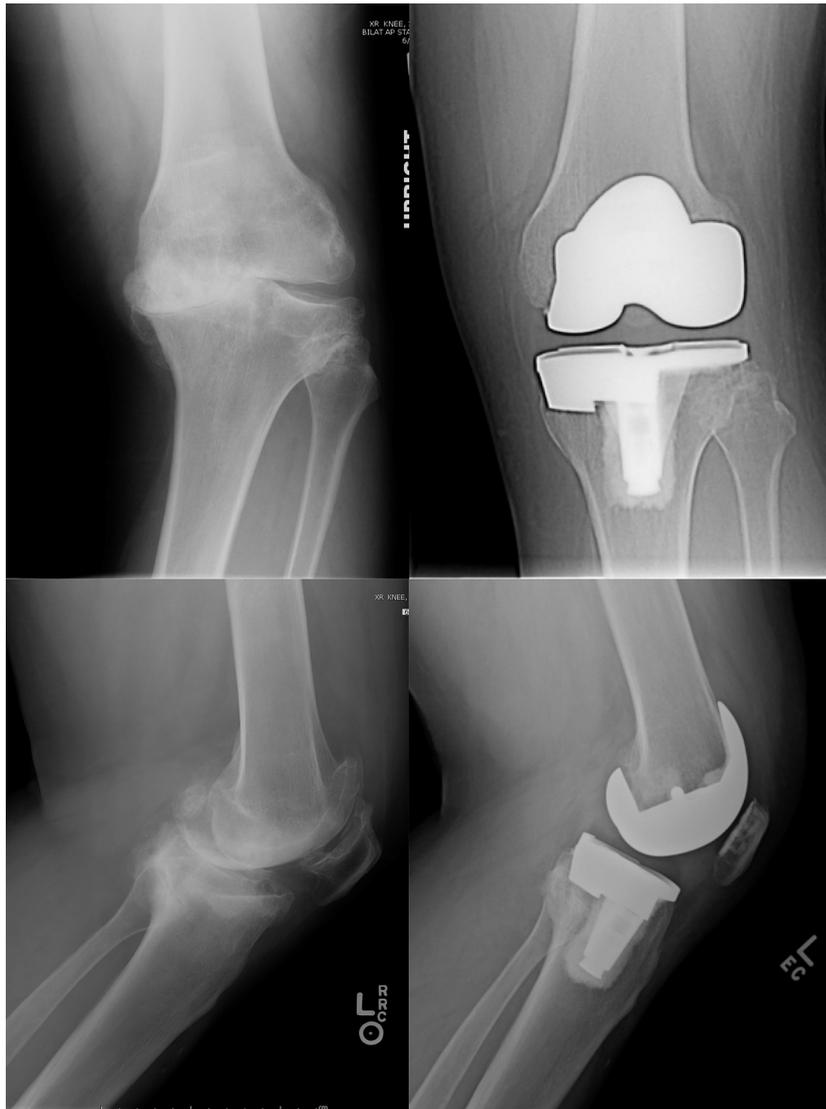
Figure 13. Pre- and postoperative radiographs showing medial tibial plateau defect prior to surgery and radiographic results four and a half years following surgery.

Our study considers an adapted approach from revision TKA of using porous tantalum cones for large tibial osseous defects in primary TKA. To our knowledge, this technique has not previously been described. Brown et al. did investigate the use of porous tantalum cones in complex primary and revision TKA; however, they presented only four primary TKA cases. Furthermore, a detailed surgical technique was not provided and the reported outcomes reflected a heterogeneous group of primary and revision arthroplasty cases [19]. As such, our paper is the first to describe the use and clinical outcomes of porous tantalum cones in primary TKA. Our short-term results support the use of porous tantalum cones to reconstruct significant tibial osseous defects in primary TKA. In all of our patients, there was no interface radiolucency, component migration, or loosening found on radiographs at any follow-up time point. There were no cases of infection or periprosthetic fractures. Immediate full postoperative weight bearing was initiated in all patients. All patients had excellent Knee Society Scores, improved range of motion, and no complications at the time of their latest minimum two-year follow-up.

There are several limitations to our study. A selection bias may exist due to our small and heterogeneous (given the use of three different tibial components) patient population. Our small cohort is due to the fact that severe tibial defects in the setting of primary TKA is rare even in high volume surgical practices. Furthermore, we intentionally chose to utilize three different tibial components to demonstrate that our technique is not implant specific and therefore should not be limited as such. This study is also limited in that it represents the experience of a single surgeon, with extensive experience utilizing porous tantalum cones. We recognize that these results may be difficult to reproduce in the hands of a less experienced surgeon. Other potential drawbacks of our technique include the difficulty of implant removal in the setting of infection, higher technical skill required during

Figure 14. Pre- and postoperative hip to ankle films showing deformity correction. Note that preoperative deformity did not allow both legs to fit on one film.

Table 2
Pre- and post-operative functional data.

	Pre-operative	Post-operative
Knee extension	4.4° ± 6.3 (0°–20°)	0.0° ± 0.0 (0°–0°)
Knee flexion	107.4° ± 15.7 (85°–130°)	119.4° ± 5.6 (110°–130°)
Knee Society Score	19.4° ± 11.5° (0°–41°)	94.6° ± 4.6° (85°–100°)
Knee Society Function Score	41.5° ± 17.0° (0°–80°)	78.5° ± 23.7° (40°–100°)

Table 3
Pre- and post-operative alignment values based on hip-to-ankle plain films.

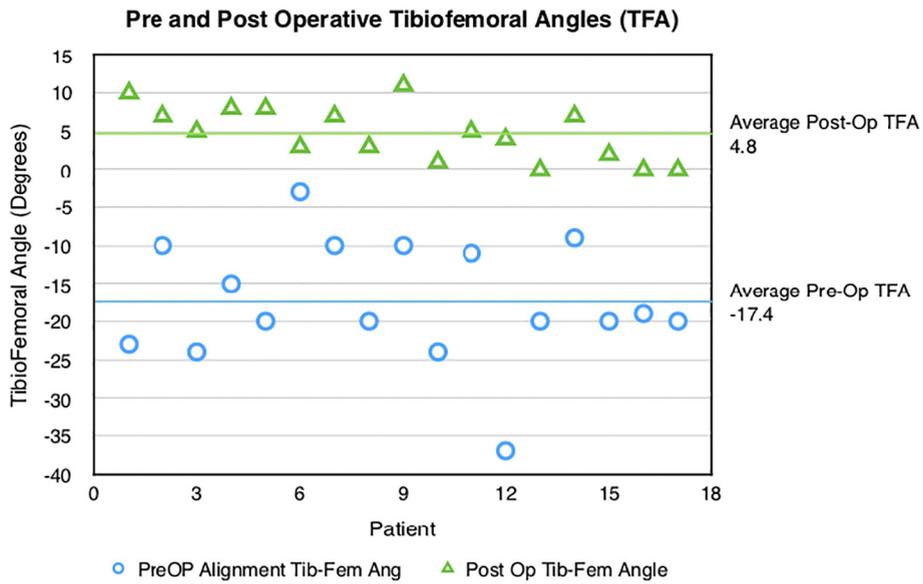|	Pre-operative	Post-operative
Tibiofemoral angle[a]	−17.4° ± 8.0° (−37° to −3°)	4.8° ± 3.5° (0° to 11°)
Mechanical axis	−22.8° ± 7.0° (−40° to −9°)	−0.86° ± 3.2° (−6° to 4°)

[a] Valgus values are positive.

Figure 15. Individual and average pre- and postoperative tibiofemoral angle (TFA) values based on hip-to-ankle plain films. Numerical averages, standard deviations, and ranges presented in Table 3.
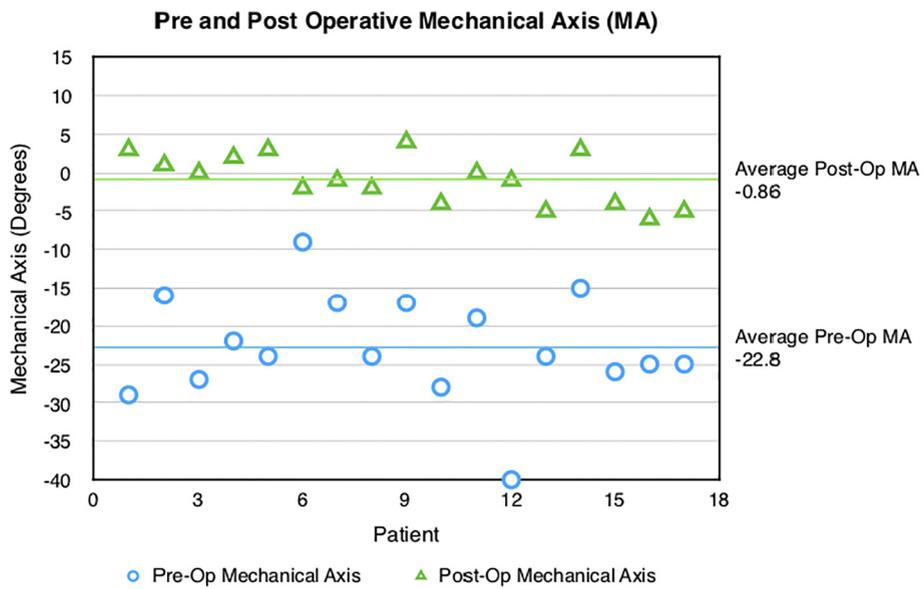

Figure 16. Individual and average pre- and postoperative mechanical axis (MA) angles based on hip-to-ankle plain films. Numerical averages, standard deviations, and ranges presented in Table 3.

Table 4
Post-operative alignment values based on standard plain film views of knee.

	Post-operative
AP femoral component angle	$5.6° \pm 1.5°$ ($3°$ to $8°$)
AP tibial component angle	$0° \pm 1.5°$ ($-3°$ to $3°$)
Lateral femoral component angle	$0.6° \pm 2.3°$ ($-3°$ to $5°$)
Tibial slope	$2.7° \pm 2.6°$ ($0°$ to $8°$)

implantation, as well as the need to remove minimal bone to fit and properly seat the adapted porous cone. Additionally, it is important to note that it is unknown whether cutting the tantalum cone to custom fit the tibial defect has any resulting effect on its strength and integrity. As such, our technique of custom cutting porous tantalum cones based on the tibial defect size should be considered an off label use. Finally, surgeons may question the additional cost of porous tantalum cone augments. On average, porous tantalum cones cost approximately $2000. At our institution, primary TKA implants average approximately $3000. Therefore, a total of approximately $5000 can be expected when porous tantalum cone augments are used for primary TKAs. In comparison, the cost of utilizing a revision tibial implant system at our institution, which typically consists of a stemmed revision tibial baseplate and at least one medial or full block augment, in addition to a standard primary femoral component, would total approximately $8000. Thus, despite the added cost, using porous tantalum cones still appears to be the more economical choice. Despite the potential limitations of this study we believe that the use of porous tantalum cones provides an immediately stable, compressively resistant reconstructive option to support a primary tibial baseplate in the presence of large tibial osseous defects encountered during a complex primary TKA.

4.1. Conclusion

In conclusion, in the short-term post-operative period we have demonstrated that porous tantalum cones provide an effective solution when faced with large osseous defects in the primary TKA setting. Furthermore, complex or more expensive revision systems are not required for good clinical results. Future studies with a larger series of patients and longer follow-up are needed to determine if this adapted technique provides long-term clinical success and does not produce mechanical or biologic complications not encountered to date.

Ethical statement

We wish to declare that all the authors have contributed to the paper. There are no financial or personal relationships with other people or organizations that inappropriately influenced this work. Dr. Nakasone has disclosed that he is a consultant for several companies; however, this relationship does not bias our work as we do not recommend any specific brand of TM cones or primary implants. We confirm that this work is original and has not been published elsewhere nor is it currently under consideration for publication elsewhere. The institutional review board has approved it.

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