The Use of Trabecular Metal Cones for the Management of Severe Bone Defects in Revision Total Knee Replacement

Ignacio García-Mansilla, Julián Costantini, Tomás Nicolino, Juan Astoul Bonorino, Lisandro Carbó
Knee Prosthesis and Arthroscopy Sector, Hospital Italiano de Buenos Aires, Autonomous City of Buenos Aires, Argentina

ABSTRACT

Introduction: Major bone defects represent a challenge during revision total knee arthroplasty (TKA) and there is still considerable debate about the best therapeutic option. The purpose of this study was to retrospectively assess the osseointegration rate of trabecular metal cones in revision TKA with severe bone defects. The secondary purpose was to evaluate the functional outcomes and complication and reoperation rates. **Materials and Methods:** A single-center, retrospective cohort including all consecutive cases of revision TKA using trabecular metal cones. All patients with a minimum 2-year follow-up were included in the study. Reasons for revision, number of previous surgeries, type of bone defect, and number and type of trabecular cones used were evaluated. Clinical and radiological outcomes were also analyzed as well as complications rates. **Results:** 35 patients (49 cones) were evaluated with a mean follow-up of 32.1 months (24-62). Most defects were localized in the tibia and were classified as AORI type 3. The rate of osseointegration of the cones was 94%; the complication rate, 20%; and the reoperation rate, 8.5%. The mean KSS increased from 39 preoperatively to 71 at the last follow-up, and the mean VAS from 8 to 2.5. **Conclusion:** The excellent osseointegration rate (94%), added to the good clinical outcomes, position the trabecular metal cones as an alternative to treat severe bone defects.

Keywords: Revision; total knee replacement; bone defects; knee; trabecular metal cones.
Level of Evidence: IV

Uso de conos de metal trabecular para defectos óseos severos en cirugía de revisión de reemplazo total de rodilla

RESUMEN

Introducción: Las alternativas reconstructivas para defectos óseos severos en la cirugía de revisión de prótesis son las camisas metafisarias, los conos de metal trabecular y el injerto óseo impactado o estructural. El objetivo del estudio fue analizar la tasa de osteointegración de los conos de metal trabecular en pacientes con cirugía de revisión de prótesis total de rodilla. El objetivo secundario fue analizar los resultados funcionales, las tasas de complicaciones y reoperaciones. **Materiales y Métodos:** Cohorte retrospectiva de pacientes con conos de metal trabecular colocados en la cirugía de revisión de prótesis y un seguimiento mínimo de 2 años. Se evaluaron las causas de la revisión, cirugías previas, tipo de defecto óseo, cantidad y tipo de conos utilizados, y los diseños de las prótesis. Se realizó una evaluación clínico-radiográfica, se registraron las complicaciones y las revisiones ulteriores. **Resultados:** Se evaluó a 35 pacientes (49 conos de metal trabecular) en forma retrospectiva, con un seguimiento promedio de 32.1 meses. La mayoría de los defectos eran tibiales AORI 3, seguidos de los femorales tipo 3. La tasa de osteointegración de los conos fue del 94%; la de complicaciones, del 20% y la de reoperaciones, del 8,5%. El KSS objetivo promedio aumentó de 39 en el preoperatorio a 71 en el último control y el puntaje de la EAV promedio fue 8 y 2,5, respectivamente. **Conclusión:** La excelente tasa de osteointegración (94%) y los buenos resultados clínicos posicionan a los conos de metal trabecular como una alternativa para los defectos óseos severos.

Palabras clave: Revisión; reemplazo total de rodilla; defectos óseos; prótesis total; rodilla, metal trabecular.
Nivel de Evidencia: IV

Received on June 9th, 2021. Accepted after evaluation on June 23rd, 2021 • Dr. IGNACIO GARCÍA-MANSILLA • ignaciogmansilla@gmail.com https://orcid.org/0000-0002-7247-3734

How to cite this article: García-Mansilla I, Costantini J, Nicolino T, Astoul Bonorino J, Carbó L. The Use of Trabecular Metal Cones for the Management of Severe Bone Defects in Revision Total Knee Replacement. *Rev Asoc Argent Ortop Traumatol* 2021;86(4):483-492. https://doi.org/10.15417/issn.1852-7434.2021.86.4.1390

INTRODUCTION

Severe bone defects continue to be a challenge in revision knee arthroplasty, mainly AORI defects 2B and 3 that compromise the stability and fixation of the revision implant (Figure 1).[1,2]

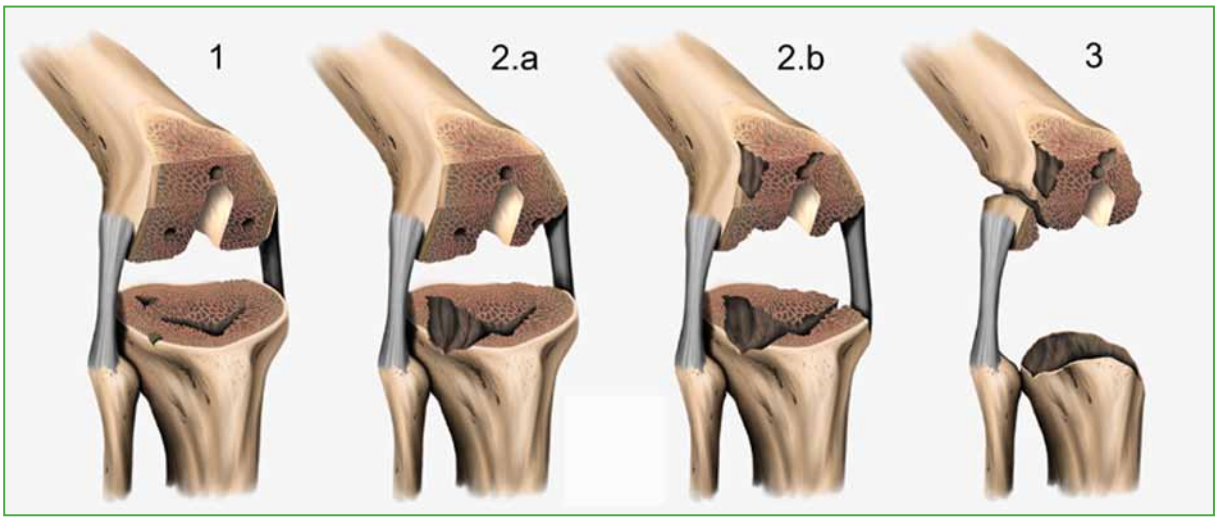

Figure 1. *Anderson Orthopedic Research Institute* (AORI) Classification of Bone Defects. Type 1: Intact metaphyseal bone with minor femoral or tibial defects which do not compromise the stability of the revision component. Type 2: Damaged metaphyseal bone, requiring reconstruction to provide stability to the revision component. Type 2A: Defects in a femoral or tibial condyle. Type 2B: Defects in both femoral or tibial condyles. Type 3: Deficient metaphyseal segment involving a significant portion of the femoral condyles or tibial plateau, occasionally associated with collateral ligament or patellar tendon injury.

Regardless of the reconstruction system used, metaphyseal fixation is decisive for implant survival.[3-5] Depending on the defect, reconstructive alternatives include metaphyseal sleeves, trabecular metal cones, and impacted or structural bone graft.

Structural bone grafting has the disadvantage of being a technically demanding option to achieve an adequate graft-host interface, and resorption rates and mechanical failures have been reported as high as 23% at 5 years.[6] In contrast, trabecular metal cones are a versatile option (various sizes and shapes compatible with almost all revision systems) and provide mechanical support without the risk of resorption and collapse.[7-12] The disadvantages are their high economic cost, not providing bone stock, the difficulty in extracting them if there is an infection that requires it, and being highly irritating to the surrounding soft tissues.

Regarding the properties of the material, trabecular metal has a structure similar to cancellous bone, with high volumetric porosity (75-80%), low modulus of elasticity (3 GPa), and high friction. In addition, it allows osseointegration while filling bone defects and has immediate tolerance to physiological loads. AORI 2B and 3 defects are its main indication and promising results have been achieved in the medium and long term.[13-21]

The objective of this study was to analyze the implant osseointegration rate in a series of patients who received trabecular metal cones in revision total knee arthroplasty surgery. As a secondary objective, functional outcomes and complication and reoperation rates were analyzed.

MATERIALS AND METHODS

Patients

In this retrospective study, we consecutively included patients operated on at our Center, in whom trabecular metal cones had been used in revision surgery for total knee arthroplasty. The inclusion criteria were revisions in one or two stages for any reason, AORI 2B and 3 bone defects, use of one or more trabecular metal cones, and a minimum follow-up of two years. Patients with trabecular metal cones in the primary surgery were excluded.

Evaluation methods

Immediate postoperative radiographs were taken at 3 and 6 months and one year after surgery, and at the last follow-up to assess signs of osseointegration and loosening of the trabecular metal cones or the implant. Signs of progressive radiolucency or osteolysis around the components and at the cone-bone interface were evaluated. Radiographic osseointegration in the last follow-up was defined as the absence of a radiolucent line between the bone and the trabecular metal.

The patients were clinically evaluated before surgery and during follow-up with the *Knee Society Score* (KSS) and the visual analog scale for pain. Intraoperative and postoperative, early and late complications were recorded. Finally, reoperation and revision rates (implant survival) were analyzed.

Surgical technique

After soft tissue debridement, the previous implant is removed along with the cement. The extent of bone loss is reassessed, the remaining defect is classified, and the indication for trabecular metal cones is confirmed. The trial implants are then placed to assess size and shape, selecting the one that provides the largest area of contact with the bone (Figure 2).

Figure 2. Intraoperative images of the surgical technique. An uncontained metaphyseal defect is observed at the tibial level after removal of the implant and debridement of the non-viable tissue (**A**). The trial implant of a metaphyseal tibial cone (**B**) is placed and then the final cone (**C**) is impacted. In this case, due to the magnitude of the remaining defect in the femur (**D**), it was decided to use a combination of a metaphyseal and a diaphyseal cone (**E and F**).

After preparing the host bone, the cone is impacted. Press-fitting the cone is of utmost importance to ensure that the cement does not penetrate between the cone and the bone. In the case of combining metaphyseal and diaphyseal cones, it is recommended to use cement at the junction of both cones. Finally, the definitive implants are cemented in the cones, it is also recommended to use cemented stems. The exposed areas of trabecular metal are coated with cement, as they are highly irritating to the soft tissues (Figure 3).

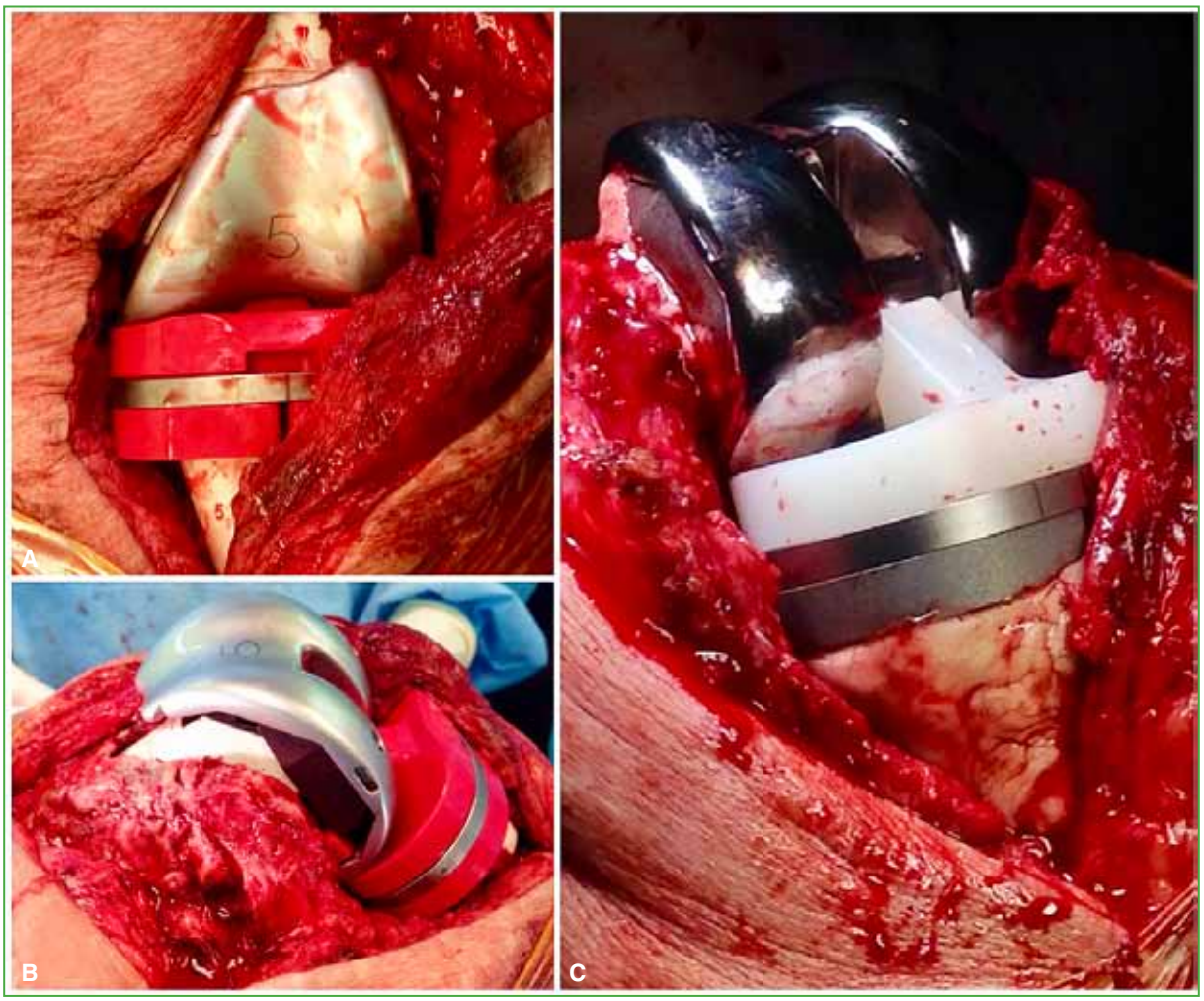

Figure 3. Continuation of the intraoperative images in Figure 2. Placement of trial implants (**A and B**) and definitive implants (**C**). The exposed area of the cone at the tibial level is coated with cement to avoid irritating the adjacent soft tissues (**C**).

RESULTS

215 total knee arthroplasty revisions have been performed at our Center since the incorporation of trabecular metal cones in late 2015. In 45 (21%) cases, trabecular metal cones were used. Eight patients were excluded for not complying with the minimum follow-up and two died before completing the two-year follow-up. Therefore, our series consisted of 35 patients, with an average follow-up of 32.1 months (range 24-62). None were lost to follow-up. Table 1 lists the characteristics of the patients and the reasons for the revision. The majority were women (n = 23; 6.7%), the most frequent previous implantation was a primary prosthesis (n = 21, 60%) and the most frequent cause of revision was aseptic loosening of a primary prosthesis (n = 12; 34.2%).

Table 1. Patient characteristics and causes of revision.

Age, years, average (range)	66.1 (35-85)
Body mass index, kg / m ^{2}, average (range)	30.7 (20-47)
Sex, Female, n (%)	23 (65.7%)
Number of previous surgeries, average (range)	2.9 (1-10)
Previous implant	
Primary prosthesis	21 (60%)
Stem revision prosthesis	12 (34.2%)
Modular prosthesis	1 (2.8%)
Alloprosthesis	1 (2.8%)
Causes of revision (n,%)	
Aseptic loosening of primary prosthesis	12 (34.2%)
Aseptic loosening of revision prosthesis	6 (17.1%)
Septic loosening of primary prosthesis	9 (25.7%)
Septic loosening of revision prosthesis	6 (17.1%)
Instability associated with the prosthesis	1 (2.8%)
Painful prosthesis	1 (2.8%)

Table 2 shows the distribution of bone defects that required filling with trabecular metal cones, classified according to AORI[1] and the location and types of cones used.

Table 2. Bone defects that required filling with trabecular metal cones classified according to the AORI. Location and type of cones used during the revision

	AORI		Cones	
	2B	**3**	**Diaphyseal**	**Metaphyseal**
Femur	5	11	7	9
Tibia	6	24	6	28

AORI = *Anderson Orthopaedic Research Institute.*

In 10 cases, a combination of femoral and tibial cones was used, and in three cases, metaphyseal and diaphyseal cones were combined in the same patient. Regarding the prosthesis designs for revision (Figure 4), more than half were constrained prostheses (n = 20; 57.1%), 20% were rotating-hinge (n = 7), 20% were megaprostheses (n = 7), and one was a medial pivot implant (2.8%). In two cases, impaction bone grafting was also used at the femoral level and, in five cases, a reconstruction of the extensor mechanism was performed (3 with allograft and 2 with mesh).

Figure 4. Prosthetic designs used in the revision. **A.** Constrained. **B.** Rotating hinge. **C.** Megaprosthesis. **D.** Medial pivot.

Regarding the radiographic evaluation, the osseointegration rate of the trabecular metal cones at the end of follow-up was 94% (n = 33). One patient had an aseptic loosening, for which a revision of the implant was carried out two years after the operation. One patient developed an early infection that was treated with implant cleaning and retention. The evolution was unfavorable with the loosening of the implant and a revision is being planned. In the rest of the series, there was an asymptomatic patient with radiolucent images in the femoral stem of a megaprosthesis, without signs of loosening at the tibial level where a metaphyseal trabecular metal cone had been placed. Revision-free survival of the trabecular metal cone was 94% in the last follow-up. Kaplan-Meier survival estimates (cone revision as the endpoint) for all implanted cones (n = 35) are shown in Figure 5.

The complication rate was 20% (n = 7) and the reoperation rate was 8.5% (n = 3). During surgery, two patients presented an incomplete periprosthetic femur fracture (treated conservatively with bone consolidation during follow-up) (Figure 6). Four postoperative complications were recorded: a case of stiffness, an extensor mechanism dislocation (treated non-surgically), a pulmonary thromboembolism, an early infection, and the aforementioned aseptic loosening. The patient with postoperative stiffness was successfully treated by mobilization under anesthesia.

Regarding the clinical evaluation, the average KSS increased from 39 before surgery to 71 at the last follow-up. The average score on the visual analog scale was 8 in the preoperative period and 2.5 in the last follow-up.

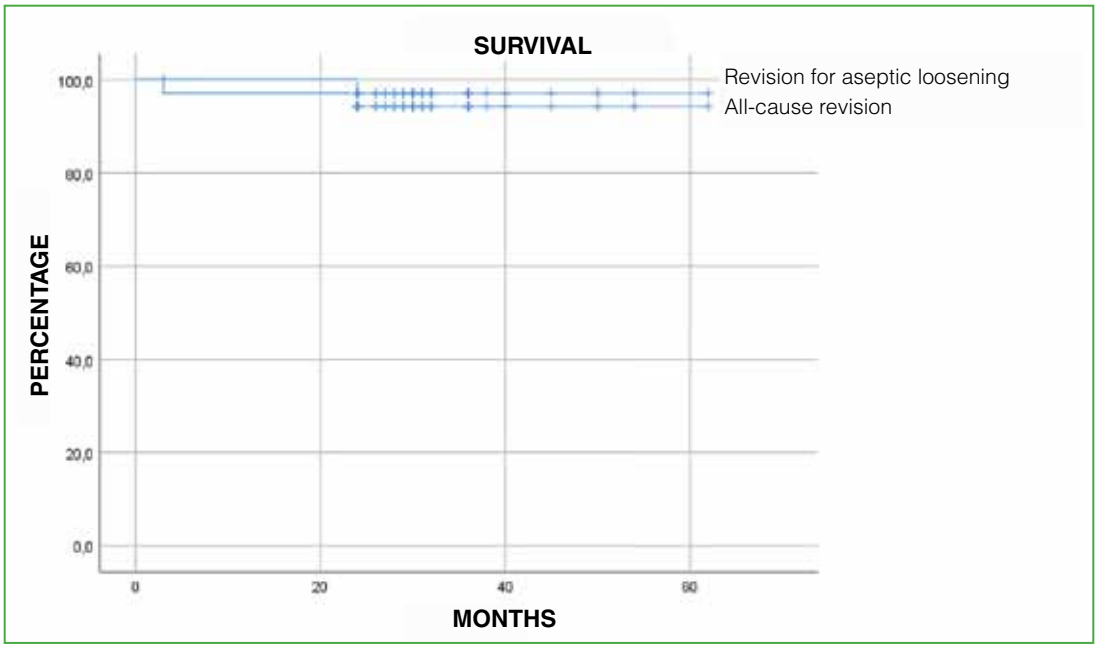

Figure 5. Kaplan-Meier survival curve. Survival rates of 97% and 94% of trabecular metal cones taking as cut-off point revisions for aseptic loosening and all-cause revisions, respectively.

Figure 6. Immediate postoperative anteroposterior (**A**) and lateral (**B**) knee radiographs. A fracture is observed at the level of the medial cortex of the femur (white arrow). **C and D.** Control radiographs one year after surgery. Fracture consolidation.

DISCUSSION

The effective treatment of bone defects is essential to guarantee the metaphyseal stability of the implant in cases of total knee arthroplasty revision.[4,22] As already mentioned, the therapeutic alternatives for severe bone defects (AORI 2b and 3) are ground impaction grafting, structural allograft, metaphyseal sleeves, and trabecular metal cones. These techniques are designed to reconstruct the damaged femoral or tibial metaphysis and create a stable platform for implant fixation.[2,3,23] The impacted morcellized bone graft converts the smooth and sclerotic femoral or tibial bone into a suitable surface for interdigitation of the cement and fixation of the stem. This is beneficial in young patients, as it is possible to restore bone stock. However, peripheral cortical defects are more difficult to treat with this technique, because a metal mesh is required to contain the graft.[24,25] Structural allografts can replace both central and peripheral deficient bone segments without the need for an additional metal mesh. In the long term, the structural allograft may resorb, fracture, become infected or fail to consolidate.[6,26] The increased failure rate of this type of reconstruction stimulated the development of highly porous trabecular metal cones that function as an alternative to structural allografts. These devices achieve solid initial metaphyseal fixation and eventual biological fixation without the risk of graft resorption or fracture.[9,10,12,13] Finally, the metaphyseal sleeves have a stepped shape and are coated with titanium beads to produce a porous surface for bone growth. The host bone is prepared with a wick and the sleeve is attached to the femoral or tibial component through a Morse taper.

Our series confirms the results already published: at 32 months of average follow-up (range 24-62), the osseointegration rate is 94%, with only one case of mechanical failure. Medium-term publications report all-cause revision rates of 8-15%[15,21] and revision rates for reinfection of 5-19%.[13] In our series, the all-cause revision rate was 6% (n = 2) and the reinfection revision rate was 3% (n = 1). In 2016, Potter et al.[19] published a series of 159 femoral tantalum cones in 157 patients and a survival rate of 70% at 5 years (includes all revision causes). 23 cones underwent a revision, 14 for infection, six for aseptic loosening (all in hinged prostheses with type 3 femur defects), and three for ligament instability. Similarly, in our series, aseptic loosening also occurred in a case of AORI type 3 defect located in the femur treated with a rotating-hinge prosthesis.

Being a salvage surgery in complex patients with multiple previous surgeries, complications are not uncommon. In a series of 63 patients treated with tibial cones (2A, 2B, and 3 defects) with a minimum follow-up of 5 years, Kamath et al.[21] reported a complication rate of 27% (both septic and aseptic). For their part, Brown et al.[14] had a very high complication rate: 45% in their series of 83 patients. The most frequent were deep infection (11, 13%) and stiffness (17, 20%). In our series, the complication rate was 20% (n = 7): one case of early postoperative infection, one aseptic loosening, two intraoperative fractures, one pulmonary thromboembolism, one case of stiffness, and one extensor mechanism dislocation.

Our study has the inherent limitations of retrospective studies, the effects of which are mitigated by prospective data collection. The number of patients could be considered low; however, the number included in the published series ranges from 9[27] to 157 in the larger series presented by the Mayo Clinic.[19] Follow-up is short due to the recent incorporation of these implants in our setting, a greater follow-up of our population will provide additional information. Furthermore, this series includes both patients with septic and aseptic loosening, various types of implants, and even patients with extensor mechanism reconstructions. This heterogeneity could make the interpretation of the outcomes difficult.

The excellent osseointegration rate (94%), added to the good clinical outcomes, position the trabecular metal cones as an alternative in the treatment of severe metaphyseal bone defects. Long-term analyses and a comparison with other reconstruction options are required to determine whether this method of reconstruction will provide superior long-term clinical success.

Conflict of interests: The authors declare they do not have any conflict of interests.

J. Costantini ORCID ID: https://orcid.org/0000-0001-8900-6254
T. Nicolino ORCID ID: https://orcid.org/0000-0002-9550-3713
J. Astoul Bonorino ORCID ID: https://orcid.org/0000-0001-6798-8242
L. Carbó ORCID ID: https://orcid.org/0000-0002-8053-0890

REFERENCES

1. Engh GA, Ammeen DJ. Classification and preoperative radiographic evaluation: knee. *Orthop Clin North Am* 1998;29(2):205-17. https://doi.org/10.1016/S0030-5898(05)70319-9
2. Lei P, Hu R, Hu Y. Bone defects in revision total knee arthroplasty and management: bone defects in revision TKA. *Orthop Surg* 2019;11(1):15-24. https://doi.org/10.1111/os.12425
3. Sculco PK, Abdel MP, Hanssen AD, Lewallen DG. The management of bone loss in revision total knee arthroplasty: rebuild, reinforce, and augment. *Bone Joint J* 2016;98-B(1_Supple_A):120-4. https://doi.org/10.1302/0301-620X.98B1.36345
4. Haidukewych GJ, Hanssen A, Dickey Jones R. Metaphyseal fixation in revision total knee arthroplasty: indications and techniques: *Am Acad Orthop Surg* 2011;19(6):311-8. https://doi.org/10.5435/00124635-201106000-00001
5. Ayerza M, Yacuzzi C, Costa Paz M, Aponte Tinao L, Makino A, Múscolo DL. Cirugía de revisión protésica en pacientes con defectos óseos masivos de la rodilla. *Rev Artrosc* 2007;14(1):34-9. Available at: https://www.revistaartroscopia.com/ediciones-anteriores/2007/volumen-14-numero-1/35-volumen-05-numero-1/volumen-14-numero-1/618-cirugia-de-revision-protesica-en-pacientes-con-defectos-oseos-masivos-de-la-rodilla
6. Bauman RD, Lewallen DG, Hanssen AD. Limitations of structural allograft in revision total knee arthroplasty. *Clin Orthop* 2009;467(3):818-24. https://doi.org/10.1007/s11999-008-0679-4
7. Meneghini RM, Lewallen DG, Hanssen AD. Use of porous tantalum metaphyseal cones for severe tibial bone loss during revision total knee replacement: *J Bone Joint Surg Am* 2009;91(Suppl 2):131-8. https://doi.org/10.2106/JBJS.H.01061
8. Boureau F, Putman S, Arnould A, Dereudre G, Migaud H, Pasquier G. Tantalum cones and bone defects in revision total knee arthroplasty. *Orthop Traumatol Surg Res* 2015;101(2):251-5. https://doi.org/10.1016/j.otsr.2014.11.020
9. Divano S, Cavagnaro L, Zanirato A, Basso M, Felli L, Formica M. Porous metal cones: gold standard for massive bone loss in complex revision knee arthroplasty? A systematic review of current literature. *Arch Orthop Trauma Surg* 2018;138(6):851-63. https://doi.org/10.1007/s00402-018-2936-7
10. Bonanzinga T, Gehrke T, Zahar A, Zaffagnini S, Marcacci M, Haasper C. Are trabecular metal cones a valid option to treat metaphyseal bone defects in complex primary and revision knee arthroplasty? *Joints* 2018;06(01):058-64. https://doi.org/10.1055/s-0037-1608950
11. Jacquet C, Ros F, Guy S, Parratte S, Ollivier M, Argenson J-N. Trabecular metal cones combined with short cemented stem allow favorable outcomes in aseptic revision total knee arthroplasty. *J Arthroplasty* 2021;36(2):657-63. https://doi.org/10.1016/j.arth.2020.08.058
12. Roach RP, Clair AJ, Behery OA, Thakkar SC, Iorio R, Deshmukh AJ. Aseptic loosening of porous metaphyseal sleeves and tantalum cones in revision total knee arthroplasty: a systematic review. *J Knee Surg* 2020 Feb 19. https://doi.org/10.1055/s-0040-1701434
13. Kim E, Patel N, Chughtai M, Elmallah RDK, Delanois RE, Harwin SF, et al. Tantalum cones in revision total knee arthroplasty. *J Knee Surg* 2016;29(08):621-6. https://doi.org/10.1055/s-0036-1593370
14. Brown NM, Bell JA, Jung EK, Sporer SM, Paprosky WG, Levine BR. The use of trabecular metal cones in complex primary and revision total knee arthroplasty. *J Arthroplasty* 2015;30(9):90-3. https://doi.org/10.1016/j.arth.2015.02.048
15. De Martino I, De Santis V, Sculco PK, D'Apolito R, Assini JB, Gasparini G. Tantalum cones provide durable mid-term fixation in revision TKA. *Clin Orthop Relat Res* 2015;473(10):3176-82. https://doi.org/10.1007/s11999-015-4338-2
16. Abdelaziz H, Jaramillo R, Gehrke T, Ohlmeier M, Citak M. Clinical survivorship of aseptic revision total knee arthroplasty using hinged knees and tantalum cones at minimum 10-year follow-up. *J Arthroplasty* 2019;34(12):3018-22. https://doi.org/10.1016/j.arth.2019.06.057
17. Abdelaziz H, Biewald P, Anastasiadis Z, Haasper C, Gehrke T, Hawi N, et al. Midterm results after tantalum cones in 1-stage knee exchange for periprosthetic joint infection: a single-center study. *J Arthroplasty* 2020;35(4):1084-9. https://doi.org/10.1016/j.arth.2019.11.016
18. Burastero G, Cavagnaro L, Chiarlone F, Alessio-Mazzola M, Carrega G, Felli L. The use of tantalum metaphyseal cones for the management of severe bone defects in septic knee revision. *J Arthroplasty* 2018;33(12):3739-45. https://doi.org/10.1016/j.arth.2018.08.026
19. Potter GD, Abdel MP, Lewallen DG, Hanssen AD. Midterm results of porous tantalum femoral cones in revision total knee arthroplasty: *J Bone Joint Surg* 2016;98(15):1286-91. https://doi.org/10.2106/JBJS.15.00874

20. Girerd D, Parratte S, Lunebourg A, Boureau F, Ollivier M, Pasquier G, et al. Total knee arthroplasty revision with trabecular tantalum cones: Preliminary retrospective study of 51 patients from two centres with a minimal 2-year follow-up. *Orthop Traumatol Surg Res* 2016;102(4):429-33. https://doi.org/10.1016/j.otsr.2016.02.010
21. 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;97(3):216-23. https://doi.org/10.2106/JBJS.N.00540
22. Ponzio DY, Austin MS. Metaphyseal bone loss in revision knee arthroplasty. *Curr Rev Musculoskelet Med* 2015;8(4):361-7. https://doi.org/10.1007/s12178-015-9291-x
23. 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;30(2):249-53. https://doi.org/10.1016/j.arth.2014.09.016
24. Lotke PA, Carolan GF, Puri N. Impaction grafting for bone defects in revision total knee arthroplasty. *Clin Orthop* 2006;446:99-103. https://doi.org/10.1097/01.blo.0000214414.06464.00
25. Hilgen V, Citak M, Vettorazzi E, Haasper C, Day K, Amling M, et al. 10-year results following impaction bone grafting of major bone defects in 29 rotational and hinged knee revision arthroplasties: A follow-up of a previous report. *Acta Orthop* 2013;84(4):387-91. https://doi.org/10.3109/17453674.2013.814012
26. 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. *J Bone Joint Surg Am* 2001;83(3):404-11. https://doi.org/10.2106/00004623-200103000-00013
27. Panni AS, Vasso M, Cerciello S. Modular augmentation in revision total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 2013;21(12):2837-43. https://doi.org/10.1007/s00167-012-2258-1