



Original Research

Modular Knee Arthrodesis as Definitive Treatment for Periprosthetic Infection, Bone Loss, and Failure of the Extensor Mechanism After Total Knee Arthroplasty

Gloria Coden, MD ^{a,*}, Maksym Bartashevskyy, BA ^b, Zachary Berliner, MD ^c,
 Ruijia Niu, MPH ^d, David Freccero, MD ^c, James Bono, MD ^a, Ayesha Abdeen, MD ^c,
 Eric L. Smith, MD ^a

^a Department of Orthopaedic Surgery, New England Baptist Hospital, Boston, MA, USA

^b Boston University Chobanian & Avedisian School of Medicine, Boston, MA, USA

^c Department of Orthopaedic Surgery, Boston Medical Center, Boston, MA, USA

^d Department of Research, New England Baptist Hospital, Boston, MA, USA

ARTICLE INFO

Article history:

Received 10 April 2023

Received in revised form

18 September 2023

Accepted 24 September 2023

Available online xxx

Keywords:

Modular knee arthrodesis

Modular knee fusion

Chronic infection

Extensor mechanism disruption

ABSTRACT

Background: Periprosthetic joint infection (PJI) after total knee arthroplasty (TKA) can result in bone and soft-tissue loss, leg length discrepancies, and dysfunctional extensor mechanisms. While above-knee amputation (AKA) is an established salvage treatment, modular knee arthrodesis (MKA) is a viable option that provides rigid stability and maintains leg length even in patients with severe bone and soft-tissue loss. We sought to report the outcomes of patients with an MKA as the definitive treatment.

Methods: We retrospectively reviewed 8 patients implanted with an MKA at 2 institutions between 2016 and 2022. The mean age was 69.63 years, and 50.0% of patients were women. All patients were indicated for conversion to an MKA as the definitive treatment in the setting of treated chronic PJI after TKA, severe bone loss, and failure of the extensor mechanism not amenable to repair. Medical records and radiographs were reviewed.

Results: No patients required incision and drainage or exchange of their MKA for PJI at mean 2-year follow-up. One patient required 2 revisions for mechanical failure of his implant at 5.0 and 6.4 years postoperatively.

Conclusions: MKA is a viable permanent alternative to AKA for patients with treated chronic PJI and dysfunctional extensor mechanism after TKA. The procedure restores leg lengths in the setting of severe bone and soft-tissue loss, therefore allowing patients to ambulate independently. Still, surgeons should be aware of the potential for mechanical failure requiring revision.

© 2023 The Authors. Published by Elsevier Inc. on behalf of The American Association of Hip and Knee Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Periprosthetic joint infection (PJI) is a devastating complication after total knee arthroplasty (TKA) and can result in severe bone and soft-tissue loss. Functionally, this can result in severe leg-length discrepancies and dysfunctional extensor mechanisms

[1–4]. In the setting of severe bone loss, severe soft-tissue loss, and failed reconstruction of the extensor mechanism, limb salvage vs amputation may be considered [1–3,5–7].

Arthrodesis and above-knee amputation (AKA) are 2 common techniques in this setting [1–3,5–7]. Indications for knee arthrodesis include failed TKA that cannot be revised to an articulated arthroplasty due to persistent infection, bone and/or soft-tissue loss, and/or an unreconstructable extensor mechanism [3,8]. Contraindications to this technique include active infection, malunited femoral and/or tibial canals that would not accept intramedullary fixation, a contralateral knee arthrodesis, and ipsilateral hip arthrodesis [8]. Advantages of intramedullary knee arthrodesis include restoration

Funding: Funding for article processing charge provided by research funds at BMC Orthopedics.

* Corresponding author. Department of Orthopaedic Surgery, New England Baptist Hospital, 125 Parker Hill Ave, Boston, MA 02120, USA. Tel.: +1 914 419 2555.

E-mail address: gscoden@gmail.com

<https://doi.org/10.1016/j.artd.2023.101261>

2352-3441/© 2023 The Authors. Published by Elsevier Inc. on behalf of The American Association of Hip and Knee Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

of limb length and alignment with early postoperative mobilization [6,8]. However, patients should be counseled on the limitations associated with knee arthrodesis, including inability to bend the knee, increased energy required for ambulation, and progression of contralateral knee arthritis [5,9,10].

Conventional arthrodesis can result in severe shortening of the extremity and violation of the hip abduction mechanism, leading to reduced function [1-6]. One alternative is a modular fusion rod in which an intercalary mechanical locking collar is used to achieve rigid stability and maintain length of the extremity [1,2,6]. However, few studies have evaluated the outcomes of definitive treatment with modular knee arthrodesis (MKA); therefore, we seek to report on our experience with this technique.

Material and methods

Patient selection

After obtaining approval from our institutional review board, we retrospectively reviewed 8 patients implanted with an MKA at our institution between 2016 and 2022. All patients had a history of PJI after TKA. All patients underwent at least one incision and drainage, explantation of their TKA, implantation of a static antibiotic cement spacer, and at least 6 weeks of intravenous antibiotics. In all 8 cases, the indication for MKA was recurrent or persistent infection, as diagnosed by a board-certified infectious disease physician. All patients were ineligible for an Achilles tendon allograft or synthetic repair of their extensor mechanism due to the concern of aggravating the chronic infection, poor soft-tissue coverage, and too extensive bone and soft-tissue loss for direct repair of the extensor mechanism (see Fig. 1). All patients were offered AKA as an alternative and counseled on the risks and benefits of MKA. Medical records were reviewed for demographics, complications, and outcomes. Radiographs were reviewed to confirm appropriate placement of the MKA.

Demographics

The mean age was 69.63 years (range 57-77 years). Four of the 8 patients (50.0%) were women. Seven of 8 patients were obese (mean body mass index of 34.47 meters (m)/kg², range 24.96-47.61 kg/m²). Four patients (50.0%) identified as former smokers, but all reported having quit smoking tobacco at least 25 years prior to implantation. Four patients (50.0%) had a history of type 2 diabetes mellitus, and 1 patient (14.3%) had a history of prediabetes. Two patients (25.0%) had an American Society of Anesthesiologists score of II, and 6 patients (75.0%) had an American Society of Anesthesiologists score of III. Patients had a mean of 4.6 knee surgeries (range 2-6 knee surgeries) prior to MKA. The mean follow-up duration was 2 years (range 96 days-6.6 years, see Table 1). Each patient had a unique combination of infectious organisms and were prescribed appropriate antibiotics by a board-certified infectious disease physician (see Table 2).

Implant studied

All patients were implanted with the Zimmer Biomet OSS Modular Knee Arthrodesis System (Warsaw, IN). Three patients had press-fit stems implanted, while 4 additional patients had uncemented stems with cement impacted at the proximal end of the tibial and distal end of the femur to fill bone defects. One patient had a fully cemented tibial stem with a press-fit femoral stem. One- and 3-centimeter (cm) diaphyseal segments can be linked together both proximally and distally to fill defects caused by extensive bone loss. Proximally, 5 patients were implanted with 1-cm diaphyseal



Figure 1. Preoperative imaging. Preoperative radiographs demonstrating extensive bone loss with placement of a static antibiotic cement spacer.

connectors, 1 patient was implanted with a 3-cm diaphyseal connector, and 2 patients required 2 linked 3-cm diaphyseal connectors. Distally, 6 patients were implanted with a 1-cm diaphyseal connector, 1 patient was implanted with a 3-cm diaphyseal connector, and 1 patient required linked 1-cm and 3-cm diaphyseal connectors. Five patients were originally implanted with a 0-degree locking collar, 3 patients were implanted with a 5-degree locking collar, and no patients were implanted with a 7-degree locking

Table 1
Demographics of patients with modular knee arthrodesis.

Demographics	MKA, n = 8
Age (y), mean (range)	69.63 (57-77)
Women, n (%)	4 (50.0%)
BMI (kg/m ²), mean (range)	34.47 meters (24.96-47.61)
Former smoker, n (%)	4 (50.0%)
Type II diabetes mellitus, n (%)	4 (50.0%)
ASA score, n (%)	
II	2 (25.0%)
III	6 (75.0%)
Knee Surgeries prior to MKA, mean (range)	4.6 (2-6)
Follow-up (y), mean (range)	2 (0.3-6.6)

BMI, body mass index; kg, kilograms; m, meter; ASA, American Society of Anesthesiologists; MKA, modular knee arthrodesis.

Table 2
Infectious organism per patient.

Patient	Infectious organism 1	Infectious organism 2	Infectious organism 3
1	Methicillin-sensitive <i>Staphylococcus aureus</i>	<i>Enterococcus faecalis</i>	<i>Morganella morganii</i>
2	Methicillin-sensitive <i>Staphylococcus aureus</i>	<i>Cutibacterium acnes</i>	"Mold", unable to obtain further information from outside hospital
3	Methicillin-resistant <i>Staphylococcus aureus</i>	<i>Corynebacterium striatum</i>	
4	Methicillin-resistant <i>Staphylococcus aureus</i>		
5	Coagulase-negative <i>Staphylococcus</i>		
6	Alpha-hemolytic Streptococcus	<i>Klebsiella pneumoniae</i>	
7	Unable to obtain fluid from aspiration, but patient with positive indium white blood cell scan		
8	Unable to obtain records of organism cultured from outside hospital		

collar, as indicated to correct preoperative varus or valgus deformity.

The postoperative protocol for all patients was weight-bearing as tolerated beginning from postoperative day 1. All patients were prescribed routine venous thromboembolism prophylaxis, based on comorbidities. Chronic antibiotic suppression and monitoring were infection-specific and as prescribed by a board-certified infectious disease physician.

Results

All patients underwent successful implantation of the MKA. One patient had 2 cerclage wires placed intraoperatively to repair the femoral metaphyseal epistomy required to remove the antibiotic cement spacer. One patient sustained a distal tibial canal fracture during implantation, which healed uneventfully. Intraoperative cultures and pathology were negative for infection in 7 of the 8 patients (87.5%). In 1 patient, intraoperative cultures grew bacillus species, which was successfully treated with a course of intravenous vancomycin and did not require revision (see Table 3). All patients successfully ambulated with physical therapy on postoperative day 1.

One patient developed a draining sinus tract and superficial infection 45 days after implantation of the MKA in the setting of obesity and poorly controlled diabetes. She was treated with a superficial irrigation, debridement, and placement of antibiotic cement after confirmation that the origin of the draining sinus tract was the superficial soft tissue without extension into the joint capsule. The modular fusion rod remained in place, and intraoperative cultures had no growth (see Fig. 2). The patient developed an additional draining sinus tract over the superficial antibiotic cement 74 days later, which grew enterococcus faecalis. She was treated with removal of the superficial antibiotic cement only and chronic antibiotic suppression, without revision of the MKA (see Fig. 3). One particularly active 69-year-old male patient required 2 revisions for mechanical failure of the implant: one at 5 years postoperatively for failure of the locking bolts and collar (see

Table 3
Outcomes of patients with modular knee arthrodesis.

Outcomes	MKA, n = 8
Complications, n (%)	4 (50.0%)
Infection	2 (25.0%)
Nondisplaced distal tibial canal fracture	1 (12.5%)
Mechanical failure	1 (12.5%)
Reoperations, n (%)	2 (25.0%)
Superficial irrigation and debridement	1 (12.5%)
Mechanical failure	1 (12.5%)
Ambulation at the most recent follow-up, n (%)	
Unassisted	1 (12.5%)
Cane/Crutches	4 (50.0%)
Walker	3 (37.5%)

MKA, modular knee arthrodesis.

Fig. 4), and a second 1.4 years later for failure of the 1-cm proximal diaphyseal connector (see Fig. 5). In both revisions, intraoperative cultures did not grow any organisms. Prior to failure of his implants, he reported walking 1 mile per day.

At the time of the most recent follow-up, all patients maintained a well-fixed and well-aligned MKA, and none required exchange of components for PJI. One patient walks unassisted daily, 4 patients ambulate with a cane or crutches, and 3 continue to ambulate with a walker (see Table 3). However, 1 patient ambulates with a walker due to a recent revision of the contralateral TKA. Two of the 8 patients reported using a shoe lift on the operative side due to persistent leg length discrepancy. All patients report being satisfied with their outcome, and no patient has elected to proceed with AKA.

Discussion

Multiple studies have shown that knee arthrodesis is a viable alternative to AKA as treatment for PJI in knees that are not suitable for TKA [1,2,5,6]. In addition, MKA allows for significantly earlier ambulation than AKA, which often has a prolonged period of nonambulation while patients await prosthesis. While MKA is meant to be a permanent solution, it is not without its complications including progression of contralateral knee arthritis, recurrent infection, and periprosthetic fracture [1,6,9-11]. Faure et al. reported no instances of mechanical failure and 26% revision rate for

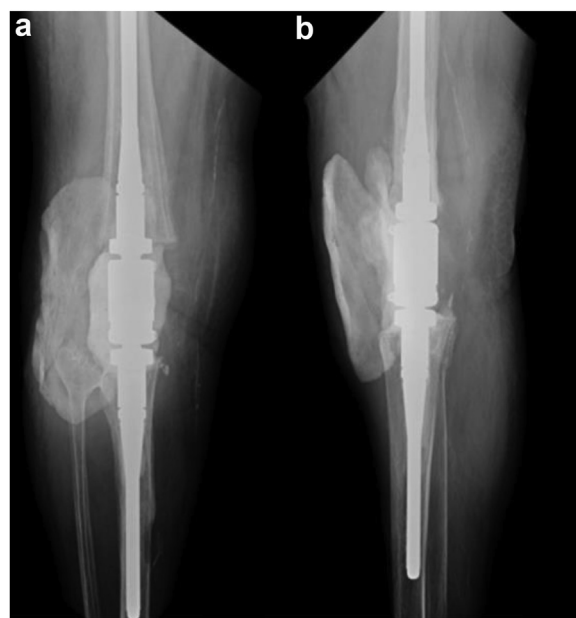


Figure 2. First reoperation for a patient with superficial infection. Postoperative radiographs after superficial irrigation, debridement, and placement of antibiotic cement with retainment of the modular knee arthrodesis (MKA).

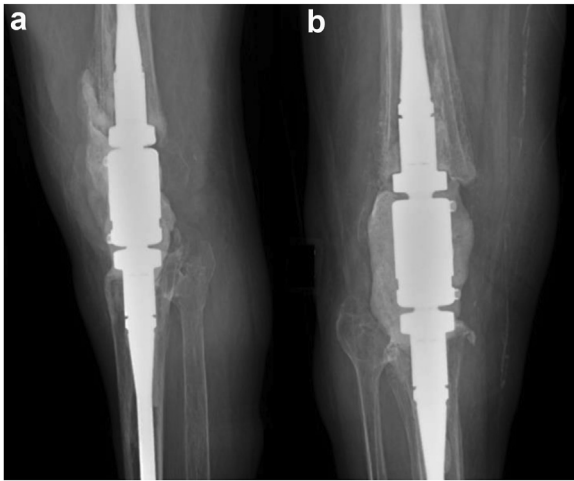


Figure 3. Second reoperation for a patient with superficial infection. Postoperative radiographs after removal of superficial antibiotic cement with retention of the modular knee arthrodesis (MKA).

infection in 31 patients with a median follow-up duration of 13.1 years [2]. One revision also sustained a fracture between the arthrodesis and the intramedullary locking nail that went on to form a septic nonunion [2]. Stavarakis et al. reported on 81 patients treated with the MKA system described earlier and did not have a case of mechanical failure [6]. However, 82% of patients went on to further endoprosthetic reconstruction, and the MKA was implanted for a mean of 220 days without long-term outcomes [6].

Mechanical failure of the modular component of the arthrodesis appears to be rare with this arthrodesis system. Mayes et al. described 1 case report of a patient who presented for revision of a loose tibial component of this knee arthrodesis system [12]. The knee arthrodesis was originally implanted at an outside hospital [12]. The patient underwent revision to a cemented tibial stem but had a fracture at the transition point of the modular component at 14 months postoperatively [12]. Other complications included 1 patient who underwent revision for septic loosening at 4 years



Figure 4. First reoperation for a patient with mechanical failure. Radiographs showing loosening of the locking collar (a) and backing out of the peripheral locking screws (b) 5 years after implantation.



Figure 5. Second reoperation for a patient with mechanical failure. Sagittal views of a computed tomography scan showing significant angulation of the modular knee arthrodesis (a) due to fracture of the proximal diaphyseal connector (b) 6.5 years after implantation.

postoperatively and 1 patient who chose to undergo AKA due to unhappiness with MKA [12].

We identified 2 other MKA systems with published findings. Unlike the system used in our study, these studies do not allow for lengthwise modularity between the femoral and tibial stems in order to restore a patient's leg length. One system is the Link Endo-Model Knee Fusion Nail (Waldemar Link, GmbH & Co. KG, Hamburg, Germany). Putman et al. reported that out of 31 patients implanted with the Link Endo-Model Knee Fusion Nail and a mean follow-up of 50 months, 3 patients required revision for draining sinus tracts 14-18 months after implantation [13]. Rao et al. reported 39.6-month mean follow-up in 7 patients implanted with the Link Endo-Model Knee Fusion Nail [14]. Complications included 1 patient who required revision for fracture of the cement mantle at 50 months postoperatively and 1 patient who was revised for recurrent infection complicated by a midshaft femoral insufficiency fracture [14]. Letartre et al. reported that in a series of 20 patients with maximum follow-up of 48 months, there was a 26% complication rate including 1 intraoperative canal fracture that successfully healed, 2 cases of delayed wound healing requiring medial gastrocnemius flap reconstruction, and 1 case of loosening of the femoral and tibial nail requiring revision [15]. Iacono et al. reported 1 case of intraoperative canal fracture and 3 instances of recurrent infection, 2 of which required AKA in 21 patients with a mean follow-up duration of 34.4 months [11]. In addition, they reported that 19 of 21 patients were ambulatory with the Link Endo-Model Knee Fusion Nail [11]. No study reported revision for mechanical failure of the implant [11,13-15].

Studies have also been published about another modular arthrodesis system (Peter Brehm GmbH, Weisendorf, Germany). Gathen et al. reported 4 cases of reinfection in 36 patients with a mean follow-up duration of 34.6 months [16]. Friedrich et al. studied 37 patients who underwent implantation with this modular arthrodesis system [1]. Five patients had a recurrent infection: One was treated with AKA, 1 died due to causes unrelated to the MKA, and 3 patients were managed with chronic fistula after refusing AKA [1]. In addition, 1 patient was successfully treated with 2-stage revision and implantation of MKA for recurrent infection [1]. Two patients also required revision for aseptic

loosening of the femoral stem at 16 and 24 months postoperatively [1]. Hungerer et al. reported 3 patients died postoperatively due to infection out of 81 patients implanted with this modular arthrodesis system [17]. Of the 55 patients with a mean 53-month follow-up, they reported 8 cases of aseptic loosening, 4 periprosthetic fractures, 1 implant failure, and 12 cases of infection, 6 of which required AKA [17]. Only 1 patient in our study had positive intra-operative cultures, although he did not require revision for infection.

Limitations include a small sample size. However, MKA is rarely indicated as most patients resolve their infections and undergo reconstruction of the extensor mechanism. In addition, some patients had additional unrelated medical problems, such as complications to the contralateral leg, that hindered their ambulatory status unrelated to MKA.

Conclusions

MKA is viable alternative to AKA in knees not amenable to revision TKA. MKA allows for retainment of the patient's extremity and early postoperative ambulation. While the modular component of these systems allows for better restoration of the patient's leg length, especially in the setting of significant bone loss, modularity risks multiple points for possible failure, especially in active patients. Therefore, surgeons should be aware of the potential for late mechanical failure of the MKA.

Conflicts of interest

J. Bono receives royalties from Stryker and Springer and is a paid consultant for Stryker. E. L. Smith is in the speakers bureau of/gave paid presentations for Pacira, is a paid consultant for Conformis and DePuy, A Johnson & Johnson Company, has stock or stock options in Conformis, receives research support from a company or supplier as a principal investigator 3M, Conformis, DePuy, A Johnson & Johnson Company, and is a board member/makes committee appointments for AAOS and AAHKS. D. Freccero receives research support from a company or supplier as a principal investigator DePuy, A Johnson & Johnson Company, has stock or stock options in ROMTech, and is a board member/makes committee appointments for AAOS and AAHKS. G. Coden is in the editorial or governing board of the *Journal of Orthopaedic Experience & Innovation*. A. Abdeen is a paid employee for Advance medical, has stock or stock options in Brixton biosciences, is in the editorial board of the *Journal of Arthroplasty*, and is a committee member at Education and Exams committee and AAHKS Quality Committee. Maksym Bartashevsky, Zachary Berliner, and Ruijia Niu have no conflicts to disclose.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2023.101261>.

References

- [1] Friedrich MJ, Schmolders J, Wimmer MD, Strauss AC, Ploeger MM, Wirtz DC, et al. Two-stage knee arthrodesis with a modular intramedullary nail due to septic failure of revision total knee arthroplasty with extensor mechanism deficiency. *Knee* 2017;24:1240–6. <https://doi.org/10.1016/j.knee.2017.05.019>.
- [2] Faure PA, Putman S, Senneville E, Beltrand E, Behal H, Migaud H. Knee arthrodesis using a custom modular intramedullary nail in failed, infected knee arthroplasties: a concise follow-up note of 31 cases at a median of 13 years post-arthrodesis. *Orthop Traumatol Surg Res* 2012;107:102898. <https://doi.org/10.1016/j.otsr.2021.102898>.
- [3] Langfitt MK, Bono OJ, Wardell SR, Bono JV. *Salvage knee surgery: arthrodesis*. In: Bono J, Scott R, editors. *Revision total knee arthroplasty*. Cham: Springer; 2018. p. 401–14.
- [4] Bono JV, Sherman P, Windsor R, Laskin R, Sculco T, Figgie M, et al. Intramedullary arthrodesis after failed septic total knee arthroplasty. *Tech Knee Surg* 2009;8:216–24.
- [5] Chen AF, Kinback NC, Heyl AE, McClain EJ, Klatt BA. Better function for fusions versus above-the-knee amputations for recurrent periprosthetic knee infection. *Clin Orthop Relat Res* 2012;470:2737–45. <https://doi.org/10.1007/s11999-012-2322-7>.
- [6] Stavrakis AI, Mayer EN, Devana SK, Chowdhry M, Dipane MV, McPherson EJ. Outcomes of modular knee arthrodesis for challenging periprosthetic joint infections. *Arthroplast Today* 2022;13:199–204. <https://doi.org/10.1016/j.artd.2021.10.015>.
- [7] Windsor RE, Bono JV. Infected total knee replacements. *J Am Acad Orthop Surg* 1994;2:44–53. <https://doi.org/10.5435/00124635-199401000-00006>.
- [8] MacDonald JH, Agarwal S, Lorei MP, Johanson NA, Freiberg AA. Knee Arthrodesis. *J Am Acad Orthop Surg* 2006;14:154–63. <https://doi.org/10.5435/00124635-200603000-00006>.
- [9] Bono JV, Talmo CT, Windsor R. Arthrodesis of the knee: indications and treatment options. *Tech Knee Surg* 2009;8:212–5.
- [10] Bono OJ, Economedes DM, Bono JV. Knee arthrodesis: the fate of the contra lateral knee. *Nov Tech Arthritis Bone Res* 2018;3:555604. <https://doi.org/10.19080/NTAB.2018.03.555604>.
- [11] Iacono F, Bruni D, Lo Presti M, Raspugli G, Bondi A, Sharma B, et al. Knee arthrodesis with a press-fit modular intramedullary nail without bone-on-bone fusion after an infected revision TKA. *Knee* 2012;19:555–9. <https://doi.org/10.1016/j.knee.2012.01.005>.
- [12] Mayes WH, Severin AC, Mannen EM, Edwards PK, Barnes CL, Stambough JB, et al. Management of periprosthetic joint infection and extensor mechanism disruption with modular knee fusion: clinical and biomechanical outcomes. *Arthroplast Today* 2021;8:46–52. <https://doi.org/10.1016/j.artd.2020.12.008>.
- [13] Putman S, Kern G, Senneville E, Beltrand E, Migaud H. Knee arthrodesis using a customised modular intramedullary nail in failed infected total knee arthroplasty. *Orthop Traumatol Surg Res* 2013;99:391–8. <https://doi.org/10.1016/j.otsr.2012.10.016>.
- [14] Rao MC, Richards O, Meyer C, Jones RS. Knee stabilisation following infected knee arthroplasty with bone loss and extensor mechanism impairment using a modular cemented nail. *Knee* 2009;16:489–93. <https://doi.org/10.1016/j.knee.2009.03.001>.
- [15] Letartre R, Combes A, Autissier G, Bonneville N, Gougeon F. Knee arthrodesis using a modular customized intramedullary nail. *Orthop Traumatol Surg Res* 2009;95:520–8. <https://doi.org/10.1016/j.otsr.2009.07.006>.
- [16] Gathen M, Wimmer MD, Ploeger MM, Weinhold L, Schmid M, Wirtz DC, et al. Comparison of two-stage revision arthroplasty and intramedullary arthrodesis in patients with failed infected knee arthroplasty. *Arch Orthop Trauma Surg* 2018;138:1443–52. <https://doi.org/10.1007/s00402-018-3007-9>.
- [17] Hungerer S, Kiechle M, von Rüden C, Militz M, Beitzel K, Morgenstern M. Knee arthrodesis versus above-the-knee amputation after septic failure of revision total knee arthroplasty: comparison of functional outcome and complication rates. *BMC Musculoskelet Disord* 2017;18:443. <https://doi.org/10.1186/s12891-017-1806-8>.