# Preservation of Fixed Cementless Femoral Stems in Patients with Chronic Periprosthetic Hip Infection

**Walter F. Martínez,[*] Fernando Tillet,[**] Eduardo J. Bochatey,[#] Fernando A. Lopreite[##]**
[*]*Clinica Privada Hispano Argentina, Tres Arroyos, Buenos Aires, Argentina; Grupo GRECARO*
[**]*Instituto Argentino de Diagnóstico y Tratamiento, Autonomous City of Buenos Aires, Argentina; Grupo GRECARO*
[#]*Instituto de Tratamiento y Rehabilitación Articular, Autonomous City of Buenos Aires, Argentina; Grupo GRECARO*
[##]*Orthopedics and Traumatology Service, Hospital Británico de Buenos Aires, Autonomous City of Buenos Aires, Argentina; Grupo GRECARO*

## ABSTRACT

**Introduction:** Two-stage revision is considered the gold standard for the treatment of chronically infected hip arthroplasty. However, during the removal of a fixed cementless femoral stem, the proximal femur can be damaged, which can lead to difficulties in reimplantation. **Objective:** We intend to determine if chronic periprosthetic hip infection can be treated with a partial exchange of its components, in two stages, keeping a fixed cementless femoral stem. **Materials and Methods:** This retrospective, multicenter case series study included 9 patients with chronic infection following hip arthroplasty, scheduled for single- or two-stage partial exchange with retention of the fixed femoral stem between January 2014 and November 2019. We assessed the patients' progress through clinical examination, Harris Hip Score evaluation, and laboratory and radiological studies. **Results:** In a mean follow-up of 5.8 years in 9 patients with cementless hip arthroplasty, 8 patients achieved infection remission (88.9%) after prosthetic reimplantation, and the mean Harris Hip Score reached 81 points at the last follow-up evaluation. There was no loosening of acetabular or femoral components. **Conclusions:** Uncemented femoral stem retention may represent an acceptable option for patients with chronic periprosthetic hip infection when removal of the femoral component would result in significant bone loss and compromise of the reconstruction. However, more studies are required on this treatment.
**Keywords:** Partial review; chronic periprosthetic infection.
**Level of Evidence:** IV

## Conservación de tallos femorales no cementados fijos en pacientes con infección periprotésica crónica de cadera

## RESUMEN

**Introducción:** La revisión en dos tiempos se considera el método de referencia para tratar a pacientes con artroplastia de cadera e infección crónica. Sin embargo, durante el retiro de un vástago femoral no cementado fijo, se puede dañar el fémur proximal, lo que puede plantear dificultades en el reimplante. **Objetivo:** Determinar si la infección periprotésica crónica de cadera se puede tratar con un intercambio parcial de sus componentes, conservando un vástago femoral no cementado fijo. **Materiales y Métodos:** Estudio de serie de casos retrospectivo, multicéntrico que incluyó a 9 pacientes con artroplastia de cadera e infección crónica, programados para el recambio parcial en uno o dos tiempos con retención del tallo femoral fijo, entre enero de 2014 y noviembre de 2019. Se evaluó la evolución mediante el examen clínico, el puntaje de cadera de Harris, y estudios de laboratorio y radiológicos. **Resultados:** En un seguimiento medio de 5.8 años de 9 pacientes con artroplastia de cadera no cementada, después del reimplante de la prótesis, la infección remitió en 8 pacientes (88,9%), y el puntaje medio de cadera de Harris fue de 81 en el último control. No hubo aflojamiento de componentes acetabulares ni femorales. **Conclusiones:** La conservación de vástagos femorales no cementados puede representar una opción aceptable para los pacientes con infección periprotésica crónica de cadera cuando la extracción del componente femoral daría como resultado una pérdida significativa de hueso y un compromiso de la reconstrucción. Sin embargo, se requieren más estudios sobre esta técnica.
**Palabras clave:** Revisión parcial; infección periprotésica crónica.
**Nivel de Evidencia:** IV

Received on June 18th, 2023. Accepted after evaluation on July 18th, 2023 • Dr. WALTER F. MARTÍNEZ • wfm5252@gmail.com https://orcid.org/0009-0004-7249-1563
**How to cite this article:** Martínez WF, Tillet F, Bochatey EJ, Lopreite FA. Preservation of Fixed Cementless Femoral Stems in Patients with Chronic Periprosthetic Hip Infection. *Rev Asoc Argent Ortop Traumatol* 2023;88(5):539-547. https://doi.org/10.15417/issn.1852-7434.2023.88.5.1777

## INTRODUCTION

Periprosthetic joint infection (PJI) of the hip is a devastating complication. It represents a diagnostic and therapeutic challenge for physicians. Approximately 0.5-3% of patients with a primary arthroplasty and 4-6% of those undergoing a revision procedure suffer a deep infection.[1] In our country, according to the VIHDA 2021 program, the rate of hip PJI ranges from 1.88% to 8.64%.[2]

Chronic PJI occurs at a variable time after surgery. Tsukuyama establishes it four weeks after the initial procedure, although there is no internationally agreed definition of chronic PJI.[3-5] It is a type of infection with a mature and stable biofilm.

Several therapeutic modalities have been described to manage the difficult problem of chronic PJI after primary hip arthroplasty. The gold standard procedure is two-stage revision surgery.[6-8] Some authors have advised removing all components to eradicate infection if it occurs more than three weeks after primary surgery.[9]

In recent years, acetabular extraction instrumentation has been refined to the point where these fixed components can be separated efficiently with minimal bone loss.[10,11] However, the removal of the femoral component remains difficult and complicated. An extended trochanteric osteotomy or a cortical window is usually necessary to remove a fixed femoral stem. This may result in unexpected femoral perforation or fracture during surgery, and increase blood loss and surgical time.[12]

The aim of this article is to present a retrospective series of patients with chronic hip PJI in whom it was decided to retain the fixed cementless femoral component because it was considered that removal could generate significant bone loss that would compromise subsequent reimplantation.

Under these circumstances, the hypothesis put forward was that some chronic PJIs could be treated successfully without removing the osseointegrated cementless femoral component in selected patients.

## MATERIALS AND METHODS

A multicenter, retrospective, case series study was performed. Between January 2014 and November 2019, nine patients with a diagnosis of chronic hip PJI underwent a single- or two-stage partial revision.

PJI was diagnosed according to the criteria established by the *Musculoskeletal Infection Society*[13] and the guidelines provided by the *International Consensus Meeting on Periprosthetic Joint Infection* (ICM).[14,15]

The inclusion criteria were: 1) patients who had undergone a single- or two-stage partial revision for a diagnosis of chronic PJI according to the Tsukuyama classification, 2) a microorganism isolated in the joint puncture fluid prior to surgery, 3) fixed femoral prosthetic components, as assessed radiographically and intraoperatively, whose removal could result in severe bone loss and compromise future fixation efforts.

Patients with a PJI of <4 weeks' evolution, immune compromise and without an identified microorganism at the time of surgery were excluded.

Prosthesis fixation was evaluated by anteroposterior and lateral hip radiographs. The acetabular cup was considered loose when migration was >2 mm, if there was a change in abduction >4° or demarcation lines in the DeLee-Charnley zones.[16]

## RESULTS

The mean age of the patients was 72.3 years (range 64-81). The mean body mass index was 29.1 kg/m$^2$ (range 26.2 -35.9). Four patients were female and five were male. Surgical procedures prior to infection had been primary cementless hip arthroplasty (3 cases) and aseptic revisions (6 cases). All but one of the included patients had at least one comorbidity (Table 1).

The microorganisms isolated in the fluid from the joint puncture performed prior to surgery are detailed in Table 2. Synovial fluid samples were sent to the laboratory in blood culture bottles and cultured for aerobic and anaerobic bacteria for 14 days. PJI was always diagnosed on the basis of the major ICM criteria, two cultures were positive with phenotypically identical germs.

Preoperative serum levels of erythrocyte sedimentation rate and C-reactive protein were high in all cases (Table 1).

**Table 1.** Characteristics of the patients with chronic late periprosthetic joint infection

| Variable | Value |
|---|---|
| Age, average (years) | 72.3 (range 64-81) |
| Sex, male/female | 5/4 |
| Average body mass index (kg/m$^2$) | 29.1 (range 26.2-35.9) |
| Arterial hypertension | 7 |
| Diabetes | 2 |
| Smoking | 3 |
| Obesity | 3 |
| Preoperative C-reactive protein, average (mg/l) | 19 (12-24) |
| Preoperative erythrocyte sedimentation rate, average (mm/1 h) | 62 (48-93) |
| Duration of symptoms before revision, average (months) | 3 (2-5) |
| Duration of follow-up, average (years) | 5.8 (3-8) |

**Table 2.** Microorganisms identified

| Microorganism identified | Number of patients |
|---|---|
| *Serratia marcescens* | 1 |
| Methicillin-sensitive *Staphylococcus aureus* | 3 |
| Methicillin-sensitive coagulase-negative *Staphylococcus* | 3 *(S. epidermidis, S. haemolyticus, S. caprae)* |
| Methicillin-resistant *Staphylococcus aureus* | 1 |
| *Cutibacterium acnes* | 1 |

Three patients had demarcation in DeLee-Charnley zones 2 and 3, while the rest had radiolucent lines in all three zones and cup migration. The femoral stem was uncemented in all cases. Radiographs showed no radiolucency lines, osteolysis or remodeling in Gruen zones 1-7.[17] All surgeries were performed through a posterolateral approach. Fixation was verified during surgery by attempting to move the implant in the anteroposterior and mediolateral directions, and rotating it clockwise and counterclockwise, and then attempting to remove the stem using an extractor. There were no visible gaps at the bone-implant interface, wear damage to the implant, frictional corrosion around the femoral cone, or movement of the prosthesis.

During the revision surgery, aggressive debridement and removal of any loose or necrotic tissue was performed. To remove the acetabular components, specific chisels were used and the exposed femoral stem was thoroughly brushed. The femoral head was always replaced (Figure 1).

**Figure 1.** Acetabular cup removal and femoral head replacement.

After the acetabular component was removed, an extensive pulsatile lavage with saline was conducted. The proximal portion of the preserved femoral component was brushed. In two patients, the revision was completed in one surgical procedure, whereas the remaining patients required two (Table 3).

**Table 3.** Description of removed and exchanged components and surgical stages

| Patient | Retained component | Extracted component | Interchanged modular elements | Surgical stages |
|---|---|---|---|---|
| 1 | Uncemented femoral stem with distal fixation | Cementless acetabular cup | Femoral head | 2 |
| 2 | Uncemented femoral stem with distal fixation | Cementless acetabular cup | Femoral head | 2 |
| 3 | Uncemented femoral stem for metaphyseal fixation | Cementless acetabular cup | Femoral head | 2 |
| 4 | Uncemented femoral stem for metaphyseal fixation | Cementless acetabular cup | Femoral head | 2 |
| 5 | Uncemented femoral stem with distal fixation | Cemented acetabular cup | Femoral head | 2 |
| 6 | Uncemented femoral stem for metaphyseal fixation | Cemented acetabular cup | Femoral head | 2 |
| 7 | Uncemented femoral stem with distal fixation | Cementless acetabular cup | Femoral head | 2 |
| 8 | Uncemented femoral stem with distal fixation | Cementless acetabular cup | Femoral head and proximal module | 1 |
| 9 | Uncemented femoral stem with distal fixation | Cementless acetabular cup | Femoral head and proximal module | 1 |

Cemented acetabular components (including cancellous allograft and ilioischial ring) were implanted in the two patients who underwent revision in a single procedure (Figure 2). These two patients had multiple comorbidities and did not accept a two-stage procedure.

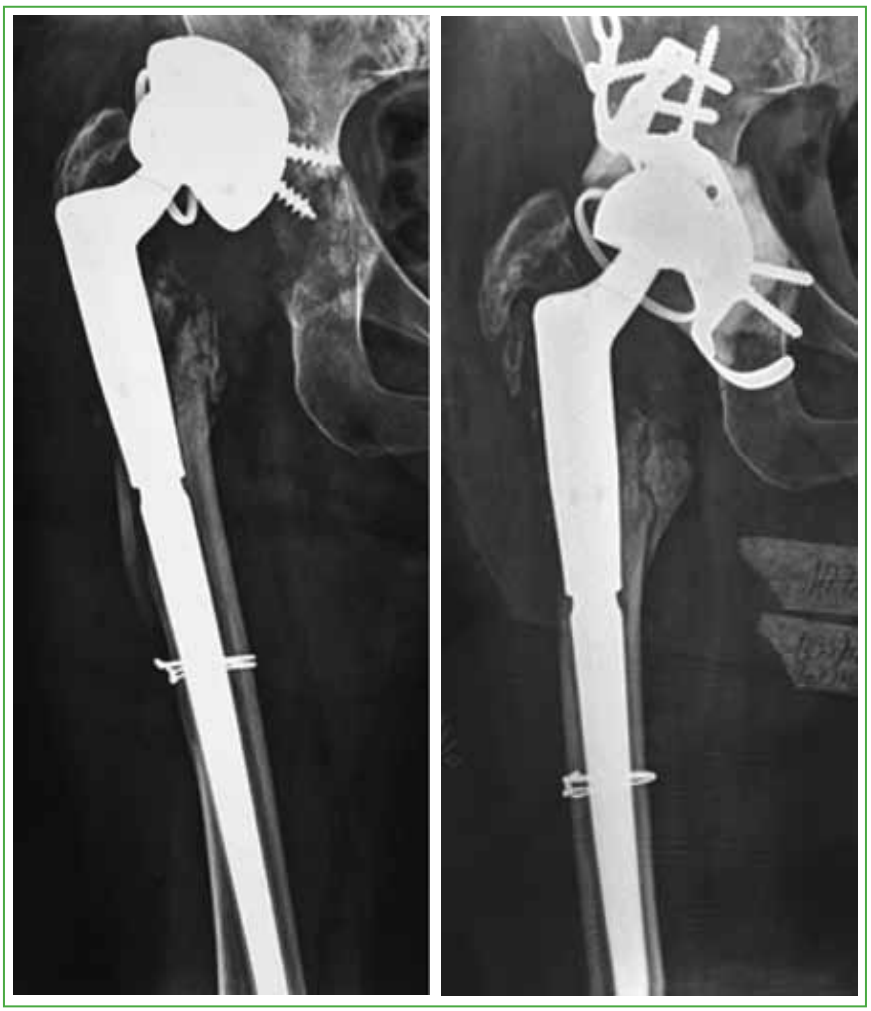

**Figure 2.** Preservation of the distal fixation cementless femoral stem. Acetabular cup replacement.

Several samples (at least 5) were sent for culture tests. Six matched the microorganisms identified in the joint puncture fluid. Despite not receiving antibiotics prior to surgery, two patients had negative intraoperative cultures. One had a single positive culture for coagulase-negative *Staphylococcus* that had not been discovered on the prior joint puncture, and it was thought to be a contaminant. If osteolytic lesions were detected, curettage was performed. The final lavage was performed with 0.35% povidone-iodine for three minutes.

In the two-stage partial revisions, an articulating functional spacer was cast from an acetabular component that was cemented in advanced stages of setting, resulting in a reduced bone interdigitation surface. A gentamicin-loaded cement (Subiton G, Buenos Aires, Argentina) was used, to which 4 g of vancomycin powder were added.

After surgery, during the 'spacer phase', all patients were administered intravenous antibiotics for at least seven days; during this period, inflammatory markers and various laboratory parameters were monitored periodically. Postoperative antibiotics were selected according to the sensitivity of the microorganism identified in the cultures. Then, patients continued with oral antibiotics, indicated according to the sensitivity of the microorganism, for at least six weeks, according to the recommendation of the physicians of the Infectious Diseases Department, while the normalization or decrease of inflammatory markers (C-reactive protein and erythrocyte sedimentation rate) was evaluated. Intravenous antibiotic therapy consisted of vancomycin, cefazolin, ceftriaxone, clindamycin and ciprofloxacin, following the guidelines established by the Clinical Guide of the *Infectious Diseases Society of America* and previous antibiograms. Rifampicin, levofloxacin and ciprofloxacin were indicated for the oral route.

The decision to perform the reimplantation was made together with these specialists. The criteria for reimplantation were: a stable medical condition and an appropriate response to treatment of the infection (decreased erythrocyte sedimentation rate, normal or decreased C-reactive protein and satisfactory wound status).

The second procedure was performed, on average, 10.3 weeks after the first procedure (range 7-16). The spacer was removed and necrotic soft tissue debridement was performed. Several samples (5) were sent for culture and sensitivity tests, leukocyte count and pathological anatomy analysis. No visible evidence of infection was found in any patient. Nor were any microorganisms identified in the cultures of the samples obtained during the procedure.

Uncemented acetabular components were re-implanted with metal-polyethylene bearings in five patients. In four others, the fixation was cemented.

After reimplantation, antibiotics were administered intravenously for 48 h and then orally for 4.3 months, on average (range 3-8), according to the criteria of the physicians of the Infectious Diseases Department. Oral antibiotics were discontinued when serum biomarker values decreased significantly or normalized and the patient had no symptoms (primarily pain, swelling or erythema).

The minimum follow-up was three years (mean 5.8 years; range 3-8). Patients were monitored in outpatient clinics at 3 and 6 weeks, at 3, 6, 9 and 12 months, and then annually, as part of a standard protocol. Prior to the consultation, blood tests were to be performed, and the results would be available at that time. The Harris hip score was evaluated. All patients attended their consultations.

Treatment was considered successful using the criteria described by Díaz Ledesma et al.,[18] based on a Delphi consensus (eradication of infection, no subsequent surgical intervention and no PJI-related deaths).

In one patient treated with single-stage partial revision, the infection recurred due to the same microorganism (methicillin-sensitive *S. aureus*) and he had to undergo a two-stage revision. The remaining eight patients were free of infection in five years of follow-up. None required suppressive treatment. The infection remission rate was 88.9%. The average modified Harris hip score improved to 81 (range 76-83) at the last assessment. No loosening of acetabular or femoral components was detected.

## DISCUSSION

Constant advances in surgical techniques and the improvement of prosthetic materials have significantly improved the integration of implants with bone tissue. This has determined a strong contribution to initial and long-term stability. However, if patients need revision surgery for a reason other than loosening of the prosthesis, it is particularly complex to remove an osseointegrated component, even in the hands of an experienced team with precise instrumentation.

Although specific instrumentation has been developed to facilitate the removal of the fixed acetabular component with minimal bone loss, the removal of an osseointegrated cementless femoral component can cause serious complications and hinder subsequent reconstruction. Removal of a fixed femoral component may result in: 1) a significant loss of bone material; 2) a femoral fracture, especially when an extended trochanteric osteotomy is required; and 3) the formation of a sequestrum due to extensive soft tissue dissection.

In this study, the treatment of chronic PJI with two-stage partial reconstruction preserving the femoral component was evaluated in nine patients. Infection recurred in only one (88.9% remission), there were no treatment-associated deaths, and the average modified Harris hip score was 81, in the qualitative range of "good".

While the accepted treatment for chronic PJI is single- or two-stage revision, the removal of fixed cementless femoral components when bone quality is poor has begun to be questioned, as removal of this component could result in significant bone loss that does not allow reimplantation in certain patients.

It is important to perform an adequate and thorough cleaning of the tissues, as well as the fixed femoral component and to remove the modular components. Likewise, it is essential to know the causal microorganism in a previous puncture sample, in order to decide whether the revision will be in one or two stages, the antibiotic to be placed in the spacer cement, and the antibiotic to be administered.

The ICM (2nd Philadelphia Consensus) states that sub-radical resection arthroplasty (leaving parts of implants in place) may be considered during the management of patients with chronic PJIs when a component is proven to be well-fixed and its removal precludes opportunity for future reconstruction.[15] Success rates with this technique have been acceptable (87-89%). These can be compared with published results on two-stage surgery, although reported success rates are highly variable. Careful patient selection through proper assessment of fixation is the key to determining whether component retention is a viable option.

The ICM reports that overall infection eradication rates with this technique ranged from 80% to 100% (mean 90%). Further on, the ICM states that: "Complete debridement of the hip or knee joint and removal of all hardware is ideal during surgical treatment of PJIs." This principle should be followed whenever possible. However, there may be rare cases of PJI in which removal of all implants may cause increased morbidity and preclude future reconstruction. In this situation, some implants may not be removed. The level of evidence for this statement reaches the "Consensus" category; the delegate vote was 97% "agree" and 3% "disagree" (unanimous and strongest consensus).

Finally, the ICM delegates ask, "Is it possible to have an isolated infection of only a portion of the joint (for example the femur and not the acetabulum, or tibia and not the femur)?" And the answer is: "Unknown. Infection of a prosthetic joint is likely to involve biofilm formation on surfaces of all foreign material. However, **there may be rare circumstances when infective organisms may not be able to reach the surface of a well-fixed implant and form a biofilm**." The level of evidence was limited and, in the delegate vote, 75% agreed (super majority, strong consensus).

In 1989, Struhl et al. published the case of a patient who underwent a two-stage revision with retention of the femoral component and remission of the infection after 18 months of treatment.[19]

Lombardi et al. reported a retrospective study of 41 patients with chronic PJI treated with a two-stage partial component exchange that included complete removal of the acetabular component, retention of the fixed femoral stem with removal of the modular components, and subsequent reimplantation of the prosthesis. The median follow-up was four years, and the recurrence rate of infection with two-stage partial replacement after chronic hip PJI was 19%.[20]

Ji et al. published a retrospective analysis that included 31 patients with chronic PJI undergoing single-stage partial revision. Twenty-seven of the 31 patients (87.1%) had satisfactory outcomes and did not require further medical or surgical treatment for recurrence of infection.[21]

In the study by El-Husseiny et al., 18 patients with chronic PJI were treated with a procedure that preserved the femoral or acetabular component. The minimum follow-up period was five years. In three cases, the infection recurred (83.34% healing of the infection) and the patients were treated with two-stage revision.[22] In our study, only the preservation of femoral components was evaluated.

Kassam et al. published a series of 89 patients in whom fixed cement mantles were retained in chronic PJI by replacing the femoral stem and acetabulum, and with the cement-in-cement technique; the infection remission rate was 92.1%.[23]

The results of these publications are similar to those we have obtained.

Our study has some limitations. This is a retrospective case series, like all the literature published to date, a comparison or control group was not included along with the study group. Patients were selected if they met all inclusion criteria, which were highly selective and subjective for the approach described. Another clear limitation is the sample size. Although nine patients were included, the number of cases in the international literature is low (from 2 to 41), so it is a procedure for highly selected patients.

As strengths, we can mention that it is the first national study on this controversial topic.

Further research is needed to confirm these results before this technique can be recommended for wider use.

## CONCLUSIONS

Partial component exchange, with retention of osseointegrated cementless femoral stems may represent an acceptable option for chronic, non-immunocompromised PJI patients with a known microorganism and fixed femoral stem, when their removal could result in significant bone loss and compromised reconstruction. However, further studies on this treatment method are required.

Conflict of interest: The authors declare no conflicts of interest.

F. Tillet ORCID ID: https://orcid.org/0000-0003-2658-9856
E. J. Bochatey ORCID ID: https://orcid.org/0000-0003-3645-6563
F. A. Lopreite ORCID ID: https://orcid.org/0000-0002-2065-8649

## REFERENCES

1. Gundtoft PH, Overgaard S, Schønheyder HC, Møller JK, Kjærsgaard-Andersen P, Pedersen A. The "true" incidence of surgically treated deep prosthetic joint infection after 32,896 primary total hip arthroplasties: a prospective cohort study. *Acta Orthop* 2015;86:326-34. https://doi.org/10.3109/17453674.2015.1011983
2. Pagano I. Reporte anual de vigilancia de infecciones asociadas al cuidado de la salud 2021. Administración Nacional de Laboratorios e Institutos de Salud (ANLIS) Dr. C. Malbrán, Buenos Aires. Available at: http://sgc.anlis.gob.ar/handle/123456789/2436
3. Vila A, Kremer G, Chuluyan J, Querci M, Sanchez M, Paz Sierra M. Diagnóstico de infecciones asociadas a artroplastias. *Medicina (Buenos Aires)* 2022;82(2):249-61. PMID: 35417390
4. Della Valle C, Parvizi J, Bauer TW. Dicesare PE, Parker Evans R, Segretiet J, et al. Diagnosis of periprothesic joint infections of the hip and knee. *J Am Acad Orthop Surg* 2010;18(12):760-70. https://doi.org/10.5435/00124635-201012000-00006
5. Parvizi J, Jacovides C, Zmistowski B, Jung KA. Definition of periprosthetic joint infection: is there a consensus? *Clin Orthop Relat Res* 2011;469(11):3022-30. https://doi.org/10.1007/s11999-011-1971-2
6. Hsieh PH, Shih CH, Chang YH, Lee MS, Yang WE, Shih HN. Treatment of deep infection of the hip associated with massive bone loss: two-stage revision with an antibiotic-loaded interim cement prosthesis followed by reconstruction with allograft. *J Bone Joint Surg Br* 2005;87(6):770-5. https://doi.org/10.1302/0301-620X.87B6.15411
7. Maurer SG, Baitner AC, Di Cesare PE. Reconstruction of the failed femoral component and proximal femoral bone loss in revision hip surgery. *J Am Acad Orthop Surg* 2000;8(6):354-63. https://doi.org/10.5435/00124635-200011000-00003
8. Younger AS, Duncan CP, Masri BA. Treatment of infection associated with segmental bone loss in the proximal part of the femur in two stages with use of an antibiotic-loaded interval prosthesis. *J Bone Joint Surg Am* 1998;80(1):60-9. https://doi.org/10.2106/00004623-199801000-00011
9. Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. *N Engl J Med* 2004;351(16):1645-54. https://doi.org/10.1056/NEJMra040181
10. Taylor PR, Stoffel KK, Dunlop DG, Yates PJ. Removal of the well-fixed hip resurfacing acetabular component: a simple, bone preserving technique. *J Arthroplasty* 2009;24(3):484-6. https://doi.org/10.1016/j.arth.2008.01.305
11. Preiss RA, Patil S, Meek RM. The use of modular femoral head trials to centre the Explant blade facilitates retrieval of well-fixed acetabular components with minimal bone loss. *Arch Orthop Trauma Surg* 2011;131(7):1003-6. https://doi.org/10.1016/j.arth.2008.01.305

12. Kaneuji A, Sugimori T, Ichiseki T, Fukui K, Takahashi E, Matsumoto T. Cementless anatomic total hip femoral component with circumferential porous coating for hips with developmental dysplasia: a minimum ten-year follow-up period. *J Arthroplasty* 2013;28(10):1746-50. https://doi.org/10.1016/j.arth.2013.06.030
13. Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, et al. New definition for periprosthetic joint infection: from the Workgroup of the Musculoskeletal Infection Society. *Clin Orthop Relat Res* 2011;469(11):2992-4. https://doi.org/10.1007/s11999-011-2102-9
14. Parvizi J, Gehrke T, Chen AF. Proceedings of the International Consensus on Periprosthetic Joint Infection. *Bone Joint J* 2013;95-B(11):1450-2. https://doi.org/10.1302/0301-620X.95B11.33135
15. Parvizi J, Gehrke T. International consensus on periprosthetic joint infection: let cumulative wisdom be a guide. *J Bone Joint Surg Am* 2014;96(6):441. https://doi.org/10.2106/JBJS.N.00023
16. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;(121):20-32. PMID: 991504
17. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;(141):17-27. PMID: 477100
18. Diaz-Ledezma C, Higuera CA, Parvizi J. Success after treatment of periprosthetic joint infection: A delphi-based international multidisciplinary consensus infection. *Clin Orthop Relat Res* 2013;471(7):2374-82. https://doi.org/10.1007/s11999-013-2866-1
19. Struhl S, Harwin SF, Stern RE, Kulick RG. Infected uncemented hip arthroplasty. Preserving the femoral stem with a two-stage revision procedure. *Orthop Rev* 1989;18(6):707-12. PMID: 2664672
20. Ekpo TE, Berend KR, Morris MJ, Adams JB, Lombardi AV Jr. Partial 2-stage exchange for infected total hip arthroplasty: An updated report. *J Arthroplasty* 2019;34(12):3048-53. https://doi.org/10.1016/j.arth.2019.07.001
21. Ji B, Xu B, Guo W. Retention of the well-fixed implant in the single-stage exchange for chronic infected total hip arthroplasty: an average of five years of follow-up. *Int Orthop* 2017;41(5):901-9. https://doi.org/10.1007/s00264-016-3291-3
22. El-Husseiny M, Haddad F. The role of highly selective implant retention in the infected hip arthroplasty. *Clin Orthop Relat Res* 2016;474(10):2157-63. https://doi.org/10.1007/s11999-016-4936-7
23. Fishley W, Selvaratnam V, Whitehouse S, Kassam A. Cement-in-cement revision of the femur in infected hip arthroplasty in 89 patients across two centres. *Bone Joint J* 2022;104-B(2):212-20. https://doi.org/10.1302/0301-620X.104B2.BJJ-2021-0598.R1