Impaction Bone Grafting for the Treatment of Vancouver Type B3 Periprosthetic Femoral Fractures. Survivorship and Complication Rate Analysis

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ABSTRACT

Aims: Because the gold standard for the treatment of Vancouver type B3 periprosthetic femoral fractures (PFFs) is yet to be defined, we sought to analyze the complication rate of the impaction bone grafting (IBG) technique with a cemented stem for the treatment of this fractures. **Materials and Methods:** We retrospectively studied 33 B3 PFFs treated with the IBG technique operated between 2000 and 2016, analyzing the complication rate. The median follow-up was 75 months (interquartile range [IQR], 36-111). The median age was 78 years (IQR, 74-83). The median grade of EndoKlink femoral bone defect was 3 (IQR, 3-3). We performed a multiple regression analysis to determine risk factors for complications, including the following variables: number of previous surgeries, femoral head diameter, and femoral bone defect. **Results:** As for infection outcomes, 2-stage revision surgery was performed in 4 patients. We registered 5 implant failures and 2 dislocations in the whole series. Multiple regression analysis showed a significant association between the grade of EndoKlink femoral bone defect and complication rate (P=0.04). **Conclusion:** Femoral reconstruction with the IBG technique evidenced a high complication rate for the treatment of B3 PFF.
Key words: B3 periprosthetic femoral fractures; impaction bone grafting technique; complications; survivorship analysis.
Level of Evidence: IV

Tratamiento de las fracturas femorales periprotésicas Vancouver B3 con injerto óseo impactado. Supervivencia y complicaciones

RESUMEN

Objetivos: El tratamiento de elección para las fracturas femorales periprotésicas Vancouver B3 aún no está definido. Por este motivo, nos propusimos analizar la tasa de complicaciones de la técnica de injerto óseo impactado con un vástago cementado cuando se utiliza para tratar estas fracturas. **Materiales y Métodos:** Estudiamos retrospectivamente 33 fracturas femorales periprotésicas B3 tratadas con la técnica de injerto óseo impactado operados 2000 y 2016, analizando la tasa de complicaciones. La mediana de seguimiento fue de 75 meses (RIC 36-111). La mediana de edad fue de 78 años (RIC 74-83). La mediana del defecto óseo femoral fue 3 (RIC 3-3) según la clasificación Endo-Klinik. Se realizó un análisis de regresión múltiple para determinar los factores de riesgo asociados a complicaciones, las variables incluidas fueron: cantidad de cirugías previas, diámetro de la nueva cabeza femoral y defecto óseo femoral. **Resultados:** Se realizó una cirugía de revisión en dos etapas en cuatro pacientes. Se registraron cinco fallas asépticas del implante y dos luxaciones en toda la serie. El análisis de regresión lineal multivariable mostró una asociación significativa entre el grado del defecto óseo femoral Endo-Klinik y la tasa de complicaciones (p = 0,04). **Conclusión:** La reconstrucción femoral con la técnica de injerto óseo impactado para tratar fracturas periproésicas Vancouver B3 provocó una alta tasa de complicaciones.
Palabras clave: Fractura femoral periprotésica B3; técnica de injerto óseo impactado; complicaciones; análisis de supervivencia.
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INTRODUCTION

One of the most complex complications after total hip replacement is a periprosthetic femoral fracture (PFF). Several studies reported a prevalence of 1.7% and 6.2% at 10 years of follow-up after primary and revision total hip arthroplasty, respectively.[1,2] However, due to the expected annual increase in primary and revision total hip arthroplasties, it is likely that there will be an exponential increase in PFFs in the coming decades.[3] To achieve a successful outcome in these cases, a surgeon trained in joint trauma and reconstruction is required, given the complexity of the disease and the requirements of the surgical technique.[1-4]

PFFs around a fixed stem (Vancouver type B1) are treated with internal fixation, and fractures around a loose implant with adequate bone quality (Vancouver type B2) are treated with revision total hip replacement. A PFF on a loose stem with loss of bone stock (Vancouver type B3) poses the challenge of simultaneously achieving implant stability and fracture healing. Therefore, the choice of the implant to treat the fracture and reconstruct the femur is of vital importance.[5] Recently, the Swedish Hip Arthroplasty Register reported a B3 PFF prevalence of 4.1% (43 out of 1049) in 21 years.[6]

B3 PFFs represent a challenge for even the most experienced surgeon. Several surgical techniques have been described for its treatment:[7] impaction bone grafting (IBG), bone bank allograft, modular distal fixation, and even proximal femoral replacement. The IBG technique was one of the most used reconstruction options until the advent of uncemented distal fixation,[1] taking into account that the latter is a less demanding technique and does not require a bone bank. On the other hand, distal fixation added the option of modularity, thus increasing the versatility to reconstruct the biomechanics of the proximal femur.[8,9] Although distal fixation conical modular stems have achieved a 90% survival and good functional outcomes in the medium term,[10,11] there are some fracture patterns which make its use difficult, such as those with massive bone loss and an unfavorable geometry of the femoral canal, such as a type C proximal femur of the Dorr classification.[11]

The evidence related to the treatment of B3 PFFs consists mainly of short case series with short-term follow-up.[12-15] In this scenario, there is no agreement on the optimal treatment for these patients. Therefore, the objective of our study was to analyze the complication rate associated with the IBG technique to treat Vancouver B3 PFF.

MATERIALS AND METHODS

After obtaining approval from the Institution's Research Ethics Committee, we retrospectively studied a series of 35 patients with PFF and stem loosening and lack of bone stock in the proximal femur, treated with the IBG technique between 2000 and 2016. All the fractures were Vancouver type B3, as they were located around a loose femoral component and were associated with poor bone stock in the proximal femur.[6] During the study period, 43 type A PFFs, 193 type B1 PFFs, and 99 type B2 PFFs were treated but not included in the study. Two cases were excluded from the series due to a history of periprosthetic infection before PFF, therefore 33 cases were analyzed. At the time of the final review, nine patients had died and no other patients had been lost to follow-up. The median follow-up of these nine patients was 58 months (interquartile range [IQR] 35-99). All the information was obtained from the institution's prospectively compiled electronic database, digitized in 2004. Only six patients had previously undergone surgery at our institution. The bone stock was classified with anteroposterior and lateral radiographs of the affected femur before surgery, confirming these findings after the removal of the components, according to the Endo-Klinik classification.[16] The demographic characteristics of the series are detailed in Table 1.

Within the study period, the same experienced group of hip surgeons performed all surgeries in laminar flow operating rooms following the general principles that have been described for the original technique (Table 2).[4] Under hypotensive epidural anesthesia, an extended posterolateral approach was performed in 29 patients while a transtrochanteric approach was used in the remaining four. Concomitant infection was systematically ruled out by sending intraoperative samples for pathological study.[17] All extracted stems were cemented. The femoral component, cement mantle, and polymethylmethacrylate residues, as well as the surrounding interface, were completely removed to identify the amount of remaining femoral bone. The acetabular component was revised in 25 cases to fit the size of the newly implanted femoral head. The extracted stems are detailed in Table 1.

Table 1. Demographic characteristics of the series.

Variable	Series (n = 33)
Median age (years)	78 (IQR 74-83)
Sex (female/male)	23/10
Median of previous surgeries (n)	1 (IQR 1-2)
Median Endo-Klinik classification	3 (IQR 3-3)
Initial diagnosis (n) Primary osteoarthritis Hip dysplasia Femoral neck fracture	 20 6 7
Stem extracted (n) Charnley Charnley Elite-Plus C-STEM® Müller Harris-Galante Exeter™ CPT	 12 10 5 3 1 2 0
Median follow-up (months)	75 (IQR 36-111)

IQR = interquartile range.

Table 2. Reconstruction technique used

Variable	Series (n = 33)
Median of cortical graft tables (n)	0 (IQR 0-1)
Median of femoral head grafts (n)	2 (IQR 2-3)
Median of metallic meshes (n)	1 (IQR 0-1)
Median of cerclage wires (n)	6 (IQR 5-8)
Implanted femoral stem (n) Charnley Exeter C-STEM®	 1 12 20
Median diameter of femoral head (mm)	28 (IQR 28-28)
Acetabular revision Yes No	 25 8

IQR = interquartile range.

Frozen bone allografts were obtained from the institution's bone bank following the American Association of Tissue Banks protocol for graft harvesting and processing.[18] The grafts were impacted according to the technique described by Gie et al.,[19] using primary impact instruments (DePuy International, Leeds, UK) and the Revision Surgery Instrument System (Stryker, Newbury, UK). The aim was to obtain a cancellous bone thickness of 10 mm in the proximal part of the reconstructed femur. Cerclage wires and metal meshes were used when necessary. The details of the reconstruction technique used are described in Table 2.

Femoral reconstruction was performed in all cases with long cemented stems (Table 2 and Figure 1). We retrogradely injected CMW surgical cement with gentamicin (DePuy, Leeds, UK) in 21 cases and Simplex cement with tobramycin (Stryker, Rutherford, New Jersey, USA) in the remaining 12.

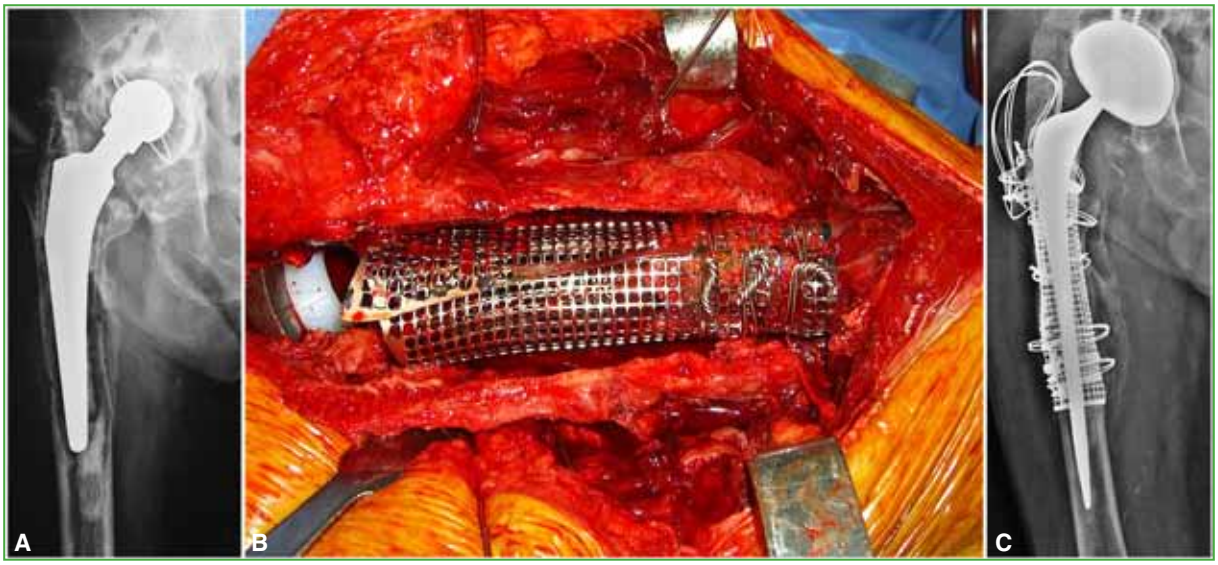

Figure 1. Impaction bone grafting technique. **A.** Preoperative anteroposterior radiograph of the right hip showing a periprosthetic femoral fracture. **B.** Intraoperative image. The impaction bone graft, the metal meshes, and the cerclage wire are observed. **C.** Anteroposterior radiograph of the right hip after femoral reconstruction with a cemented long stem.

Routine prophylaxis for thromboembolic disease was administered subcutaneously with 40 mg/day enoxaparin during the first postoperative month.[20] We did not prescribe routine prophylaxis against heterotopic calcification. The rehabilitation protocol included early mobilization 48 h after surgery, ambulation with a walker, and contact with the foot on the operated side for 90 days. Then, weight-bearing was progressively indicated according to tolerance with the use of a cane for at least one month, depending on the incorporation of the graft and the consolidation of the osteotomy and the fracture observed in the control radiographs.

Anteroposterior and lateral radiographs of the operated pelvis and femur were taken immediately after surgery, 45 days, 3, 6, and 12 months after surgery, and then once a year. For this study, all patients were contacted for a follow-up radiographic appointment. Consolidation of the fracture/osteotomy was considered when there was radiographic evidence of bone bridging in both views or absence of the fracture line.[21,22] Radiographs taken immediately after the operation were compared with those of the last control. Femoral radiolucency, defined as any irregular line between the stem and the bone interface; and periprosthetic osteolysis, defined as progressive bone loss >5 mm, were evaluated using the Gruen zones.[23] The subsidence of the femoral stem was determined using the method described by Loudon and Charnley,[24] which measures the distance from a selected (but variable) point in the femoral prosthesis to a fixed point in the bone. Loosening was defined as a depression >5 mm or progressive demarcation around the stem. Stem fixation was assessed using Engh criteria.[25] Septic failure was considered to be any case requiring revision surgery due to infection at the surgical site. Aseptic implant failure was considered when signs of loosening, stem fracture, or a new periprosthetic fracture were found, requiring revision surgery.

Continuous variables are expressed as medians and IQR because they have a non-Gaussian distribution. Categorical variables are expressed as frequencies and percentages. Continuous variables were compared using the Mann-Whitney U-test, since the data had an abnormal distribution. Categorical variables were compared using chi-square and Fisher's exact tests. The survival analysis according to Kaplan-Meier was estimated considering

revision surgery as the endpoint of follow-up regardless of the cause. A multivariate linear regression analysis was performed to determine the independent risk factors associated with complications. Variables that were considered significant in the univariate analysis or that had clinical relevance were included. Regression coefficients (RC) were reported with their 95% confidence intervals (CI). A p-value <0.05 was considered statistically significant. The statistical program Stata 13™ (Stata Corp., College Station, Texas, USA) was used for data analysis.

RESULTS

There were 11 surgical complications in the series. Regarding periprosthetic infections, four (12%) patients developed a deep infection in a median of 17 months (IQR 14-20) and were treated with a revision surgery in two stages without recurrences in a median follow-up of 22 months (IQR 18-28) after reimplantation.

Five (15%) aseptic implant failures were recorded: a femoral loosening of a Charnley stem at 47 months of follow-up treated with revision surgery with a new IBG technique; one Vancouver B1 atraumatic femoral fracture treated with open reduction and internal fixation; and three atraumatic femoral stem fractures, all long C-Stems (DePuy International, Leeds, UK) (Figure 2). These last three occurred in a median of 60 months (IQR 44-86) from the initial surgery and were immediately revised with an uncemented modular stem (2 cases) and a new IBG technique in the remaining case.

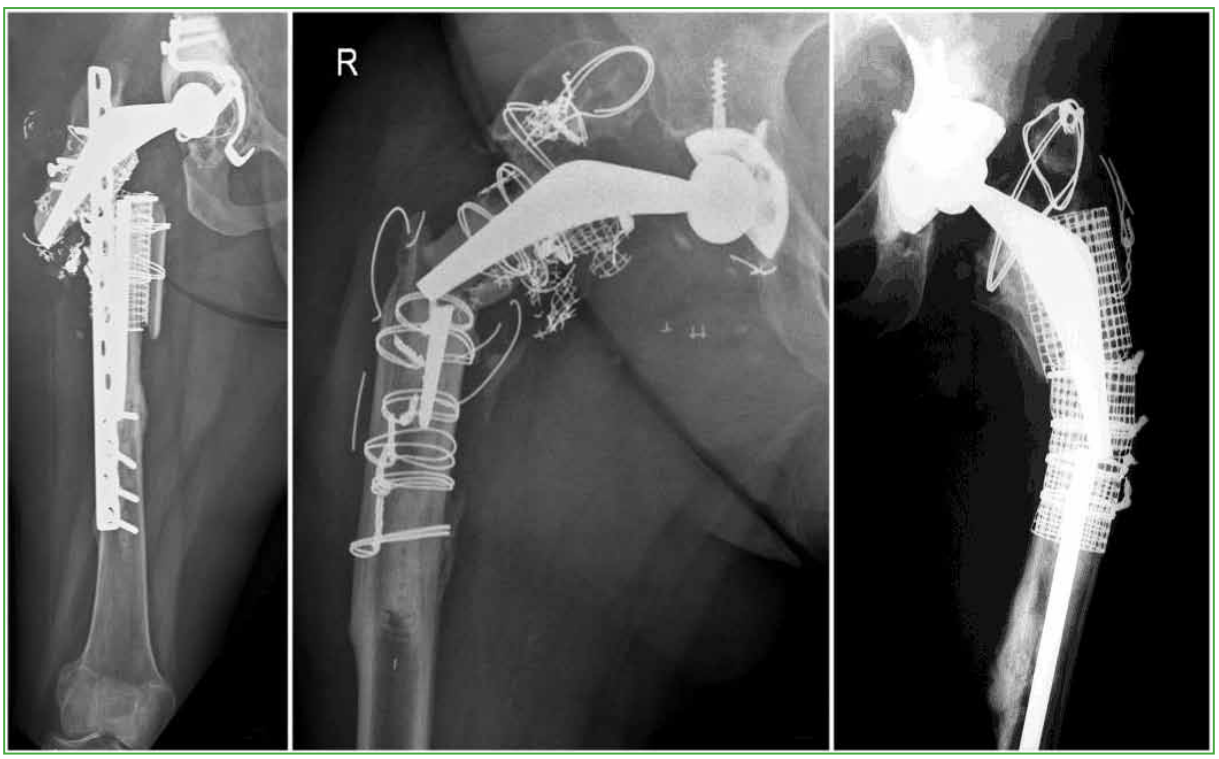

Figure 2. Preoperative anteroposterior radiographs of the femur and hip showing the three fractured C-Stems.

Two (6%) patients had recurrent instability episodes. All occurred in cases operated with a 28 mm diameter femoral head. One patient had two instability episodes treated conservatively with closed reduction and a hip abduction splint for six weeks. Although revision surgery was indicated, the patient preferred conservative treatment. The other patient suffered recurrent instability and, therefore, underwent revision with a constrained and cemented liner 10 months after surgery. No new episodes of instability were detected in these patients at the end of follow-up.

One of the four patients operated by a transtrochanteric approach developed an asymptomatic pseudoarthrosis of the greater trochanter that was treated conservatively. There were six cases of subsidence of up to 2 mm; all stems were considered stable with signs of bone incorporation according to Engh criteria[25] at the end of follow-up. There were no cases of periprosthetic osteolysis.

Other minor medical complications that were not included in the survival analysis were also recorded. Four patients had deep vein thrombosis and another two had pneumonia during their hospital stay.

The multivariate linear regression analysis showed a significant association between the degree of the femoral bone defect and the development of complications (RC -0.45; 95% CI -0.91 to 0.01; p = 0.04) (Table 3). With the revision of the femoral stem as the endpoint, implant survival was 73% in a median of 75 months (IQR 36-111) (Figure 3).

Table 3. Complications recorded in the series

Complication	Series (n = 33)
Infection, n (%)	4 (12%)
Aseptic implant failure, n (%)	5 (15%)
Dislocation	2 (6%)

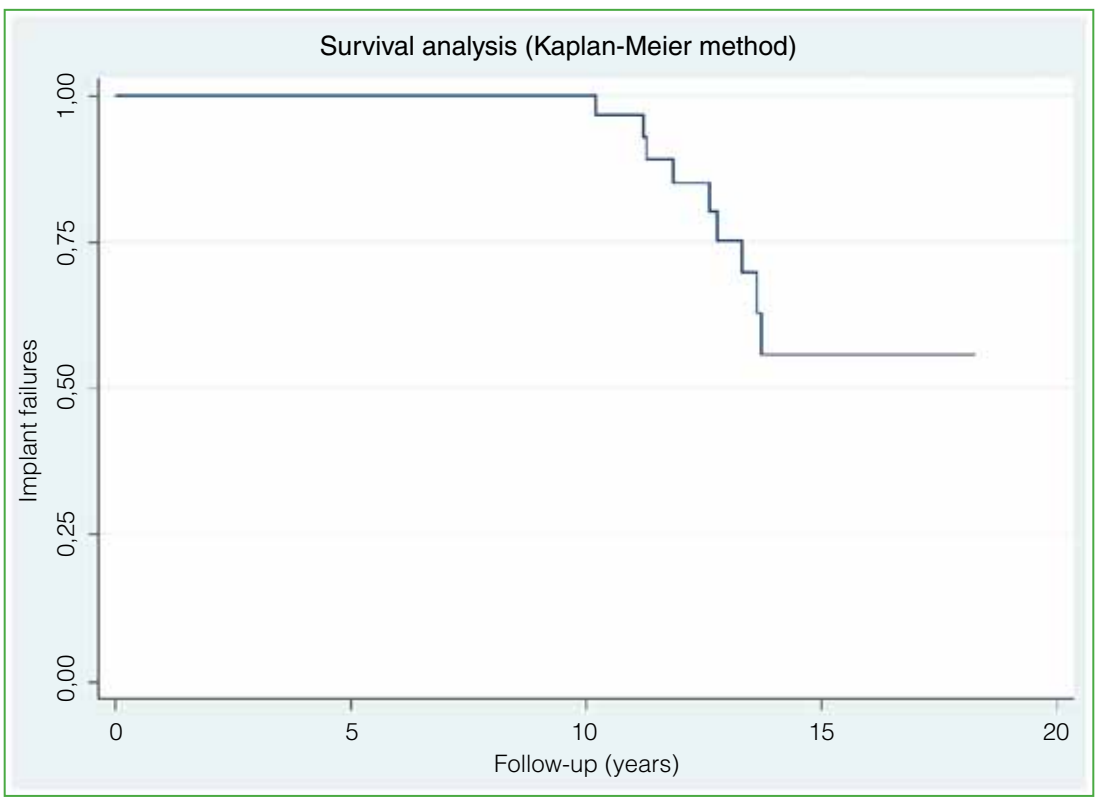

Figure 3. Survival analysis of the impaction bone grafting technique using the Kaplan-Meier method. With femoral stem revision as the endpoint, implant survival was 73% at a median of 75 months (IQR 36-111).

DISCUSSION

In this retrospective series, the IBG technique had a high rate of postoperative complications. The ideal treatment of Vancouver B3 PFFs remains controversial. Several therapeutic options have been reported, such as IBG, modular distal fixation, alloprosthesis, and even proximal femoral replacement.[26] All have achieved good short-term outcomes. However, there is still no reasonable algorithm for choosing one technique over the other.

Our study has certain limitations. First, due to its retrospective nature, it was affected by the biases inherent to this methodological design. The sample size resulted in a small number of included cases, which restricted the production of a more precise statistical analysis; however, it is a highly selected subgroup of patients with a low-prevalence condition. Thus, it can be argued that the lack of statistical significance observed for some of the variables analyzed may be the result of a Type II error (β) (low-power study). However, it is one of the largest studies analyzing the surgical outcomes of this technique in cases of B3 PFF. Secondly, we have not analyzed the clinical-functional outcomes of this reconstruction method. In this sense, postoperative pain, abnormal gait, and the ability to perform activities of daily living could have added more information about the failed expectations of patients, which can only be underestimated by analyzing the advent of a new revision surgery. Thirdly, we believe that our survival rate should be considered the best estimate of cases. Given that there was a long and heterogeneous follow-up period, we expect that some of these patients will still undergo revision arthroplasty for any reason, after a longer follow-up. Fourthly, our data did not include complete information on demographic data and specific comorbidities or perioperative factors that contributed to infection or dislocation, as they were the most common complications. Therefore, our complication results should also be considered the best-case estimates. Fifthly, due to the poor quality of the analog and scanned radiographs in our database of those patients operated before 2003, the Barrack classification could not be used. As many of the defects were reconstructed with metal mesh, this was an added limitation when making an accurate evaluation of the cementation technique and bone incorporation.

Although long, fully porous, uncemented femoral stems can be used effectively to treat most of these fractures,[11] there is a group of patients with specific fracture patterns, massive bone loss below the femoral isthmus, and unfavorable canal geometry that exclude the use of these implants. In 2004, Tsiridis et al.[27] reported 106 cases of Vancouver B2 and B3 PFFs; 89 underwent a cemented revision with IBG and the remaining 17, a cemented revision without IBG. The authors found that patients treated with IBG and a long stem that exceeded the distal fracture line were significantly more likely to have bone consolidation than those with a long stem without IBG. More recently, Li et al.[28] retrospectively evaluated the outcome of 33 Vancouver B3 PFFs; 17 were treated with IBG and 16 were treated with IBG combined with cortical structural allograft. The authors reported a reoperation rate of 9%, with a stable stem with bone incorporation in 24 patients, with fibrous fixation in eight, and no fixation in the remaining patient. Although this procedure is technically demanding, it has been shown to restore bone stock with a survival rate of 87.7% at 20 years of follow-up, taking revision for any reason as the endpoint.[29]

However, as we describe in this study, IBG is not free from complications. Five aseptic implant failures occurred, including three atraumatic femoral stem fractures. A retrospective review of the Swedish National Registry[30] reported 1305 cases of IBG with a survival of 94% at 15 years, including all causes of failure. Interestingly, there were no differences in survival between a long and a short femoral component. Most of the complications that required revision occurred within four years and consisted of infection and femoral fracture (33 cases, 47.5%), aseptic loosening (11 cases, 15.7%), and subsidence (13 cases, 18.6%). Implant fatigue fractures can also occur when the proximal bone support is inappropriate,[31] and can be avoided by following the strict principles of the original technique, which has been refined through the development of an instrumented femoral revision system.[32] It has been reported that a body mass index >30, the use of irradiated bone allografts, and an advanced Endo-Klinik grade are independent predictors of failure.[33,34] Although we were unable to analyze body mass index as an independent variable, all of the included cases had a large proximal bone defect, which could have been implicit in the genesis of the implant fractures described.[31] Although it is a speculation, the cemented long stem showed some intolerance to the loss of integrity of the proximal femur, which resulted in three implant fractures.

Revision with an uncemented modular stem is another feasible option, provided there is enough bone for distal fixation and there is no comminution extending into the distal femoral metaphysis, which can be a particular challenge for planning and achieving fixation of the stem.[7] It has been acknowledged that uncemented modular stems can reconstruct the proximal femoral bone with a high rate of union, while their most frequent complication is instability.[35] Mulay et al.[36] published 10 B2 and 14 B3 PFFs using a tapered, fluted, distal fixation stem (Link MP Reconstruction Hip Stem, Waldemar Link GmbH & Co, Hamburg, Germany). The fracture consolidation rate was 91% and the dislocation rate was 21%; there were no cases of subsidence. Similarly, Moreta et al.[37] reported 43 PFFs (31 type B2 and 13 type B3) with a 93% consolidation rate, with no signs of loosening at five years of follow-up; however, instability was the most common complication (16.3%), with no differences between modular and monobloc stems. In spite of the multiple version, offset, and stem length options, the high rate of dislocation still appears to be a problem in this group of elderly patients. Two possible causes could be impingement due to excess scar tissue on the medial side of the proximal femur[36] and subtle subsidence of the implant causing shortening and loss of soft tissue tension.[37]

Other options have been used to treat these types of fractures. Springer et al.[11] analyzed 118 femoral revisions due to PFF and found that fully coated cylindrical stems had better survival than partially coated prostheses and cemented stems. Moreover, of the 18 revision surgeries for PFF with an alloprosthesis or tumor prosthesis, seven failed due to aseptic loosening and another due to infection.[11] In one of the largest series of B3 PFF treated with a proximal femoral allograft (25 cases), Maury et al.[14] reported satisfactory outcomes with an average follow-up of five years, although two patients suffered a dislocation and four (16%) required a new revision procedure. Given their high complication rate, we consider the use of such implants only when other therapeutic options have failed.

In summary, femoral reconstruction with the IBG technique had a high rate of postoperative complications for the treatment of Vancouver B3 PFFs. For this reason, in our current practice and due to the demanding surgical technique, IBG is only indicated in strictly selected cases, especially in young patients with massive bone loss and unfavorable femoral canal geometry.

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

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