Efficacy of two bone grafting methods for Vancouver B3 type PFFs in uncemented stems: a retrospective study of functional and radiological outcomes from 2000 to 2017

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Research article

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Abstract

Background Peripheral femoral fractures (PFFs) are a devastating complication after total hip arthroplasty (THA). The accepted treatment for the Vancouver B3 fracture is revision surgery. However, there is still no consensus on which bone grafting technique to treat the bone defect around the femoral prosthesis in revision surgery. Therefore, we designed a retrospective study to evaluate the efficacy of ICA (impacted cancellous allograft) and ICA+CSA (cortical strut allograft) in B3-type PFFs revision surgery using uncemented stems. Methods We retrospectively assessed 47 Vancouver-type B3 PFFs in 47patients who have been treated between 2000 and 2017. All patients underwent intraoperative bone grafting.18 patients treated with ICA and 29 patients treated with ICA+CSA. Functional outcomes were assessed using Harris hip score, SF-36 scores and complications. Radiological findings were classified using Engh standard. Kaplan–Meier survival curve was used to assess patient and implant survival. Results There were 18 males and 29 females with an average age of 62.5 ± 9.9 years. The average follow-up time was 63.5 months. 90.7% of patients achieved fracture healing and 17.0% received secondary revision surgery. The overall 5-year Kaplan–Meier survival rate for the patients was 64.7% (95% CI, 50.6-78.8), and the 10-year rate was 47.4% (95% CI, 30.4–64.5). The last evaluated mean SF-36 was 46.1; Harris hip scores were 44.6 (3 months), 61.7 (12 months); respectively. Conclusions The use of ICA and ICA+CSA to reconstruct bone stock can provide stable prosthesis support and satisfactory fracture healing rate.

Background

Hip replacement has become one of the most successful operations in orthopedics. It has become the treatment of choice for most patients with end-stage arthritis and femoral neck fractures in the elderly[1]. The number of primary THA and hip revision surgery is increasing year by year. Some scholars predict that by 2030, the number of primary THA in the United States will increase by 174%, and the number of hip revisions will increase by 137%[2]. Periprosthetic fractures have become the third leading cause of hip revision. Data from the Australian Orthopaedic Association National Joint Replacement Registry and Swedish Hip Arthroplasty Register showed that surgery for periprosthetic fractures revisions accounted for 9.3% to 14.7% of all THA revision surgery[3-5]. According to reports in the literature, the incidence of periprosthetic femoral fractures (PFFs) in the first 10 years after primary replacement and revision was 1.7% and 6.2%[6; 7], respectively. The incidence of postoperative complications and mortality after surgery for PFF is high.[8; 9]. The treatment of PFFs is considered to be a huge challenge for orthopaedic surgeons, requiring surgeons that have extensive experience in trauma and joint revision surgery.

The Vancouver[10] classification not only assesses the location of the fracture line, but also assesses the stability of the prosthesis and the surrounding bone mass. It is the most widely used PFFs classification. The Vancouver B3 is the most serious type, and its treatment is also the most difficult[11]. While dealing with B3-type fractures, we not only have to revise the prosthesis, but also to deal with bone defects. Good bone condition is the key to maintaining prosthesis stability and fracture healing during PFFs revision surgery. If the bone defects is not handled well, it will cause serious complications, including nonunion, loosening of the prosthesis, re-fracture. ICA (impacted cancellous allograft) and CSA (cortical strut allograft) are two commonly used methods to treat bone defects. ICA is beneficial for bone defect repair in mild or moderate bone loss, reconstruction of the femoral structure from the inside out. The open structure of loose cancellous bone allows for angiogenesis and subsequent early remodeling, and provides initial stability and scratch-fit to the femoral component. However, ICA does not have a good effect in dealing with severe bone defects. In a 15-year follow-up study, Have[12] reported extensive subsidence and femoral fractures when ICA was applied to treat severe bone defects. CSA is widely used to treat femoral lateral bone defects. A series of studies[13-20] have reported cortical strut allogeneic for the treatment of femoral lateral bone defects, even when treating Paprosky grade IV femoral defects, can also achieve satisfactory results. CSA effectively increases femoral diameter and cortical width, which is beneficial for restoring bone reserve and ensuring the stability of the components. However, when applying CSA, a large amount of soft tissue peeling is required, which may cause delayed bone healing and may increase the infection rate. Moreover, tightening the wire around the stiff cortical strut allograft and the relatively weak host bone increases the risk of fracture of the host bone[20; 21]. Therefore, some scholars still have doubts about the efficacy of this treatment[22-24].

At present, there is no clear consensus on the treatment of bone defects in B3-type fractures. Due to the lack of relevant reports and appropriate comparative studies, we designed this retrospective study. The aim was to report the efficacy of ICA and CSA in the treatment of B3-type fractures.

Method

1.1Patient inclusion and data collection

The study was conducted in accordance with the principles of the Declaration of Helsinki and the study was approved by the Ethics Committee. Because of the retrospective nature of the study, patient consent for inclusion was waived. All data are retrieved from the Research Institute's forward-looking electronic database. These data were reviewed by 3 researchers (CW, ZY and FS).

We retrospectively reviewed clinical and radiographic data of 47 Vancouver B3-type fractures that underwent THA revisions performed between 2000 and 2017. There were 18 males and 29 females with an average age of 62.5 ± 9.9 years. Of the 47 cases included, the fractures were seen in 38 cases after a previous primary total hip, in 9 cases patients had already revision surgery before. The primary THA group fracture occurred at 9 to 187 months after surgery, with an average of 109.8 ± 40.1 months. The revision group fracture occurred 12-129 months after surgery, with an average of 92.9 ± 43.4 months. The reasons for the primary THA included 19 cases of osteoarthritis,10 cases of femoral head necrosis, 13 cases of femoral neck fracture, and 5 cases of DDH. The reasons for the revision included 8 cases of aseptic loosening and 1 case of PFF. The injury mechanism included 30 cases of mild trauma, 7 cases of immense trauma, and 10 cases of unknown cause.

The original prosthesis type and bone defect grading were clarified by preoperative pelvic X-ray images. The types of prostheses included 14 cemented prostheses and 33 non cemented prostheses. According to the Paprosky[25] classification: 5 of them were in grade II (10.6%), 30 were in grade IIIA (63.8%), 9 were in grade IIIB (19.1%), and 3 were in grade IV (6.4%).

1.2 Surgical technique

All surgeries were performed at the tertiary referral center by physicians with extensive experience in joint revision and trauma surgery. The uncemented extensively porous-coated long femoral stem prosthesis was selected in all revisions. Methods of intraoperative bone grafting include apply ICA alone and the combination of ICA + CSA. All surgeries were performed through posterolateral approach, and the length of the incision determined by the magnitude of the femoral reconstruction. For mild to moderate bone defects, adequately intramedullary ICA was performed to restore the bone store, adequately intramedullary impacted cancellous allograft was performed to restore the bone stock. **(Fig.1)** But when dealing with severe bone defects, the CSA was employed in addition. Choose the right strut allograft which best matched the host bone size radiographically. The strut allograft was cut to fit the shape of the host femur and allowed at least 5 cm exceeding the distal end of the fracture line. The cancellous allografts were used to restore the intramedullary bone defects and fill the space of the cortical strut to the host bone. **(Fig 2)** When the implanted bone mass is satisfactory, double-loop cerclage wires with a spacing of 3-4cm were applied for definitive fixation of the fractures. Fluoroscopy was used during the operation to observe the stability of prosthesis and the reduction in fracture. The wounds were stitched, and a drainage tube was placed.

1.3 Clinical assessment

All patients were followed up by outpatient reexamination and telephone inquiry. Clinical data of the patient includes Harris hip score, and short-term complications. Follow-up included hip joint X-ray review, SF-36 score, long-term complications, and survival. Short-term complications include wound complications, nerve damage, and lower extremity thrombosis during hospitalization. Long-term complications include non-union of the fracture, loosening of the prosthesis, infection of the prosthesis, dislocation, and the like. The prosthetic survival endpoint is defined as a prosthesis was re-revised for any reason. The fracture healing and the stability of the prosthesis were evaluated by reviewing the hip X-ray. The Engh[26] standard was used to evaluate the loosening of prosthesis. Looseness was detected when the prosthesis continuously sinks for more than 3 mm or extends beyond 2 mm of the translucent line. All imaging data were evaluated by a radiologist and an orthopaedic physician, and the controversial part was submitted to a third senior physician for evaluation.

For patients with Alzheimer's disease, contact their close relatives to obtain information on the patient's quality of life and joint function. For patients who died during the follow-up period, contact their close relatives to obtain the cause and time of death.

1.4 Statistical analysis

Statistical analyses were performed by using SPSS 19.0 (Chicago, IL, USA), the Kaplan–Meier survival curve was used to assess patient and implant survival, and a log-rank (Mantel–Cox) test was performed to compare the survival curves.

Result

All patients underwent intraoperative bone grafting.18 patients treated with ICA and 29 patients treated with ICA+CSA. The average follow-up time was 63.5 ± 39.0 months (range: 1-153 months). A total of 21 patients died during the follow-up period, and 4 patients died within 3 months after surgery. The overall 5-year Kaplan–Meier survival rate for the patients was 64.7% (95% CI, 50.6-78.8), and the 10-year rate was 47.4% (95% CI, 30.4–64.5). **(Fig.3)**

A total of 8 (17.0%) patients died within first year after surgery. The time and cause of death are shown in **Table 1**. In the following years, the patient's mortality rate has been maintained at a low level, although the curve has some small fluctuations, we consider this is related to the patient's natural death. This was confirmed by follow-up, and no patient's death was directly related to surgery.

A total of 39 patients achieved fracture healing and the healing rate was 90.7% (39/43, 4 cases of early death have been excluded). The average time of fracture healing was 3.9 ± 0.5 (range:3-5 months) months. Patients with nonunion include 3 cases of Paprosky grade [illegible] B and 1 case of grade [illegible]. All the bone grafts were CSA + ICA.

There were 9 (19.1%) cases of early complications after operation, including 4 cases of delayed healing, 3 cases of cutaneous nerve injury, and 2 cases of thrombosis of lower limb, which were improved after symptomatic treatment.

A total of 19 cases of long-term complications occurred during follow-up. **Table 2.** There were 4 cases of nonunion, 2 cases of joint infection, 3 cases of dislocation of the prosthesis, 4 cases of re-fracture, 4 cases of loosening of the prosthesis, and 2 case of cortical strut allograft failed osseointegration. **(Fig.4)** 8 of the patients underwent secondary revision surgery and the remaining 11 patients underwent conservative treatment. The 5-year Kaplan–Meier survival rate for the implants was 84.6% (95% CI, 73.2–96.0), and the 10-year rate was 74.4 % (95% CI, 57.4–91.5). **(Fig.5)**

The Harris hip score and SF-36 score information are shown in **Table 3**. There is no significant difference between the two bone grafting methods on Harris scores, and SF-36 scores($p<0.05$).

Discussion

The incidence of PFFs is associated with a variety of factors. The elderly people, especially women, often suffer from osteoporosis, and are slow-moving and prone to fall. These factors increase the risk of PFFs[27; 28]. Falling, spraining, falling from a chair or other low-energy damage are the most common causes of PFFs[29; 30]. Intraoperative fractures are a special type of PFFs, which are reported to account for approximately 12% of total PFFs. Poor bone conditions and revision with non-cemented stems are risk factors for intraoperative fractures, and PFFs are more likely to occur during revision of the prosthesis stem loosening. In our study, 7 cases were intraoperative fractures, including 1 case of Paprosky grade II and 6 cases of grade III A. The mechanism of preoperative fracture injury included 23 cases of mild violent injury, 7 cases of car accident or high fall, and 10 cases had no obvious cause.

In our study, the interval between primary THA and PFFs was 9-187 months with an average of 106.6 ± 40.8 months. This is longer than the statistics of 7.4 years (Swedish Registry) and 8.1 years (Mayo Clinic Total Joint Registry)[31]. This is related to the different fracture types selected in our study. The Swedish and Mayo Clinic Registry counts all types of PFFs, and short-term fractures after primary THA often do not have bone defects. These fractures will not be classified as type-B3. In addition, the interval between hip revision surgery and PFFs was 12-129 months with an average of 92.9 ± 43.4 months.

Surgical treatment of B3-type PFFs requires recovery of sufficient bone mass of the femur to provide stable support for the revision femoral stem prosthesis. Currently commonly used bone grafting methods for hip revision surgery include ICA (impacted cancellous allograft) and CSA (cortical strut allograft). In our study, 5 patients with Paprosky grade II and 13 patients with Paprosky grade IIIA were treated with ICA and achieved satisfactory results. CSA is suitable for most types of bone defects and is widely used in PFFs and stem loosening. Compared with ICA, CSA not only restores bone mass, but also provides early fixation for fractures. In our study, 17 cases of Paprosky grade IIIA, 9 cases of grade IIIB, and 3 cases of grade IV were treated with ICA+CSA. There were 2(6.9%) cases of osseointegration failure in these 29 patients. However, because we used ICA+CSA combined bone grafting, these 2 patients did not have nonunion complications. We consider larger graft bones, resulting in slow and limited invasion of host vessels and new bone replacement. Eventually led to the formation of dead bone, and the dead bone could not be integrated with the host bone.

It is reported that the postoperative mortality of patients with periprosthetic fractures varies from 0.9% to 24%. Bernd reported a 13.2% mortality and a 16.5% re-revision rate in 121 patients with PFFs in the first year after surgery. Similar results were reported by Shields. The mortality rate was 14.2% (16/113) within 3 months and 17.7% (20/113) within 1 year after surgery. In our study, 4 (8.5%) patients died within 3 months after surgery. 1 died of lung infection, 1 died of heart failure, 1 died of renal failure and 1 died of MODS (Multiple organ dysfunction syndrome). A total of 8 (17.0%) patients died in the first year after surgery in our surgery. The early-stage mortality rate of our patients is similar to that of Bernd and Shields, although our patients were all B3-type PFFs. But since the second year after surgery, the death toll has been maintained at a lower number. The overall 5-year Kaplan–Meier survival rate for the patients was 64.7% (95% CI, 50.6-78.8), and the 10-year rate was 47.4% (95% CI, 30.4–64.5).

Long-term complications include nonunion, joint infection, dislocation, etc. In our study, a total of 19 long-term complications occurred during follow-up, including 4 cases of nonunion, 2 cases of joint infection, 3 cases of dislocation of the prosthesis, 4 cases of re-fracture, 4 cases of loosening of the prosthesis, and 2 cases of osseointegration failure. Long-term complication rate is 40% (19/47). Mukundan reported a

35.3% (6/17) incidence of long-term complications with type-B3 PFFs, which was similar to our study. Barden[32] performed stem revision and CSA bone grafting on 19 case of B3 PFFs, and the rate of nonunion was 11.1%. Similar results were obtained in our study. Twenty-nine patients with CSA bone grafting developed 4 nonunion and the rate of nonunion was 13.8%. CSA bone graft may fail to integrate with host bone, but this incidence is not high. There were 2 cases of osseointegration failure in our study, but fortunately we used CSA+ICA combined bone grafting, both of which achieved clinical healing. A total of 17% (8/47) patients underwent a second revision surgery, specific information is shown in **Table 2**. We found that all 4 patients with re-fracture were concentrated in ICA bone grafts, and 3 of them occurred in the first year after surgery. We considered that first year after surgery is a high incidence of re-fracture, combined with CSA bone graft can reduce the incidence of early re-fracture in patients with B3-type PFFs. Whether considering early fixation or supplementing bone reserve, combined CSA bone grafting seems to be more dominant. But the number of cases is too small, we need more data to prove this. The 5-year Kaplan–Meier survival rate for the implants was 84.6% (95% CI, 73.2–96.0), and the 10-year rate was 74.4 % (95% CI, 57.4–91.5). There was no significant difference in survival rate (P=0.377) and revision rate (P=0.618) of different bone grafting methods.

Despite the different bone grafting methods, the surviving patients showed similar results on the SF-36, and Harris hip scores. The average Harris score for patients at 3 months and 12 months was 48.8 ± 6.9 and 74.4 ± 9.7, respectively. This result is similar to the previous result[32-34].

Our research has some limitations:1. The number of cases is still small, mainly because the incidence of B3-type PFFs is very low;2. The exact type of prosthesis is not taken into account, but is classified as the uncemented extensively porous-coated long femoral stem prosthesis, which may cause bias;3. This is a retrospective study, which may have compromised the analysis. However, due to the low incidence of this disease and the special treatment, it is difficult to implement RCT.

Conclusions

In B3-type PFFs revision surgery, ICA is used for mild to moderate bone defects, and ICA+CSA combined bone grafting for medium to severe bone defects can effectively reconstruct bone reserve to provide stable support for the prosthesis, and the fracture healing rate is satisfactory.

Abbreviations

PFF: Peripheral femoral fracture

THA: total hip arthroplasty

ICA: impacted cancellous allograft

CSA: cortical strut allograft

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethic Committee of the Affiliated Hospital of Xuzhou Medical University (NO. XYFY2018-aL040–08). Informed consent was obtained from all patients included in the study.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this article.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

JNS did the study, analyzed the data, and wrote the manuscript. CW, HZH, SF, XYC, BYH, DHY were involved in the design, data management, and analysis of the study. All authors read and approved the final manuscript.

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Tables

Table 1 Data of patients who died within one year after revision

Number	Time of death（month）	Age（year）	Sex	Cause of death
1	1	84	F	MODS
2	2	76	F	Renal failure
3	2	70	F	Lung infection
4	3	58	F	Heart failure
5	7	70	F	Lung infection
6	10	55	M	Suspicious pulmonary embolism
7	11	59	M	Respiratory failure
8	12	68	F	Suspicious pulmonary embolism

*M：Male，F：Female; MODS：Multiple organ dysfunction syndrome

Table 2: Long-term complications occurred during our follow-up

Complication	Number	Treatment
Dislocation	3	1□recurrent dislocation revised to constrained liner 2□closed reduction. No further dislocation
Aseptic loosening	4	4□Conservative treatment and reduced activity
Re-fracture	4	3: Receive second revision operation 1□Conservative treatment and reduced activity
Infection	2	1□I&D with head and liner exchange 1□chronic antibiotic suppression
Nonunion	4	3□Receive a second revision operation 1□Conservative treatment and reduced activity
Osteogenesis failure	2	2: Conservative treatment

*I&D□irrigation and debridement

Table 3 The basic data of ICA and CSA+ICA

Bone grafting method	ICA	CSA+ICA	Total
Number	18	29	47
Age (years)	58.7±7.6(46-70)	65.0±10.5(48-84)	62.5 ± 9.9
Gender (female/male)	10/8	19/10	29/18
Time from primary THA to PFFs(months)	105.9±35.8(9-155)	107.0±44.3(12-187)	106.6±40.8
Injury mechanism			
mild trauma	9	21	30
immense trauma	5	2	7
unknown cause	4	6	10
Paprosky femoral defect (n)			
□	5	0	5
□A	13	17	30
□B	0	9	9
□	0	3	3
Harris score (month)			
3rd	44.4±12.2	44.8±17.1	44.6±15.2
12th	59.2±33.7	63.3±27.3	61.7±29.6
60th	83.2±10.2	80.6±7.2	81.8±8.6
SF-36 (last time)	47.1±13.3	45.6±16.9	46.1±15.5

Figures

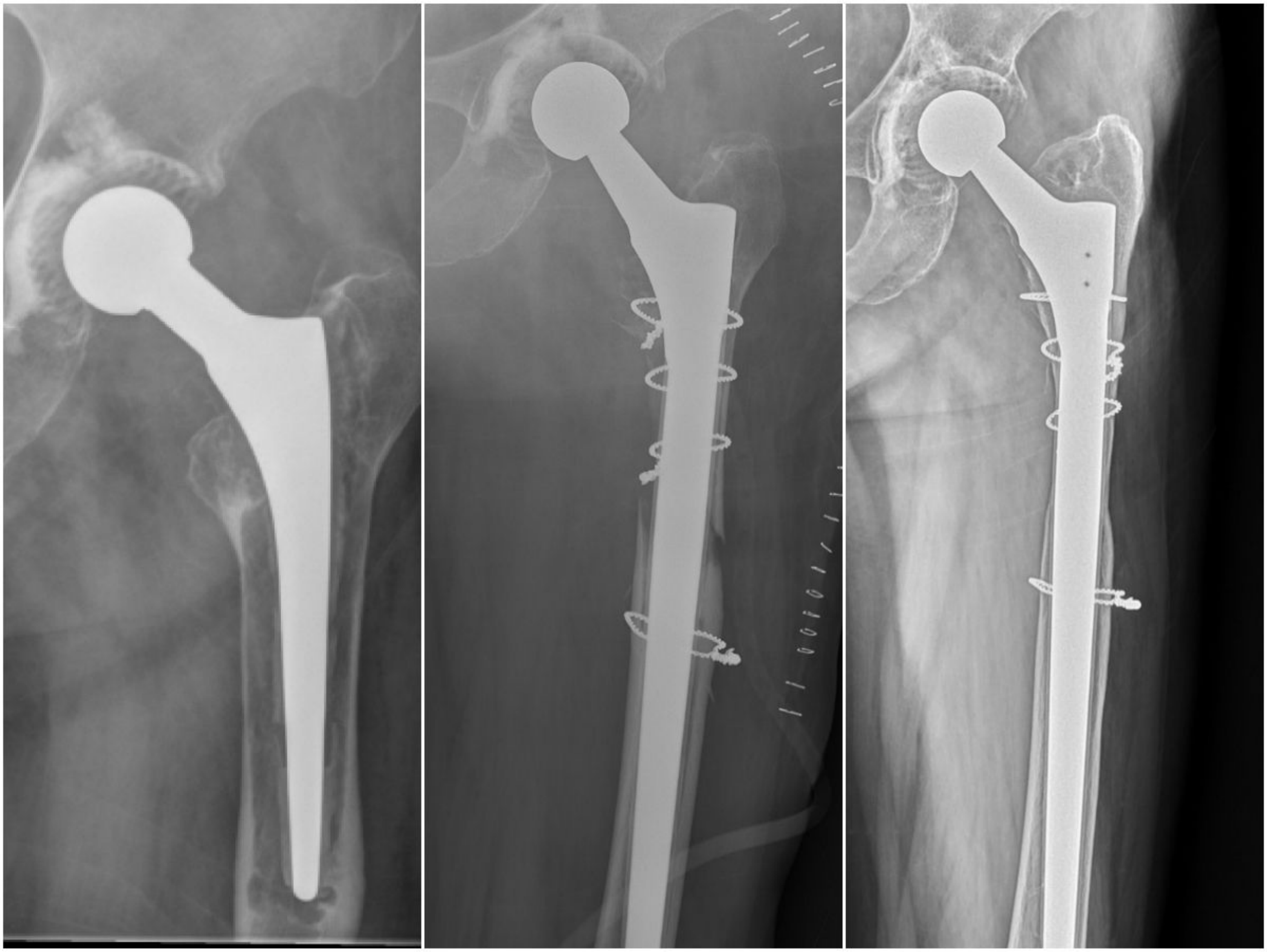

Figure 1

A case of intraoperative PFF treated with ICA.

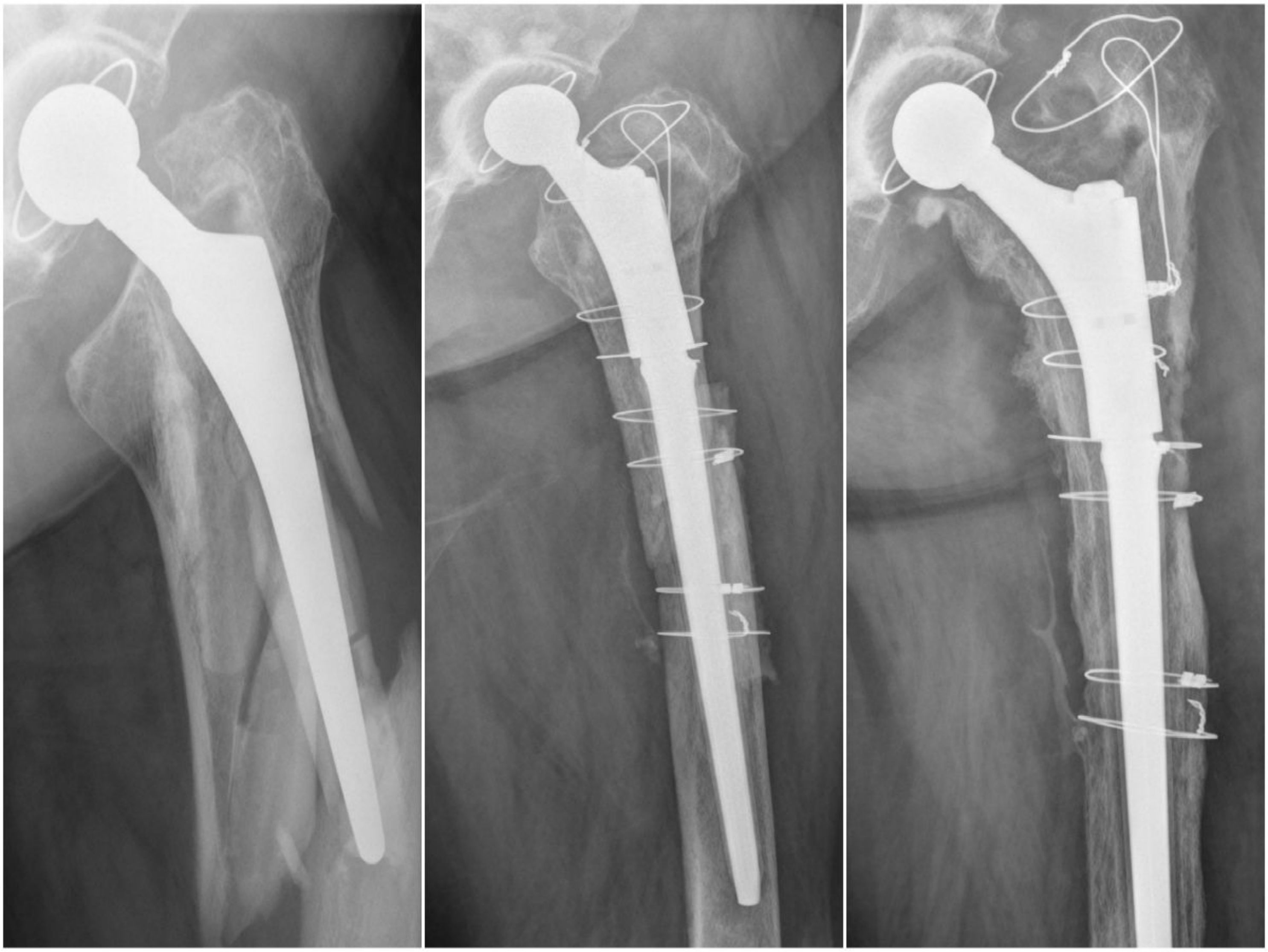

Figure 2

Vancouver B3 type PFF treated with CSA+ICA, radiological result at three-year after revision showing union of cortical strut allograft to host femur, but there was osteolysis around the stem.

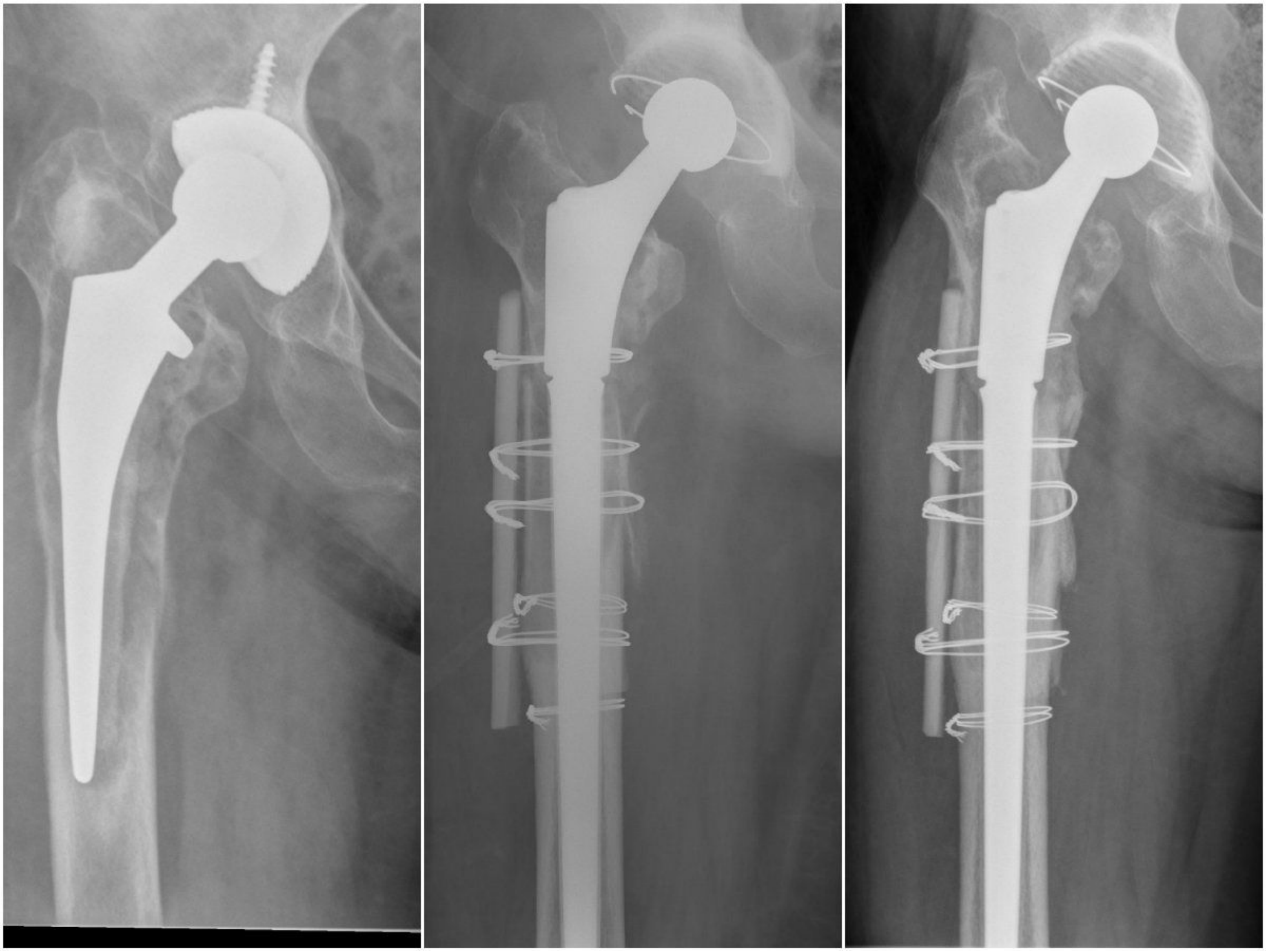

Figure 3

Kaplan-Meier survival curve for patients after revision total hip arthroplasty (THA) for Vancouver type B3 PFFs

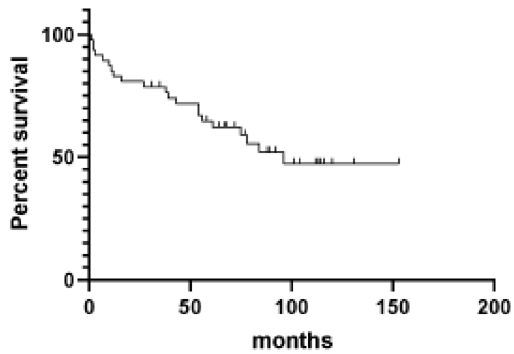

Figure 4

A case of intraoperative PFF treated with CSA+ICA, one-year postoperative X-ray showing cortical strut allograft failed osseointegration.

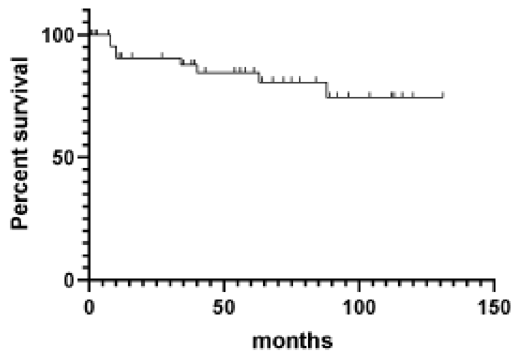

Figure 5

Kaplan-Meier survival curve (revision for any cause) for revision total hip arthroplasty (THA) due to Vancouver type B3 PFFs