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RESEARCH

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Surgical management of fracture-related infection (FRI) in the proximal femur: treatment options and long-term outcome

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Abstract

Background The treatment of fracture-related infection (FRI) in the proximal femur presents a challenge due to the need to maintain both stability and function of the hip joint while eradicating the infection. This study aimed to analyze the outcomes of antibiotic-loaded bone cement(ALBC) combined with a locking plate for the treatment of these patients.

Patients and methods From January 2013 to January 2024, adult patients diagnosed with FRI in the proximal femur were included. All were treated with ALBC combined with a locking plate after debridement at our clinical center. Patients with a minimum of 2 years of follow-up, along with clinical and functional results, were retrospectively analyzed.

Results A total of 83 consecutive patients were included. The initial osteosynthesis was with a nail in 56(67.5%) patients and with a plate in 27(32.5%). The *S. epidermidis (20.5%)* was the most common pathogen, followed by *S. aureus (16.9%)* and *E. coli (14.5%)*. A staged reconstruction procedure was performed in 61 (73.5%) patients due to larger bone defects. After a median follow-up of 36 (range: 24–72) months, nine patients (10.8%) required additional revision, with seven due to recurrence and two due to nonunion. Infection-free bone union was achieved in all patients (100%) at the final follow-up. A significant increase in the Harris hip score (HHS) was observed, from a preoperative value of 65.7 ± 10.6 to a postoperative value of 84.3 ± 7.5 ($P > 0.05$). No cases of re-fractures or implant/cement spacer loosening were reported. Univariate analysis showed that prolonged infection duration, diabetes, and systemic diseases were associated with the additional revision.

Conclusion The use of ALBC combined with a locking plate served as a low-burden alternative in management of FRIs in the proximal femur, effectively reconciling infection eradication with functional preservation. Prolonged infection duration and increased comorbidities complicated the treatments.

Keywords Femur, Fracture-related infection, Antibiotic-loaded bone cement

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Introduction

Fracture-related infections (FRIs) are significant complications [1–4] in orthopedic surgery, with the treatment of FRI in the proximal femur representing a particular clinical challenge due to its rich vascular supply, proximity to the joint, and the complexity of surgical interventions in this area. The management of FRIs in the proximal femur [5, 6] must balance the maintenance of the stability and function of the hip joint with infection eradication. FRIs in the proximal femur are often associated with substantial morbidity, prolonged hospital stays, increased medical costs, and potential long-term disability. In addition to debridement and systemic antibiotic therapy [7, 8], local antibiotic delivery systems [9] have emerged as an effective method for treating orthopedic infections. Among these systems, antibiotic-loaded bone cement (ALBC) [9–11] has gained widespread acceptance for its ability to deliver high local concentrations of antibiotics while minimizing systemic toxicity. ALBC is typically used as spacers or beads placed at the infection site during debridement surgery. The localized release of antibiotics from the cement helps create a hostile environment for bacteria, facilitating infection eradication.

In addition to antibiotic therapy, maintaining the stability of the fracture site is crucial for the successful treatment of FRI. Traditionally, the external fixation [12] has been considered the gold standard for treating orthopedic infections, as it aids in eradicating infection and protecting fragile soft tissue. However, it often poses a high burden of complications and intolerance [12, 13], particularly in patients with FRIs in the proximal femur. The external fixation often needs to across hip joint in this area, it is inconvenient to both functional recovery and patients care. Recently, there has been an increasing use of locking plates combined with ALBC [14–16] in the treatment of various orthopedic infections. In which, the ALBC helps reduce subsequent bacterial colonization on inert surfaces and supports locking plates for internal fixation, providing enhanced stability and allowing for earlier patient mobilization. However, these treatment strategies largely rely on surgeon preference and institutional experience [16]. The specific role and efficacy of this combined approach in managing FRI in the proximal femur have not been fully elucidated.

This study aimed to investigate the outcomes of patients treated with ALBC combined with locking plates for FRIs in the proximal femur. We analyzed data from a cohort of patients with surgical treatment for FRIs in the proximal femur at our institution. We hypothesized that the combined use of ALBC and locking plates would result in high infection eradication rates and favorable functional outcomes for patients with FRIs in the proximal femur. Our results complemented the existing body of knowledge on this topic and provided evidence-based guidance for future treatment.

Patients and methods

Patients and preoperative evaluation

Following a review of digital medical records, 83 consecutive patients with FRIs after proximal femur fractures were selected for retrospective analysis. These patients were treated with ALBC combined with locking plates after debridement at our center between January 2013 and January 2024. The diagnosis of FRI was established based on a comprehensive assessment, including at least one of the following findings [4, 17, 18]: (i) Patients with the presence of a fistula, sinus, or wound dehiscence, purulent drainage from the wound, or the detection of pus during surgery; (ii) Patients with phenotypically indistinguishable pathogens identified by culture from at least two distinct deep specimens; or (iii) Patients with the microorganisms detected in deep specimens confirmed by histopathology or histological evidence suggestive of infection. The local institutional review board approved this retrospective study, and the investigation was conducted in accordance with in accordance with the Declaration of Helsinki, the informed consent was waived as this is an observational cohort study.

Upon diagnosis, a multidisciplinary team(MDT) (e.g. orthopedic surgeons, infectious disease specialists, and clinical pharmacists) collaboratively determined treatment plans based on clinical, radiological, and microbiological assessments. The MDT then classified disease severity(e.g. Cierny-Mader host classification) and eligibility for conservative or surgical management. These patients underwent comprehensive local and systemic evaluations to optimize preoperative conditions. For surgical candidates, specific surgical plan were finalized by the operating orthopedic surgeon in consultation with the patient. In thus case, twenty-one patients were excluded from the study for various reasons: five were younger than 18 years, three had Cierny-Mader (C-M) Host Type C infections (deemed unsuitable for surgery), nine had less than 24 months of follow-up, and four had concurrent hip joint infections, which would impact joint function assessment. Consequently, the final study population consisted of 83 patients. Preoperative information was collected, including the patients' history of previous trauma and surgery, current laboratory diagnostic indicators, imaging procedures, and physical examination findings. In the absence of hip joint infections, the scope of debridement and fixation method were determined based on radiography, radionuclide bone scans, magnetic resonance imaging (MRI), and computed tomography (CT). Table 1 presents the basic data of these cases.

Table 1 Patients characteristics

Patients	n=83	Patients	n=83
Mean age (yrs)	48.44±16.02	**Systemic Antibiotic therapy**	
Age stratification, n(%)		IV therapy, median days	21(14-28)
18-39 yrs	25(30.1)	Oral therapy, median days	14(7-42)
40-59 yrs	38(45.8)	**Bone reconstruction**, n(%)	
≥60 yrs	20(24.1)	None	22(26.5)
Male, n(%)	61(73.5)	Staged bone graft	43(51.8)
Smoke, n(%)	24(28.9)	Bone transport	18(21.7)
Prior fracture, n(%)		**Microbiology**, n (%)	
Closed	62(74.7)	*S. epidermidis*	17(20.5)
Open	21(25.3)	*S.aureus*	14(16.9)
Prior debridement≥2, n(%)	44(53.0)	*E. coli*	12(14.5)
Initial osteosynthesis, n(%)		*P. aeruginosa*	5(6.0)
Intramedullary nail	56(67.5)	*K.pneumonia*	4(4.8)
Osteosynthesis plate	27(32.5)	None	33(39.8)
Clinical features, n(%)		**Treatment outcome**	
Diabetes	9(10.8)	Follow up, median mths	36(24-72)
Systemic disease	16(19.3)	Additional revision, n(%)	9(10.8)
Sinus	52(62.7)	Final infection cure, n(%)	83(100)
Infection duration≥3 mths	61(73.5)	Final bone union, n(%)	83(100)
Cierny- Mader host, n (%)		**Harris Score***	
Type A	14(16.9)	Preoperative	65.7 ± 10.6
Type B	69(83.1)	Post-op 2 year	84.3 ± 7.5

*Paired-sample t-test, $P < 0.001$

Surgical technique and postoperative treatment

Debridement was generally carried out through the original incision (Fig. 1), and the gauze compression method was actively used to control bleeding, ensuring a relatively bloodless surgical field. Soft tissue debridement was performed with a 2 mm margin of healthy tissue, and bone debridement extended to a 5 mm margin of healthy bone. Sinuses, scars, sequestra, inflammatory granulation tissue, and foreign bodies (including implants and allografts) were thoroughly removed until healthy bone was exposed. Following radical debridement, antibiotic-loaded polymethyl methacrylate (PMMA) bone cement containing gentamicin (Heraeus, Germany) was used to fill bone defects (Figs. 1D-E and 2B). Our surgical team added 5 g of vancomycin to 40 g of gentamicin PMMA bone cement. For patients with initial nail osteosynthesis, a bone cement rod was implanted into the bone marrow, with K-wires serving as the inner cores (Fig. 3D). The fractured ends were stabilized using an antibiotic cement-coated locking plate(Fig. 1E-F). Broad-spectrum antibiotics were empirically administered as part of the anti-infective therapy. The anti-infection plan was adjusted based on bacterial culture results and drug sensitivity testing. All patients received intravenous antibiotics for two weeks, followed by four weeks of oral antibiotics.

For patients with larger bone defects, a second-stage bone reconstruction surgery was planned. This surgery was scheduled six to eight weeks after the first stage. During the second stage, the bone cement and implants were completely removed, and the fractured bone ends were cleaned to create fresh wounds. Subsequently, fixation was performed using a properly nail or sized locking plate (Synthes, Switzerland). An autograft from the anterior or posterior iliac crest was used to fill the bone defect for patients with bone graft, and bone transport was performed inpatients with larger defects. Non-weight-bearing functional exercises were permitted within three months after surgery. Initially, patients were instructed to perform range-of-motion exercises for the hip joint, with strict prohibition of weight-bearing. After three months, radiographs were performed to assess the feasibility of gradually increasing weight-bearing.

Follow-up

Follow-up evaluations, including radiological and clinical assessments, were conducted at two, four, six, nine, twelve, eighteen, and twenty-four months. The Harris hip score (HHS) was used to quantify functional outcomes. During each follow-up appointment, plain radiographs of the affected proximal femur were obtained in both the medial-lateral and anterior-posterior planes. Radiological healing was defined as the formation of callus in at least three of the four cortices. Patients who were able to fully bear weight and were free of pain were considered to have achieved clinical healing. Recurrence of infection, defined as a relapse at the same site from which the infection had been previously eradicated following the cessation of therapy and a period of infection cure, aligning with the established diagnostic criteria for fracture-related infection (FRI). A patient who remained infection-free for 2 years post-treatment was classified as having achieved an "infection cure". The two independent and experienced trauma surgeons were responsible for the clinical assessment.

Statistical analysis

All data were analyzed using SPSS version 22.0 statistical software (IBM, USA). Continuous variables were expressed as means and standard deviations, whereas those with non-normal distributions were presented as

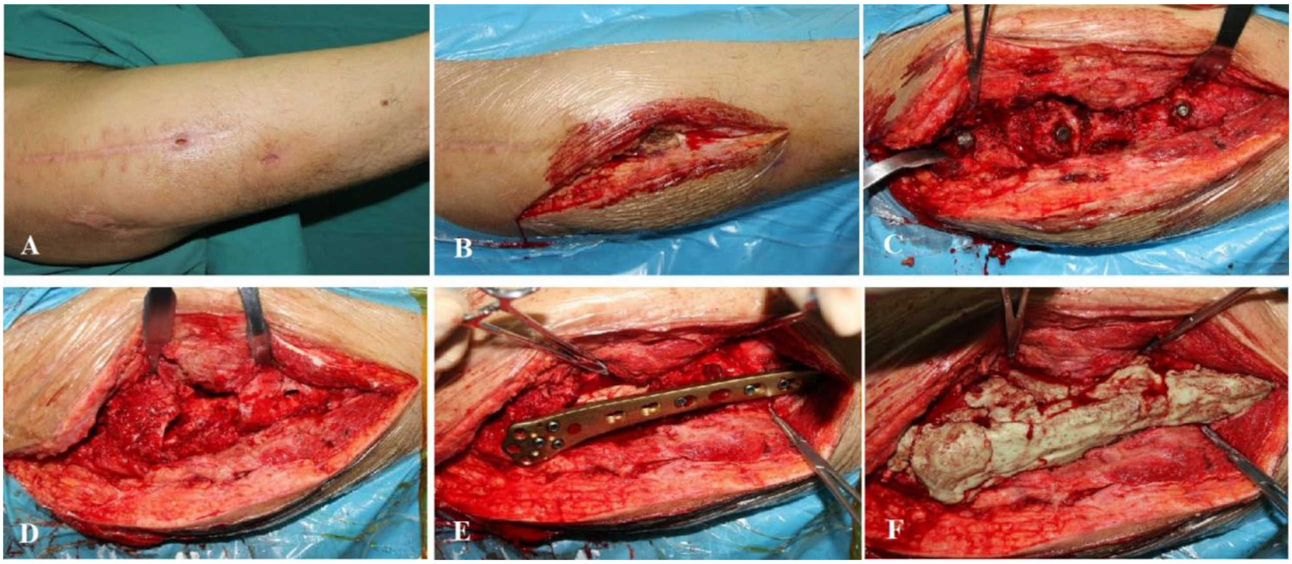

Fig. 1 Representative pictures of intraoperative debridement and combined treatments with ALBC and locking plate. (**A**) Shows an obvious sinus tracts in proximal thigh. (**B**-**C**) The sinus tract was removed along the original incision, all necrotic tissue and implant were completely removed. (**D**-**E**) Residual bone defects were filled with antibiotic-loaded bone cement, skeletal stabilization with locking plate internal fixation. (**F**) The bone cement coated the plate completely

Fig. 2 Surgical treatments and results of a FRI patient in proximal femur within younger group (18–39 years). (**A**) Preoperative radiograph showed the initial osteosynthesis was with a nail. (**B**) Post-debridement radiograph showed combined treatments with ALBC and locking plate. Radiograph follow-up with 2 month (**C**) and 4 month (**D**) after second stage bone graft. The long-term follow-up at 9 month (**E**), 12 month (**F**), 24 month (**G**) and 48 month (**H**), showing an complete bone healing achieved

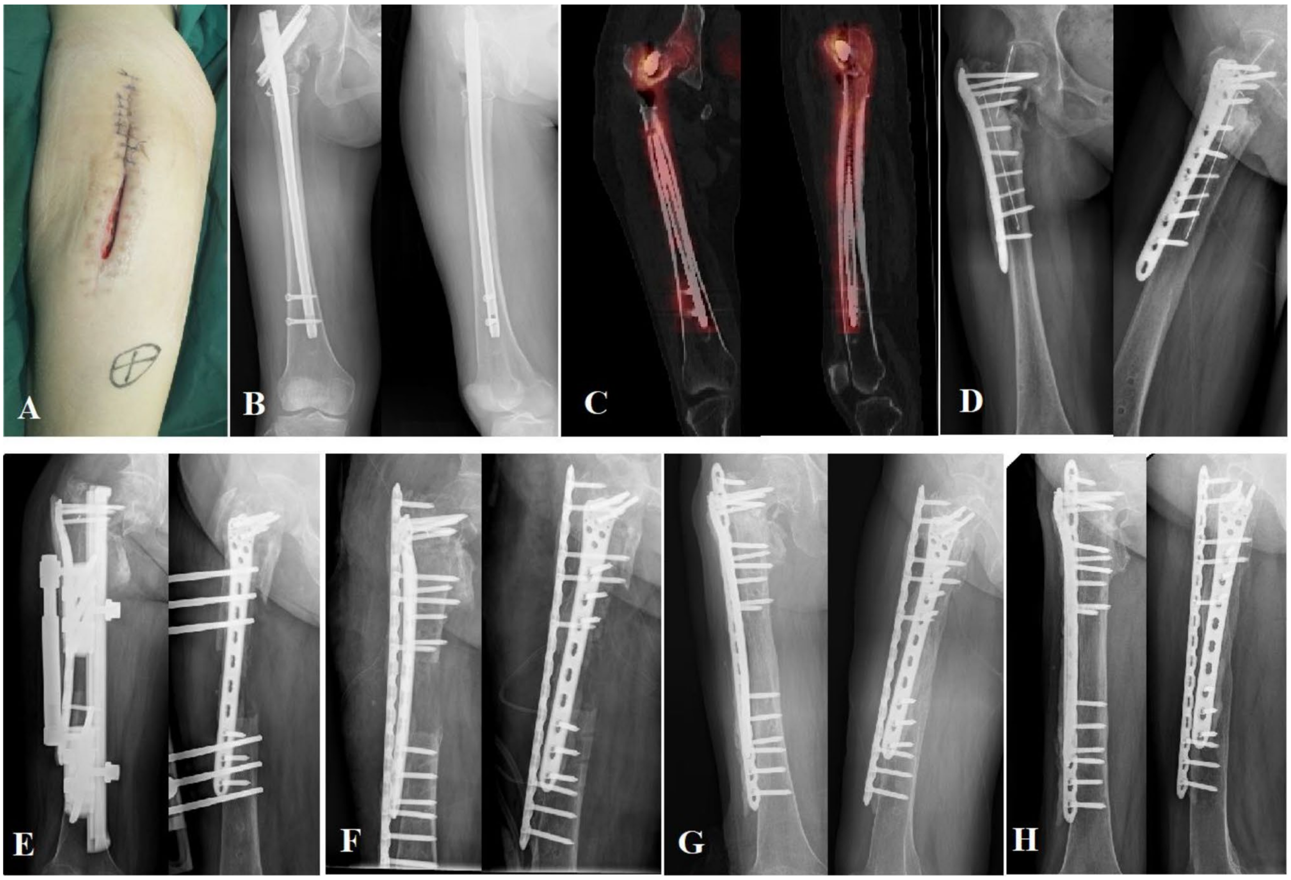

Fig. 3 Surgical treatments and results of a FRI patient in proximal femur within middle-age group (40–65 years). (**A**) Shows an obvious open wound in proximal thigh. The Radiograph (**B**) and bone scan **C**) showed a nail-related infection in proximal femur. (**D**) Post-debridement radiograph showed combined treatments with ALBC and locking plate. (**E**) Second stage bone reconstruction with bone transport. (**F**)The external fixation was removed and the bone ends strengthened using a steel plate. The long-term follow-up at 6 month (**G**) and 24 month (**H**), showing an complete bone healing achieved

medians and ranges. Categorical variables were described using frequencies and percentages, and were analyzed using the chi-square test or Fisher's exact test, as appropriate. A p-value of less than 0.05 from a two-sided test was considered statistically significant.

Results

Among the 83 patients, the mean age was 48.44 ± 16.02 years, the majority were male (73.5%), 21 (25.3%) patients had open fractures, while 62 (74.7%) had closed fractures. And the initial osteosynthesis was with a nail in 56(67.5%) patients and with a plate in 27(32.5%). The diagnostic signs of FRI included open sinus in 52 patients (62.7%), most patients (73.5%) had more than 3 months infection duration. A proportion (53.0%) of patients had undergone more than one revision surgery before admitted to our hospital (see Table 1). Bacterial detection was observed in 50 patients (60.2%), with *Staphylococcus epidermidis* (*S. epidermidis*, 20.5%) being the most prevalent pathogen, followed by *Staphylococcus aureus* (*S. aureus*, 16.9%) and *Escherichia coli* (*E. coli*, 14.5%).

All 83 patients achieved satisfactory outcomes during the median follow-up period of 36 months (range: 24 to 72 months), with none requiring amputation. Following initial debridement, 61 patients underwent two-stage reconstruction surgery for larger bone defects, treated with autografts (Fig. 2C) in 43 patients and bone transport (Fig. 3E) in 18 patients. The remaining 22 patients did not undergo reconstructive surgery (Fig. 4). Nine patients required additional revision surgeries: seven underwent repeated debridement due to recurrent infections, and two underwent additional bone grafting for nonunion (Table 1). At the final follow-up, all patients (100%) achieved infection-free bone union. The median radiological healing occurred at 6 months post-surgery, with an interquartile range of 4 to 12 months. No re-fractures or implant/cement spacer loosening were reported during at least 24 months of follow-up.

The mean HHS at the final follow-up was 84.3 ± 7.5 points, representing a significant improvement compared to the preoperative score of 65.7 ± 10.6 points. Univariate logistic regression analysis revealed that factors such as age, sex, smoking status, prior fractures,

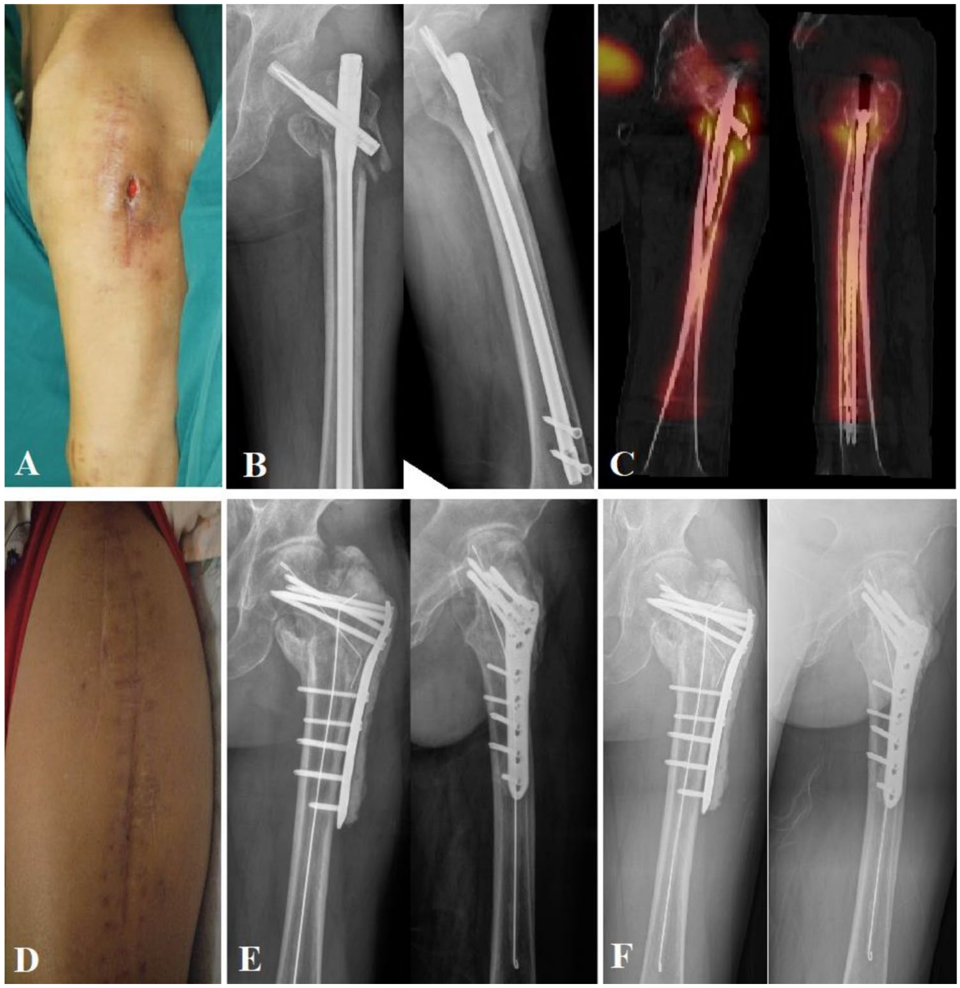

Fig. 4 Surgical treatments and results of a FRI patient in proximal femur within older group (>65 years). (**A**) Shows an obvious sinus tract in proximal thigh. The Radiograph (**B**) and bone scan(**C**) showed a nail-related infection in proximal femur. (**D**) Showed good soft-tissue healing and infection cure after debridement. (**E**) Post-debridement radiograph showed combined treatments with ALBC and locking plate. Patients did not undergo reconstructive surgery in considering the smaller bone defect and life expectancy, the long-term follow-up at 24 month (**F**), showing an complete bone healing achieved, and no implant/cement spacer loosening occured

previous debridement, prior implant use, C-M host type, sinus formation, bone reconstruction, and specific bacterial strains (e.g., *S. aureus*, *S. epidermidis*, Gram-negative bacilli) were not associated with the need for additional revision surgery (Table 2). However, an extended duration of infection (≥ 3 months) ($p = 0.025$) and comorbidities such as diabetes ($p = 0.004$) and systemic diseases ($p = 0.034$) were significantly associated with the need for additional revision surgeries ($P < 0.05$). To determine predictors of functional recovery, factors such as age, infection duration, and prior operations were analyzed. Patients older than 60 years ($p = 0.009$), those with a history of external fixation use ($p = 0.011$), and those with a prolonged duration of infection ($p < 0.001$) were more likely to experience poor functional outcomes, as determined by independent-samples t-tests (Table 3).

Discussion

This study demonstrate the dual efficacy of our approach: ALBC ensured localized infection control and dead space management, while locking plates provided stable fixation to facilitate early mobilization—critical for preserving hip function in this anatomically complex region [2, 5, 6]. In our cohort of 83 patients with FRIs in the proximal femur, we implemented an initial debridement procedure, followed by combined treatments of ALBC and a locking plate for internal fixation. Notably, all patients achieved 100% infection-free bone union at the final follow-up, with satisfactory restoration of hip joint function. Recurrence occurred in 8.4% (7/83), predominantly associated with prolonged infection duration, diabetes, or systemic comorbidities. This contrasts with a large-scale DHS study ($n = 532$) reporting a 1.3% infection rate post-osteosynthesis, where 29% of infections ultimately

Table 2 Univariate logistic regression analysis of potential predictive factors associated with additonal revision (*n*=9)*

Variables	OR (95% CI)	*P* value	Variables	OR (95% CI)	*P* value
Demographic			Clinical features		
Age stratification:≤39 yrs (ref)			Infection duration:≥ 3 mths vs. less (ref)	0.07(0.01-0.72)	0.025**
40-59 yrs	2.28(0.22-23.69)	0.490	C- M host type: B vs. A (ref)	1.18(0.12-11.67)	0.890
≥ 60 yrs	1.46(0.08-25.53)	0.795	Diabetes vs. no (ref)	19.88(2.54-155.58)	0.004**
Male vs. female (ref)	2.05(0.31-13.53)	0.457	Systemic disease vs. no (ref)	8(1.17-54.88)	0.034**
Smoke vs. no (ref)	0.59(0.06-5.66)	0.646	Sinus vs. no (ref)	1.02(0.16-6.56)	0.988
Prior fracture: open vs. closed (ref)	0.46(0.05-4.42)	0.503	Bone reconstruction vs. none (ref)	2.71(0.28-25.78)	0.387
Multiple debridement(≥2)vs. no (ref)	3.86(0.41-36.71)	0.240	**Microbiology**		
Prior implant: none (ref)			S. epidermidis vs. no (ref)	3.13(0.46-21.27)	0.242
Nail	0.93(0.09-10.10)	0.953	S.aureus vs. no (ref)	1.33(0.13-1.35)	0.807
Plate	0.47(0.03-8.46)	0.611	Gram negative bacilli vs. no (ref)	0.94(0.10-9.18)	0.956

*CI, confidence interval; OR, odds ratio; C- M host type, Cierny- Mader host type; ***P*<0.05

Table 3 Harris score between different goups*

Patient groups(*n*)	Harris Score(SD)	Patient groups(*n*)	Harris Score(SD)
Age stratification		Infection duration	
18-59 yrs(63)	83.10(8.73)	≥3 mths(61)	78.32(6.92)
≥60 yrs(20)	77.14(6.98)	Less than 3 mths(22)	86.48(9.16)
P value	0.009**	*P* value	<0.001**
Sex		**Prior debridements**	
Male(61)	83.50(10.04)	*n*≥2(44)	79.47(4.81)
Female(22)	80.09(7.86)	*n*<2(39)	81.60(9.49)
P value	0.158	*P* value	0.258
Smoke		**Prior use of external fixation**	
Yes(24)	80.65(8.63)	Yes(19)	76.78(7.28)
No(59)	81.52(8.70)	No(64)	82.84(8.55)
P value	0.694	*P* value	0.011**
Prior fracture, **n(%)**		**Bone reconstruction**, n(%)	
Closed(62)	81.96(8.68)	Yes(61)	80(7.03)
Open(21)	77.42(7.55)	None(22)	82.48(10.27)
P value	0.101	*P* value	0.288
Cierny- Mader host, n (%)		**Addtional revision**	
Type A(14)	82.77(9.10)	Yes(9)	83.20(6.91)
Type B(69)	79.39(7.86)	No(74)	80.67(8.89)
P value	0.122	*P* value	0.400

*Independent-sample t-test, ***P*<0.05

failed to heal [19]. The result highlighted the successful application of this combined treatment approach in managing FRIs in the proximal femur.

Radical debridement [5, 19–22] is crucial for managing bone infections, as treatment success is associated with the thorough removal of dead and poorly vascularized tissue. However, the commonly used 'paprika sign' has limitations in accurately determining the appropriate extent of bone resection. Simpson et al. [23] recommended excising all necrotic and infected bone with a 5 mm or greater margin of healthy tissue for C-M Host B, and a smaller margin for C-M Host A. In our study, we determined the extent of bony infection using a combination of imaging modalities, including radionuclide bone scans, CT scans, and plain radiographs. The infected bone was visualized as a cystic structure containing sequestrum, pus, and implants, with the junction between infected and normal tissue serving as the cyst wall. Radical debridement was performed to completely remove the entire cystic structure, including a 2 mm margin of normal soft tissue around the cyst wall. This approach transformed infected wounds into contaminated wounds, optimizing conditions for internal fixation stabilization. Impressively, 91.6% (76/83) of our patients achieved satisfactory infection control after just one surgery, underscoring the efficacy of our radical debridement technique.

Dead space management [9–11] is critical in FRI treatment. The unaddressed dead space may provide an ideal environment for bacteria and can be a potential site for recurrent infection. For this reason, there is an increasingly use of local antibiotic delivery systems [10], both for local antimicrobial activity and dead space management. Among these, antibiotic-loaded PMMA bone cement is the most commonly used clinical option. Since its introduction in 1970s for orthopedic infection treatment, ALBC has emerged as a vital strategy for managing dead space and delivering antibiotics locally [9, 11]. The subsequent studies have consistently demonstrated its efficacy in infection control, with infection cure rates ranging from 87–100% [24–26]. In the stage method of the induced membrane technique [24], antibiotic cement spacers not only deliver antibiotics locally but also eliminate dead spaces and induce the formation of a bioactive membrane, facilitating future bone grafting. For intramedullary infections, the use of antibiotic bone cement-coated rods [26–28] is also common. In our study, 56 patients (67.5%) with initial osteosynthesis using a nail were treated with this method, which kept closer contact with the entire medullary cavity and effectively eluted antibiotics to the endosteal surface (the primary focus site). Although bone cement is typically removed during secondary surgery, the spacers can also serve as a definitive treatment in some cases of bone infection. The favorable infection cure rate observed in our case series further emphasizes the importance of dead space management using ALBC.

Another significant advantage of ALBC is its ability to support internal fixation using locking plates. This is achieved through coating strategies [29] that enhance local antimicrobial therapy and reduce bacterial adhesion. Conway et al. [14] were among the first to integrate antibiotic bone cement with locking plates to manage infected nonunion, successfully achieving both fracture healing and infection control in all four patients with tibial infections. In China, our team has pioneeringly applied this technique to stabilize bone defects following chronic osteomyelitis debridement. In an early report [15], twelve patients of femoral osteomyelitis treated with this approach achieved complete infection cure, prompting some scholars to refer to it as the "Chongqing Technique" [30]. One of the main advantages of this antibacterial coating for internal fixation is its ability to reduce complications and burdens, such as nail tract infections, joint contractures, and patients intolerance, which are often associated with prolonged external fixation in traditional bone infection treatments. Recently, an comparative study [31] including 40 osteomyelitis cases treated with this method reported an impressive overall infection cure rate of 92.5%, which is competitive with outcomes from external fixators group (95.7%, $P = 0.621$). Of note, although bone stabilization procedures largely rely on clinical experience, they must also consider several factors, including the infection location, the quality of surrounding soft tissue, solid fixation for treatment, and patient comfort. Our study suggests that antibiotic cement-coated locking plates provide a low-burden option for the treatment of FRIs in the proximal femur. To optimize clinical outcomes, we emphasized the importance of thorough surgical debridement, tailored antibiotic sensitivity based on pathogens, and adequate soft tissue coverage.

In addition to infection eradication, achieving definitive bone union and restoring hip joint functionality are key objectives. Our study enrolled 61 patients who required bone reconstruction, all of whom achieved bone union, demonstrating the efficacy of antibiotic cement-coated locking plates for stable bone healing. Importantly, this stabilization did not adversely affect hip joint function. The mean HHS significantly improved from 65.7 ± 10.6 points preoperatively to 84.3 ± 7.5 points at the final follow-up. This improvement is attributed to early functional exercises post-debridement. The minimal burden and convenience provided by internal fixation further facilitated this recovery process. Generaly, the prolonged joint immobility, exceeding three to four weeks, can lead to permanent joint stiffness. Our findings were consistent with previous reports [6, 32, 33] that a longer infection duration compromised joint function. Specifically, we observed a direct correlation between the duration of infection and postoperative functional recovery. Comorbidities such as advanced age, diabetes, and systemic diseases, as well as prior use of external fixation, also influenced treatment outcomes, providing a basis for optimizing clinical management and patient counseling.

Despite the strengths of our study, this study has limitations inherent to its retrospective, single-center design. The absence of a control group precludes direct comparisons of treatment efficacy, while potential selection bias and heterogeneity in surgical protocols may confound outcome interpretations. Although our cohort represents the largest reported series of proximal femoral FRIs managed with ALBC-locking plate fixation, the sample size limited granular analyses of rare pathogens or complex comorbidities. Furthermore, although we have provided a long term follow-up(median 36-month), the extra-long-term complications may still be overlooked. The single-center setting, while ensuring standardized multidisciplinary care, raises generalizability concerns for institutions lacking comparable expertise. Nevertheless, our findings provide foundational evidence supporting this approach as a low-burden alternative in anatomically challenging FRIs, balancing infection control with functional preservation. Future prospective, multicenter studies with matched controls are warranted to validate these results and refine patient selection criteria.

Conclusion

Managing FRI in the proximal femur is challenging, as it requires both effective infection eradication and the preservation of hip stability and function. The use of ALBC combined with a locking plate for internal fixation offers a low-burden alternative for the treatment of FRI in the proximal femur, effectively reconciling both infection cure and functional recovery. The successful treatment relies on thorough radical debridement, the use of antibiotic cement to fill dead spaces and cover the internal fixation plate, and prompt infection control. Additionally, optimizing patient management is important for achieving a good outcome.

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Author contributions

H.Wu: Conceptualization, Investigation, Writing– original draft. J. Shen: Conceptualization, Investigation, Writing– original draft. S. Wang: Investigation, Data curation. J.Fu: Investigation, Data curation. D. Sun: Conceptualization, Formal analysis. X. Wang: Investigation, Data curation. T. Xu: Conceptualization, Funding acquisition, Writing– review & editing.Z. Xie: Conceptualization, Funding acquisition, Writing– review & editing.

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Data availability
The data that support the findings for this study are available to other researchers from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Southwest Hospital, Chongqing, China (No. KY201878). The informed consent was waived by Ethics Committee of Southwest Hospital, Chongqing, China, as this is an observational cohort study and personal information was de-identified (Clinical trial number: not applicable).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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