CLINICAL ARTICLE

Conversion Hip Arthroplasty Using Standard and Long Stems after Failed Internal Fixation of Intertrochanteric Fractures

Tengbin Shi, MD[1,2], Xinyu Fang, MD, PhD[2], Changyu Huang, MM[2], Weiming Li, MD, PhD[3], Ruijin You, MD, PhD[4], Xu Wang, MD[5], Chun Xia, MD, PhD[6], Wenming Zhang, MD, PhD[2]

[1]Department of Orthopaedic, Fujian Medical University Union Hospital, [2]Department of Orthopaedic, The First Affiliated Hospital of Fujian Medical University and [3]Department of Orthopaedics, Fuzhou Second Hospital Affiliated to Xiamen University, Fuzhou, [4]Department of Orthopaedics, 910th Hospital of PLA, Quanzhou, [5]Department of Joint Surgery, Mindong Hospital Affiliated to Fujian Medical University, Ningde and [6]Department of Joint Surgery, Zhongshan Hospital Xiamen University, Xiamen, China

Objective: Failed internal fixation of intertrochanteric fractures (FIF-ITF) is often treated by conversion hip arthroplasty (CHA). This study aimed to evaluate the results and complications of using standard and long femoral stems in this operation.

Methods: This retrospective, multi-center study enrolled 31 total hip arthroplasty (THA) and 23 hemiarthroplasties (HA) cases (30 women, 24 men; mean age 76 years) after FIF-ITF between 2012 and 2019, divided into two groups: standard stem group (n = 20) and long stem group (n = 34). The initial internal fixation includes 38 cases of proximal femoral nail anti-rotation (PFNA), eight cases of the dynamic hip screw (DHS), and eight cases of locking proximal femoral plate (LPFP). The indications for CHA included 38 cases of failure of fixation, seven cases of nonunion, and nine cases of avascular necrosis or posttraumatic osteoarthritis. Perioperative data and complications related to fracture and operation were collected, and preoperative and postoperative clinical and radiological data were analyzed. Clinical outcomes were assessed using Harris hip score (HHS) and 36-item Short Form survey (SF-36: including physical function (PF) score and body pain (BP) score). Statistical analyses were performed using the chi-square or Fisher's exact test, and the 2-sample *t*-test or Wilcoxon rank sum test.

Results: At an average of 5.6 years with a minimum of 2 years follow-up. A significant overall surgeon-related complication rate was detected (27.8% [15/54]), five cases had an intraoperative femur fracture, one case had a late periprosthetic femoral fracture, two cases had a stem penetration, one case had a cement leakage, and two patients had an early postoperative dislocation, one infection and three cases of stem loosening or subsidence. Long stems had an increased risk of complication (13/34) compared to standard stems (2/20) ($P = 0.031$). The operation time and blood loss in the long stem group were higher than those in the standard stem group ($P = 0.002$; 0.017). HHS and SF-36 significantly improved in both groups from preoperative to the final follow-up and did not present significant differences at the final follow-up ($P > 0.05$).

Conclusion: CHA following FIF-ITF showed a successful mid-term clinical result, long stem arthroplasty should be approached with caution for the risks of higher complication rate, especially intraoperative femoral fractures.

Key words: Failed internal fixation; Hip arthroplasty; Intertrochanteric fracture; Long femoral stem; Standard femoral stem

Introduction

The incidence of intertrochanteric fractures (ITF) has rapidly increased with the population ages, and most intertrochanteric fractures can be effectively treated with internal fixation,[1,2] nevertheless, previous studies have reported that the failure rate of internal fixation has reached

Address for correspondence Wenming Zhang, MD, PhD, Department of Orthopaedics, The First Affiliated Hospital of Fujian Medical University, No.20 Chazhong Road, Fuzhou, 350005, China. Email: zhangwm0591@fjmu.com Chun Xia, Department of Joint Surgery, Zhongshan Hospital Xiamen University, Xiamen, Fujian, 361004, China. Email: chunxia@xmu.edu.cn
Received 23 May 2022; accepted 1 October 2022

Orthopaedic Surgery

up to 1.2% to 9.6%,[3,4] manifests in coxa vara, internal fixation loosening or fracture, serious hip pain, and loss of hip function; and often requires reoperation. The surgery of failed internal fixation includes re-osteosynthesis or conversion hip arthroplasty (CHA). Surgeons prefer a revision internal fixation with selected bone grafting for young patients with failed internal fixation of intertrochanteric fracture (FIF-ITF), in older patients with poor proximal bone quality and acetabular destruction by implant cutout from the femoral head, CHA is more preferred,[5] to effectively relieve hip pain, promote hip function recovery with earlier walking, avoid many complications caused by long-term bed rest, and improve the quality of life of patients.

Previous studies reported that hip arthroplasty for FIF-ITF is associated with higher blood loss, a longer length of stay, and increased total costs compared to primary THA,[6–8] therefore necessitating a separate discussion. Hip arthroplasty following such patients faces several challenges, including proximal femoral bone loss, proximal femur deformities, poor bone quality, possible gluteus medius muscle injury, and bone defects caused by residual screw holes. Prosthesis-related complications such as periprosthetic fracture, dislocation, prosthesis subsidence, and even periprosthetic joint infection are significantly higher compared to primary hip arthroplasty.[9,10] For these challenges, surgeons need to formulate an appropriate surgical plan, among which the selection of femoral prosthesis type, especially the long and standard femoral stems, is one of the most fundamental problems. However, the choice of standard or long femoral stems in this issue has lasted for a long time and has not subsided to this day.

Different studies have reported several types of femoral prosthesis in CHA for FIF-ITF patients,[11–15] and few studies have paid attention to the length of the femoral prosthesis, which has a momentous impact on the surgical results. In a previous study,[16] the standard stem was defined as having a standard length (total length greater than twice the distance from the tip of the greater trochanter to the base of lesser trochanter vertical distance) with metaphyseal fixation only or with meta- and diaphyseal fixation, and long stems as having a prolonged length with diaphyseal fixation only. For consideration of the possible stress riser effect at the distal screw hole, many researchers recommended the use of a long femoral stem in these osteoporotic patients, aiming to increase the contact area of the medullary cavity and bridge previous holes and defects. Previous studies have demonstrated that a long femoral stem has satisfied clinical results and suggested a long femoral stem as an optional implant choice.[13–15] However, a more expensive cost and higher surgical technical request compared to the standard femoral stem are the primary concern for surgeons, and possible thigh pain, further bone stock loss, stress shielding effect, high complications including intraoperative and postoperative periprosthetic fractures, and difficult revision in future are all the disadvantages of long femoral stems.[13] However, Zhang *et al.*[11] retrospectively analyzed 19 patients with cemented standard femoral stems, and no stress fracture occurred. Similarly, Morsi *et al.*[12] reported no late periprosthetic femoral fractures or implant loosening in 102 patients treated with standard stems after an average of 7.4 years of follow-up, these studies indicating a good prognosis for standard femoral stems treating FIF-ITF patients. Therefore, the choice of the length of the femoral stem remains controversial, and further study is needed.

The purpose of this multicenter retrospective study was: (i) to evaluate the results, technical problems, and complications of CHA following FIF-ITF patients in multicenters; and (ii) to compare the clinical efficiency of standard and long stems in this operation.

Materials and Methods

This retrospective study was approved by the institutional ethics of the First Affiliated Hospital of Fujian Medical University (IEC/IRB No: [2020]338), and a waiver for informed consent was obtained. From December 2012 to December 2019, FIF-ITF patients who received conversion hip arthroplasty at multi-centers including two university hospitals, two orthopedic centers, and five tertiary-care centers in the region were retrospectively analyzed.

Inclusive Criteria and Exclusion Criteria

Inclusive criteria: (i) patients received THA or HA for failed internal fixation of ITF (type AO/OTA 31. A) caused by previous trauma; and (ii) patients with radiographic follow-up until healing or failure and with a minimum of 2 years follow-up. Internal fixation failure was defined as any reason for required surgical intervention to replace the internal fixation. Exclusion criteria: patients with: (i) incomplete data; (ii) hip dysfunction before fractures; (iii) rheumatoid arthritis or other inflammatory diseases; (iv) renal or other organ failures, serious infectious diseases, tumors, and mental disorders; and (v) insufficient follow-up.

All preoperative clinical, laboratory, and radiographic data, the type of initial fracture, and the internal fixation performed were recorded, along with the cause of the fixation failure and the time between the fixation and its failure.

After excluding 12 patients who were lost to follow-up, and had insufficient data, 54 patients (30 women, 24 men) were eventually included (Table 1). Among them, 16 were from two university hospitals, 16 were from two orthopedic centers, and the remaining patients come from tertiary hospitals in various regions. The mean age at the time of the CHA was 75.64 ± 11.58 years. All fractures were unilateral (27 left cases and 27 right cases). The mean time from fixation to failure was 6.4 (1–13.75) months. The mean interval between fracture and CHA was 6.4 (range, 1–13.75) months. The fracture type includes 19 cases of A1.2, 11 cases of A1.3, eight cases of A2.2, four cases of A2.3, 5 cases of A3.1, one case of A3.2, and six cases of A3.3. For the initial fixation devices, proximal femoral nail anti-rotation (PFNA) was used in 38 cases, the dynamic hip screw (DHS) was used in eight cases, and a locking proximal femoral plate (LPFP) was used in eight cases. The indications for CHA were cut out in 38 cases of failure of fixation, seven cases of nonunion, and nine cases of avascular necrosis or posttraumatic osteoarthritis.

TABLE 1 Patient demographics between standard and long stem groups

Variables	Total (n = 54)	Standard stem (n = 20)	Long stem (n = 34)	Statistics	*P*-value
Age (y)	75.6 ± 11.6	75.0 ± 13.9	75.6 ± 10.2	t = −0.192	0.849[a]
Gender(M/F)	24/30	11/9	13/21	$\chi^2 = 0.835$	0.231
BMI (kg/m^2)	26.2 ± 5.9	25.9 ± 5.7	26.5 ± 6.5	t = −0.232	0.315[a]
BMD, T-score	−3.6 ± 0.7	−3.7 ± 0.6	−3.6 ± 0.6	t = 0.608	0.264[a]
Diabetes	13(24.1)	5(25.0)	8(23.5)	$\chi^2 = 0$	1.000[c]
Smoking	5(9.3)	2(10.0)	3(8.9)	$\chi^2 = 0$	1.000[c]
Side, R/L	27/27	12/8	15/19	$\chi^2 = 1.271$	0.260[c]
Singh index>4	21(38.9)	7(35.0)	14(41.2)	$\chi^2 = 0.202$	0.653[c]
ASA physical status				$\chi^2 = 0.018$	0.922[c]
I	33(61.1)	12(60.0)	21(61.8)		
II	13(24.1)	5(25.0)	8(23.5)		
III	8(14.8)	3(15.0)	5(14.7)		
AO/OTA fracture type				$\chi^2 = 5.290$	0.071[c]
31A1	30(55.6)	15(75.0)	15(44.1)		
31A2	12(22.2)	3(15.0)	9(26.5)		
31A3	12(22.2)	2(10.0)	10(29.4)		
Time to failure (months)	11.6 ± 14.4	14.6 ± 17.2	10.4 ± 12.5	t = 0.106	0.916[b]
Failure type				$\chi^2 = 0.292$	0.864[c]
Cut out	38(70.4)	13(75.0)	25(73.5)		
Nonunion	7(13.0)	3(15.0)	4(11.8)		
Posttraumatic osteoarthritis or Avascular necrosis	9(16.7)	4(20.0)	5(14.7)		
Primary internal fixation				$\chi^2 = 2.621$	0.270[c]
PFNA	38(70.4)	12(60.0)	26(76.5)		
DHS	8(14.8)	5(25.0)	3(8.8)		
LPFP	8(14.8)	3(15.0)	5(14.7)		
Mean follow-up time (m)	51.9 ± 6.9	55.2 ± 32.1	50.1 ± 23.6	t = 0.497	0.621[a]

Abbreviations: ASA, American Society of Anesthesiologists; BMD, bone mineral density; BMI, body mass index; DHS, dynamic hip screw; PF-LPFP, locking proximal femoral plate; PFNA, proximal femoral nail anti-rotation; *Notes*: [a] Analyzed using the student's *t*-test; [b] Analyzed using the Mann–Whitney test; [c] Analyzed using the Pearson chi-square test or Fisher's exact test.

Operative Protocol

All patients received detailed clinical examination and evaluation for medical comorbidities on admission, and laboratory examinations including routine blood tests with a white cell count, C-reactive protein (CRP), and erythrocyte sedimentation rate.

(ESR) were performed. If an infection was suspected, joint punctures were performed preoperatively to obtain synovial fluid, followed by cell counting and bacterial culture. X-rays and CT were taken for all patients to access bone quality, proximal and distal femoral defects, the condition of the greater trochanter, and the evaluation of limb length.

A posterolateral approach was used in all patients, prior scar was used and extended. The surgeon decided to perform total hip arthroplasty (THA) or hemiarthroplasty (HA) according to the degree of acetabular cartilage injury and the life expectancy of patients. The type (cemented or cementless) and length (standard or long) of the femoral stem used were based on bone quality, the geometry of the femoral medullary canal, and the stability of the proximal femur. An elastic system of cerclage wires was indicated for intraoperative bone-cracking, metaphyseal comminution, and cerclage wires, tension band wiring, or articulated hook plate were used for the reconstruction of a nonunion greater trochanter, depending on the surgeon's preference.

A suction drainage tube was placed after flushing and closure of the incision and was removed within 24 hours. Frozen sections were routinely performed. The operation time, total blood loss, intraoperative technical problems, and complications were recorded. Prophylactic antibiotics and anticoagulation therapy with low molecular weight heparin were routinely used.

Implantations

Thirty-one patients underwent THA due to acetabular cartilage wear or injury, and the remaining 23 received HA. On the acetabular side, a cementless cup was used on all hips. Feyen *et al.*[16] defined standard and long stems based on stem length, the level of the osteotomy of the femoral neck, and the intended site of primary stability (Fig. 1). Based on that, patients were divided into two groups: the standard-stem group (n = 20) including 14 cemented stems and six cementless stems, and the long-stem group (n = 34) including four cemented stems and 30 cementless stems.

Clinical Evaluation

Follow-up occurred at 1, 6, and 12 months after CHA and annually thereafter. X-ray films were taken to assess the prosthesis survival condition during the follow-up. Harris hip score (HHS, contains four items: pain, function, degree

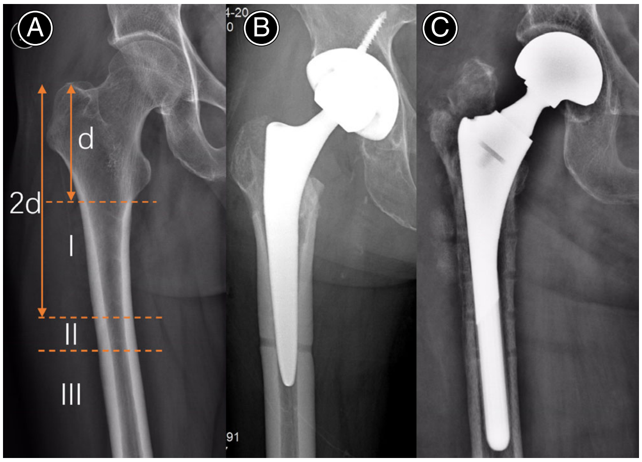

Fig. 1 (A) d: distance between the tip of the greater trochanter and the base of the lesser trochanter. I: short stem, total length less than twice the distance from the tip of GT to the base of LT vertical distance; II: Standard stem, total length greater than twice the distance from the tip of GT to the base of LT vertical distance, with metaphyseal fixation only or with meta- and diaphyseal fixation; III: Long stem, total length greater than twice the distance from the tip of GT to the base of LT vertical distance, with diaphyseal fixation. (B) Standard stem; (C) Long stem

of deformity, and range of motion of the hip joint) and 36-item Short Form survey (SF-36: including physical function [PF] score and body pain [BP] score) health questionnaire scores were used to evaluate the recovery of hip joint function and limb recovery.

Radiographic Analysis

Osteolysis was defined as the appearance of a radiolucent zone, osteolysis around acetabulum (zones 1–3 of DeLee & Charnley[17]) and/or stem (zones 1–7 of Gruen *et al.*[18]) was recorded. Definite loosening of the acetabular component was diagnosed when a continuous radiolucent line >2 mm could be observed, and a change in the angle of at least 4 or >3 mm of migration was observed. In cases that underwent uncemented fixation, the stability of the femoral component was classified as bone ingrown, fibrous stable, or unstable according to the system of Massin *et al.*,[19] and in cases that underwent cemented fixation, femoral components were judged by the criteria of Barrack *et al.* using immediate postoperative radiographs.[20] The subsidence of the femoral stem was measured by Callaghan *et al.*,[21] and subsidence of more than 10 mm was considered to be of clinical significance. Heterotopic ossification (HO) was classified according to the method of Brooker *et al.*,[22] classifying HO into four grades ranging from just visible (grade 1) to total ankylosis (grade 4) in standardized X-rays in two planes. After an agreement was reached between the two observers, each parameter was independently measured twice by two orthopedic surgeons.

Statistical Analysis

SPSS 21.0 (IBM, Armonk, NY, USA) was used to conduct the statistical analysis. Normally distributed data are expressed as the mean ± SD, while skewed distribution data are expressed as the median and interquartile range (IQR). Measurement data were compared between groups. Comparisons of variables between groups were performed using 2-sample *t*-tests for continuous normally distributed data, Wilcoxon rank-sum tests for continuous nonnormally distributed data, and chi-square or Fisher exact tests for categorical variables. Differences were considered statistically significant when P values were less than 0.05 ($P < 0.05$).

Results

The mean follow-up time was 51.98 ± 26.91 months (25–134 months), except two patients died of causes unrelated to the operation (one died of cerebral apoplexy and one died of myocardial infarction within 2 years after the operation, there were no other patients lost to follow-up during the study period).

The operation time and total blood loss of the long stem group were significantly higher than those of the standard stem group (137.13 ± 43.63 *v.* 113.75 ± 28.61 min, $P = 0.002$; 79 ± 374.38 *vs* 436.00 ± 299.43 ml, $P = 0.017$, respectively). The mean length of stay was not significantly different between groups, with a mean of 7.3 ± 3.5 days in the standard- stem group, and 8.8 ± 4.4 days in the Long-stem group ($P = 0.222$) (Table 2). The greater trochanter was reconstructed with cable cerclage in eight patients, and two patients were fixed with a steel plate and cable (Fig. 2).

Clinical Outcome

All patients had different degrees of hip pain and movement limitations before the operation, and most patients had different degrees of limb shortening and coxa varus deformity. After the conversion, most patients reported remarkable pain relief and functional recovery. The average HHS, SF-36 PF, and SF-36 BP were significantly improved in both groups (Table 3), suggesting significantly pain relief, function recovery, and improvement in overall health-related quality of life. No significant difference was found in HHS, SF-36 PF, and SF-36 BP between the standard-stem group and the long-stem group at the last follow-up ($P > 0.05$).

Complications

Table 2 shows the orthopedic and general complications of patients after CHA. There were 13 (24.07%) patients who had surgical complications related to the operation. A total of five cases (11.32%) had intraoperative femur fractures during the operation, three cases had proximal femoral cracks that occurred during intramedullary reaming and implantation of the stem, which were treated with cerclage wires and healed without additional complications. Two patients had distal femoral screw hole fractures during intraoperative reaming, and then the planned femoral stems

TABLE 2 Comparison of curative effect between standard and long stem groups

Variables	Total (n = 54)	Standard stem (n = 20)	Long stem (n = 34)	Statistics	*P*-value
Type of arthroplasty, N(%)				$\chi^2 = 0.075$	0.784[c]
Total hip arthroplasty	31(57.4)	11(55)	20(58.8)		
Hemiarthroplasty	23(42.6)	9(45)	14(41.2)		
Operation time (min)	133.9 ± 43.6	113.8 ± 28.6	137.1 ± 43.6	$t = -3.317$	0.002[a,*]
Intraoperative blood loss (mL)	587.2 ± 364.9	436.0 ± 299.4	678.8 ± 374.4	$t = -2.460$	0.017[a,*]
Hospital stays (d)	8.2 ± 4.1	7.3 ± 3.5	8.8 ± 4.4	$t = -0.176$	0.222[b]
Overall complications, N(%)	24(44.4)	10(50.0)	14(41.2)		
Orthopedic complication	15(27.8)	2(10.0)	13(38.2)	$\chi^2 = 5.004$	0.025[c,*]
Patients affected	13(24.1)	2(10.0)	11(32.4)	$\chi^2 = 2.328$	0.127[c]
Intraoperative femur fracture	5(93)	0	5(14.7)	$\chi^2 = 1.727$	0.189[c]
Postoperative periprosthetic fracture	1(1.9)	1(5.0)	0	$\chi^2 = 0.073$	0.786[c]
Stem penetrate	2(3.7)	0	2(5.9)	$\chi^2 = 0.129$	0.719[c]
Dislocation	2(3.7)	0	2(5.9)	$\chi^2 = 0.129$	0.719[c]
Cement leakage	1(1.9)	0	1(2.9)	$\chi^2 = 0$	1.000[c]
Stem loosening or subsidence	3(5.6)	1(5.0)	2(5.9)	$\chi^2 = 0$	1.000[c]
Infection	1(1.9)	0	1(2.9)	$\chi^2 = 0$	1.000[c]
General complication	15(27.8)	7(35.0)	8(23.5)	$\chi^2 = 0.826$	0.363[c]
Patients affected, N(%)	9(16.7)	5(25.0)	4(11.8)	$\chi^2 = 0.778$	0.378[c]
Acute deep vein thrombosis	3(5.6)	1(5.0)	2(5.9)	$\chi^2 = 0$	1.000[c]
Delirium	2(3.7)	2(10.0)	0	$\chi^2 = 1.284$	0.257[c]
Congestive heart failure	1(1.9)	0	1(2.9)	$\chi^2 = 0$	1.000[c]
Urinary tract infection	2(3.7)	1(5.0)	1(2.9)	$\chi^2 = 0$	1.000[c]
Hypostatic pneumonia	3(5.6)	1(5.0)	2(5.9)	$\chi^2 = 0$	1.000[c]
Reoperation for any reason	1(1.9)	1(5.0)	0	$\chi^2 = 0.073$	0.786[c]

* *Notes*: Statistically significant values.; [a] Analyzed using the student's *t*-test; [b] Analyzed using the Mann–Whitney test; [c] Analyzed using the Pearson chi-square test or Fisher's exact test.

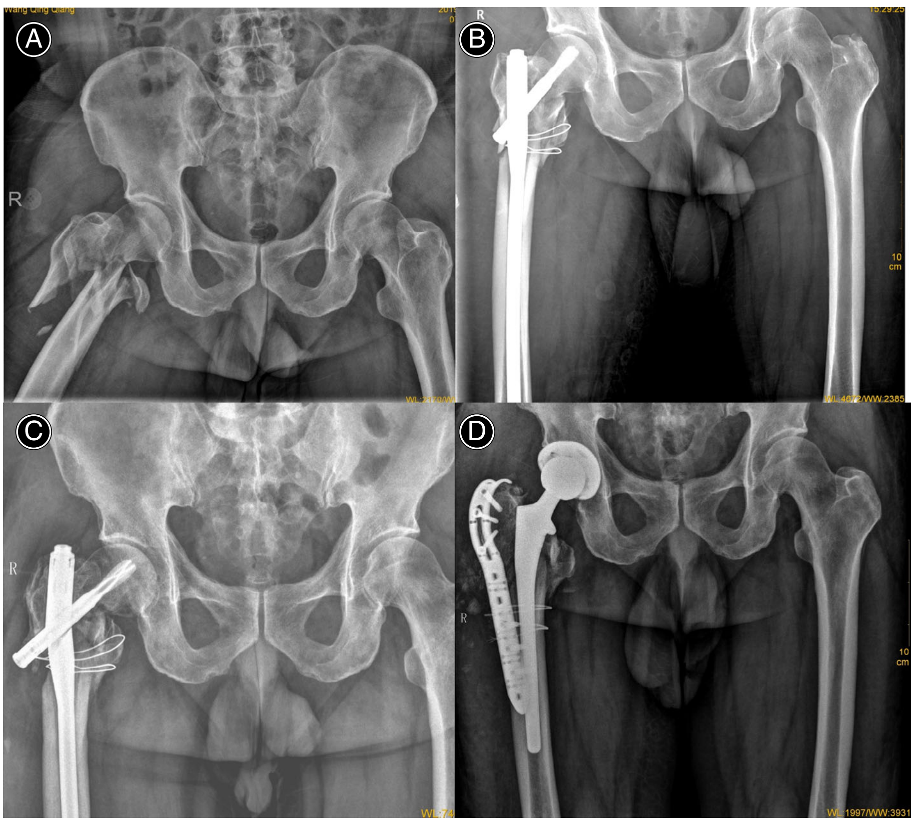

Fig. 2 A 70-year-old man with a right comminuted intertrochanteric fracture was treated with PFNA and received THA after failed internal fixation. (A, B) Right comminuted intertrochanteric fracture treated with PFNA; (C) At 13 months post-surgery the patient exhibited nonunion and the medial and lateral walls were incomplete; (D) A successful THA reconstruction using Corail Revision femoral stem (DePuy Orthopedics Inc.) and hook cable plate

TABLE 3 Comparison of functional outcomes between standard and long stem groups

Variables	Standard stem (n = 20)	Long stem (n = 34)	Statistics	*P*-value
HHS				
Preop	38.5 ± 4.2	41.1 ± 4.6	t = −1.051	0.215[a]
Final	79.7 ± 5.4	81.8 ± 6.2	t = −1.112	0.271[a]
Statistics	t = −17.181	t = −21.497		
p-value	<0.001[b]	<0.001[b]		
SF-36 PF				
Preop	29.1 ± 4.2	28.9 ± 3.6	t = 0.986	0.292[a]
Final	75.8 ± 16.8	76.2 ± 13.8	t = −1.295	0.197[a]
Statistics	t = −25.284	t = −27.812		
p-value	<0.001[b]	<0.001[b]		
SF-36 BP				
Preop	28.6 ± 3.7	30.8 ± 4.8	t = −1.726	0.269[a]
Final	78.1 ± 12.7	80.3 ± 15.7	t = −1.085	0.123[a]
Statistics	t = −27.842	t = −26.563		
p-value	<0.001[b]	<0.001[b]		

Abbreviations: HHS, Harris hip score; SF-36 BP, SF-36 body pain; SF-36 PF, SF-36 physical function; *Notes*: [a] Analyzed using the independent-samples *t*-test; [b] Analyzed using the paired samples t-tests.

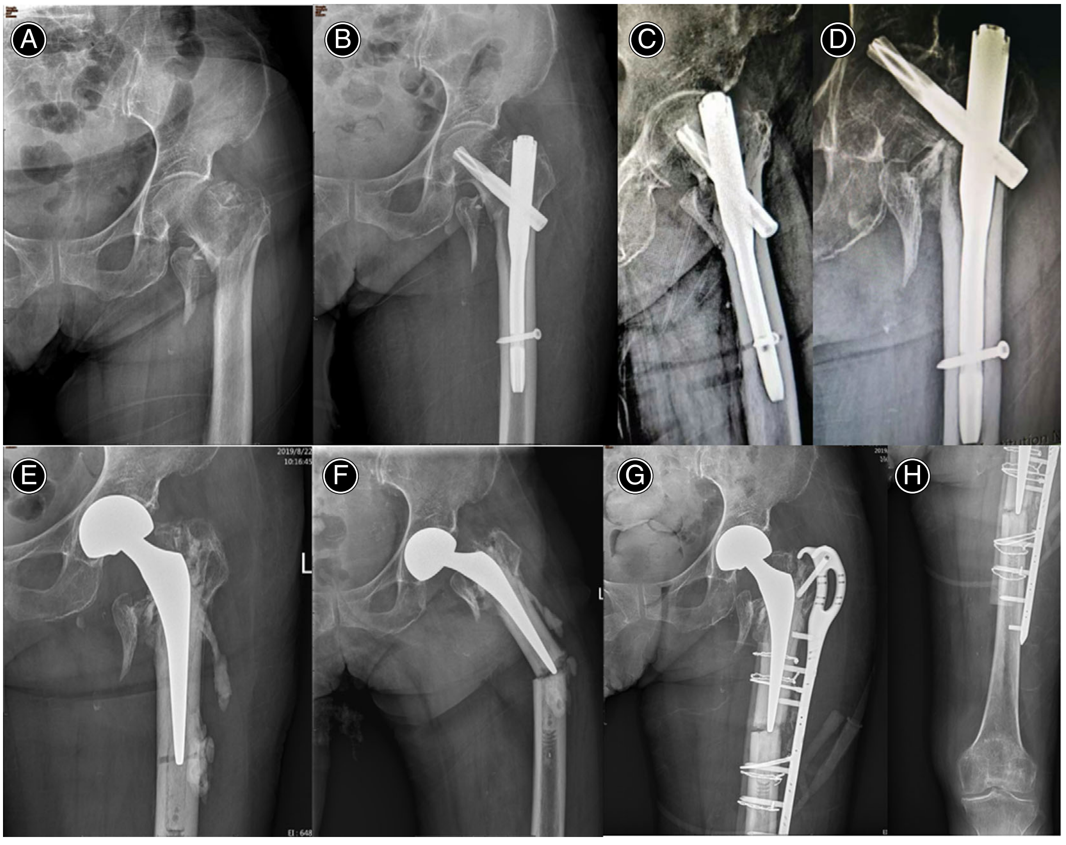

Fig. 3 A 93-year-old female with failed internal fixation with PFNA for left intertrochanteric fracture underwent cemented HA 7 months after initial surgery, the tip of the stem was just at the position of the distal screw hole. (A, B) PFNA was performed for the left ITF; (C, D) The spiral blade cutting out from the femoral head was observed 7 months after the operation, and multiple locking holes could be seen in the femur; (E) She underwent a conversion HA, and a standard cemented stem was selected, and the tip of the stem was just at the position of the distal screw hole; (F) Severe pain occurred in the affected thigh 4 months after HA without trauma and sustained Vancouver type B1 periprosthetic femoral fracture; (G, H) The fracture was treated with open reduction and internal fixation with a blade plate and cannulated screws, placement of a cortical bone plates allograft was successfully performed

were changed to lengthened uncemented revision stem to bypass the screw hole.

One patient suddenly developed hip pain badly during walking 4 months after CHA and sustained Vancouver type B1 periprosthetic femoral fracture at the previous screw hole (Fig. 3). The prosthesis was retained, and the fracture was successfully treated with open reduction and internal fixation with a plate and screws. Two patients suffered early postoperative dislocation due to improper exercise and were given closed reduction and both had no recurrent dislocations. One acute infected case was managed with debridement and retention of the prosthesis 3 weeks postoperatively. One case had bone cement leakage from a previous screw hole that did not affect the stem stability, surgical intervention was not required.

The major general complications were hypostatic pneumonia in three patients, acute deep vein thrombosis in three, delirium in two, and congestive heart failure in one.

Radiographic Evaluation

Radiographs were available for all patients at the last follow-up. According to the preoperative X-ray Singh index measurement grading, only 20 patients had grades >4, suggesting that most patients had different degrees of osteoporosis. All patients achieved a successful bony union of the fracture and previous screw holes. All stems had stable bony ingrowth except three cases (5.6%) of stem loosening or subsidence. One case with cemented femoral stem had probable femoral loosening at 10 years, two cases had stem subsidence occurred within the first year after the operation and there was no progressive subsidence, the patients had minimal discomfort, and none of them need revision surgery. There were five cases (9.3%) of ectopic ossification on imaging, including two cases of Brooker type-1 heterotopic bone and three cases of Brooker type-2 heterotopic bone, which did not affect function.

Discussion

Summary of Results

The present study retrospectively analyzed 54 CHA following FIF-ITF, and the results showed a satisfactory curative effect, which for most patients relieved their pain and restored good joint function, HHS and SF-36 significantly improved in both groups from preoperative to the final follow-up. However, a significant rate of orthopedic complications (15/54 [27.8%]) was detected, and long stems had an increased risk of complication (13/34) compared to standard stems (2/20) ($P = 0.031$), especially intraoperative femoral fractures (5/34 *vs* 0/20).

Surgical Techniques

Compared with primary hip arthroplasty, CHA following FIF-ITF faces several challenging technical problems, including removal of previous failed internal fixation devices, management of nonunion or mal-union great trochanteric, residual screw holes, possible intraoperative femur fracture, and reliable fixation of the femoral stem,[7,23–25] with a higher risk of early complications and poor function[10] and requires a high level of surgical skill.[25,26] In the present study, not surprisingly, the average operation time and the average intraoperative blood loss were high (137.13 min; 587.17 ml), which was similar to previously reported results.[27] One of the possible reasons for the lengthy operation time is the reset of fractured fragments of the head and neck, which are usually in a deformed or rotating position. This process requires great care to avoid damaging the adjacent important blood vessels, nerves, and tendons, which often leads to an increase in operation time and blood loss.

A nonunion or separated greater trochanter could cause pain, limb shortening, and even affect the abductor function of the hip joint and the stability of the prosthesis. Therefore, the healing of the greater trochanter should be evaluated during the operation. Several methods for the reconstruction of the greater trochanter have been reported, including contoured plating, tension band wiring, and trochanter claw plating with wiring.[28] In this study, the greater trochanter was reconstructed with cable cerclage in eight patients, and two patients were fixed with a steel plate and cable.

Comparison of Standard and Long Stems

There is still much controversy over many issues related to the use of a femoral stem, and there is no compelling evidence to support the selection of either a standard or a long femoral stem. As a result, studies propose using a long stem to improve the medullary cavity contact area, and bridge previous holes, and defects to prevent potential periprosthetic fracture caused by stress effects. Several studies have reported satisfactory results of standard stems treating FIF-ITF patients. In a propensity score matching study by Lee *et al.*[29] no periprosthetic femur fracture or implant loosening happened in any of the 33 patients with standard stems at a mean of 3-year follow-up. Also, Morsi *et al.*[12] reported 99% implant survivorship with a standard cemented stem in 107 patients after aseptic failed fixation of ITF, and 102 cases had good clinical and radiological outcomes at an average follow-up of 7.4 years. In this study, 20 standard stems and 33 long stems were used and the results showed that there was no significant difference in HHS, SF-36 PF, SF-36 BP, and the length of hospital stay between the two groups ($P > 0.05$), while the average operation time and intraoperative blood loss in the long group were higher than in the standard group [137.1 ± 43.6 min *vs* 113.8 ± 28.6 min, $P = 0.002$; 678.79 ± 374.4 ml *vs* 436.0 ± 299.4 ml, $P = 0.017$]. Significantly, the long stem group had a higher incidence of orthopedic complications compared to the standard stem group ($P = 0.031$), and the incidence of intraoperative femur fracture in the long stem group (5/34) was also higher than that of a standard stem (0/20), but this was not statistically significant, although the cases in this study are from multiple centers, and the skill and experience of surgeons are inconsistent, such a high incidence of intraoperative fractures still cannot be ignored.

It is inappropriate to simply generalize that the use of standard or long stems for FIF-ITF patients is sufficient, the integrity of the proximal femoral structure, the degree of osteoporosis, the previous fracture pattern, as well as the size of diaphyseal bone defect, must guide the selection of femoral stem. The use of long stems is not necessary in all cases, such as cases of avascular necrosis or posttraumatic osteoarthritis, in which the previous fracture has healed and a standard metaphyseal locking stem could provide rigid stability, preserve more bone mass, reduce cost and possible revision surgery in the future, systematic use of long stems is not recommended and should be reserved for severe osteoporotic cases. It is important to note that the surgeon should avoid situations where the tip of the stem is just located in the area of the screw holes, stress riser at the tips may cause periprosthetic fracture, and previous screw holes should be closed when using a cemented stem. For cases with an incomplete medial wall of the proximal femur, with femoral calcar defect, meta-diaphyseal mismatch, or lower limb discrepancy, which is frequently seen in FIF-ITF patients, the long stems should be selected. Several studies reported good results of the use of a modular, distally fixed cementless stem in the management of failed intertrochanteric fractures,[14,15,30] and some authors suggested using standard stems as long as the holes are closed with bone cement.[12]

Strengths and Limitations

A major strength of our study was its retrospective cohort design, which avoids the control selection problem in case–control studies: to our knowledge, this is the first multicenter retrospective study that compares the clinical efficiency of standard and long stems in CHA following FIF-ITF. However, as a retrospective cohort study, some limitations were inevitable. First, this study was limited by a small sample size, which may have an impact on our conclusions. Although we collected cases from multiple centers in this region, the number of cases in this study reached or exceeded previous similar studies because of the rarity of this disease. Second, as a multicenter retrospective cohort study, patient selection bias exists. Incomplete data collection of some patients, diversity of prostheses, and operations not performed by the same surgeon may also have some impact on the results of the study. The promising results should be cautiously interpreted and generalized, and still, need to be confirmed through well-designed cohort or large-scale prospective randomized controlled trials, and related biomechanical experiments are still needed to confirm our results.

Conclusion

In conclusion, CHA following FIF-ITF showed a successful mid-term clinical curative effect, and an increased risk of complications including intraoperative femoral fractures of long stems was observed. Therefore, the present study suggests that long stems should be circumspectly used in CHA following FIF-ITF, future large-scale prospective RCT should confirm our findings.

Acknowledgments

The authors thank Weiming Li (Fuzhou Second Hospital Affiliated to Xiamen University), Ruijin You (910th Hospital of PLA), Xu Wang (Mindong Hospital Affiliated to Fujian Medical University), Rijiang Chen (Longyan First Hospital, Affiliated to Fujian Medical University), Chun Xia (Zhongshan Hospital Xiamen University), Yiqiang Zhou (Xiamen Chinese Medicine Hospital), Xiaoqing Chen (Quanzhou First Hospital Affiliated to Fujian Medical University), Zhaoke Wu (Quanzhou orthopedic-traumatological Hospital of Fujian), Xiaojie Chen (Nanping First Hospital), Xianwei Wu (The Affiliated Hospital of Putian University Putian), Fuming Lian (Sanming First Hospital, Fujian), Xingbin Liang (Ting Zhou Hospital, Fujian), for access to the medical record and valuable help in carrying out the study. This paper is supported by the Joint Funds for the Innovation of Science and Technology, Fujian Province, China (2019Y9136) and Fujian Medical Innovation Grant, China (2020CXA038).

Conflict of Interest

The authors declare that they have no competing interests.

Availability of Data and Materials

The data utilized are accessible from the corresponding author upon reasonable

Authors' Contributions

Tengbin Shi, Xinyu Fang and Wenming Zhang developed the study idea, designed the study, and interpreted the data. Tengbin Shi and Changyu Huang obtained and refined data collection, planned and performed the statistical analysis, and graphical presentation, and drafted the paper. Weiming Li, Ruijin You, Xu Wang and Chun Xia, provided data access, interpreted data, and revised the paper. Critical revision of work and final approval of manuscript: all authors.

References

1. Grosso MJ, Danoff JR, Murtaugh TS, Trofa DP, Sawires AN, Macaulay WB. Hemiarthroplasty for displaced femoral neck fractures in the elderly has a low conversion rate. J Arthroplasty. 2017;32(1):150–4.
2. Yoon YC, Kim J, Cho JW, Cho WT, Kim HJ, Oh JK. Simple guidelines for evaluating intraoperative alignment after the reduction of intertrochanteric fractures. Asian J Surg. 2021;44(1):66–71.
3. Matre K, Havelin LI, Gjertsen J-E, Vinje T, Espehaug B, Fevang JM. Sliding hip screw versus IM nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian hip fracture register. Injury. 2013;44(6):735–42.
4. Ovesen O, Andersen M, Poulsen T, et al. The trochanteric gamma nail versus the dynamic hip screw: a prospective randomized study. One-year follow-up of 146 intertrochanteric fractures. Hip Int. 2006;16(4):293–8.

5. Haidukewych GJ, Berry DJ. Hip arthroplasty for salvage of failed treatment of intertrochanteric hip fractures. J Bone Jt Surg. 2003;85(5):899–904.
6. Ryan SP, Dilallo M, Attarian DE, et al. Conversion vs primary total hip arthroplasty: increased cost of care and perioperative complications. J Arthroplasty. 2018;33:2405–11. https://doi.org/10.1016/j.arth.2018.03.006
7. Douglas SJ, Remily EA, Sax OC, Pervaiz SS, Delanois RE, Johnson AJ. How does conversion total hip arthroplasty compare to primary? J Arthroplasty. 2021; 36(7):S155–9. https://doi.org/10.1016/j.arth.2020.12.023
8. Newman JM, Webb MR, Klika AK, Murray TG, Barsoum WK, Higuera CA. Quantifying blood loss and transfusion risk after primary vs conversion total hip arthroplasty. J Arthroplasty. 2017;32:1902–9. https://doi.org/10.1016/j.arth.2017.01.038
9. Mehlhoff T, Landon GC, Tullos HS. Total hip arthroplasty following failed internal fixation of hip fractures. Clin Orthop Relat Res. 1991;269:32–7.
10. Kligman M, Roffman M. Conversion total hip replacement after failed internal fixation of intertrochantric fracture. Harefuah. 1998;134(9):690-692,751.
11. Zhang B, Chiu K-Y, Wang M. Hip arthroplasty for failed internal fixation of intertrochanteric fractures. J Arthroplasty. 2004;19(3):329–33.
12. Morsi ESMZ, Drwish AEE, Saber AM, Nassar IM, Zaki AEM. The use of standard cemented femoral stems in total hip replacement after failed internal fixation of intertrochanteric femoral fractures. J Arthroplasty. 2020;35:2525–8.
13. Te CY, Chen WM, Lee KS, et al. Diaphyseal locking hip arthroplasty for treatment of failed fixation of intertrochanteric hip fractures. J Arthroplasty. 2008; 23(2):241–6.
14. Thakur RR, Deshmukh AJ, Goyal A, Ranawat AS, Rasquinha VJ, Rodriguez JA. Management of failed trochanteric fracture fixation with cementless modular hip arthroplasty using a distally fixing stem. J Arthroplasty. 2011;26(3):398–403.
15. Weiss RJ, Kärrholm J, Hailer NP, Beckman MO, Stark A. Salvage of failed trochanteric and subtrochanteric fractures using a distally fixed, modular, uncemented hip revision stem. Acta Orthop. 2012;83(5):488–92.
16. Feyen H, Shimmin AJ. Is the length of the femoral component important in primary total hip replacement? Bone Jt J. 2014;96(4):442–8.
17. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop Relat Res. 1976;121(121):20–32.
18. 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.
19. Massin P, Schmidt L, Engh CA. Evaluation of cementless acetabular component migration: an experimental study. J Arthroplasty. 1989;4(3):245–51.
20. Barrack RL, Mulroy RD, Harris WH. Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty. A 12-year radiographic review. J Bone Jt Surg. 1992;74(3):385–9.
21. Callaghan JJ, Dysart SH, Savory CG. The uncemented porous-coated anatomic total hip prosthesis. Two-year results of a prospective consecutive series. J Bone Jt Surg. 1988;70(3):337–46.
22. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Jt Surg. 1973;55(8):1629–32.
23. Masri BA, Meek RMD, Duncan CP. Periprosthetic fractures evaluation and treatment. Clin Orthop Relat Res. 2004;420:80–95.
24. Morice A, Ducellier F, Bizot P. Total hip arthroplasty after failed fixation of a proximal femur fracture: analysis of 59 cases of intra- and extra-capsular fractures. Orthop Traumatol Surg Res. 2018;104(5):681–6. https://doi.org/10.1016/j.otsr.2018.04.015
25. Enocson A, Mattisson L, Ottosson C, Lapidus LJ. Hip arthroplasty after failed fixation of trochanteric and subtrochanteric fractures. Acta Orthop. 2012;83(5):493–8.
26. Mortazavi SMJ, Greenky R, M, Bican O, et al. Total hip arthroplasty after prior surgical treatment of the hip fracture is it always challenging? J Arthroplasty. 2012;27(1):31–6.
27. Moon NH, Shin WC, Kim JS, Woo SH, Son SM, Suh KT. Cementless total hip arthroplasty following failed internal fixation for femoral neck and intertrochanteric fractures: a comparative study with 3-13 years' follow-up of 96 consecutive patients. Injury. 2019;50(3):713–9.
28. Liu P, Jin D, Zhang C, Gao Y. Revision surgery due to failed internal fixation of intertrochanteric femoral fracture: current state-of-the-art. BMC Musculoskelet Disord. 2020;21(1):573.
29. Lee Y-K, Kim JT, Alkitaini AA, Kim KC, Ha YC, Koo KH. Conversion hip arthroplasty in failed fixation of intertrochanteric fracture: a propensity score matching study. J Arthroplast. 2017;32:1593–8. https://doi.org/10.1016/j.arth.2016.12.018
30. Laffosse J-M, Molinier F, Tricoire J-L, Bonnevialle N, Chiron P, Puget J. Cementless modular hip arthroplasty as a salvage operation for failed internal fixation of trochanteric fractures in elderly patients. Acta Orthop Belg. 2007; 73(6):729–36.