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Original research

Use of locking plates for fixation of the greater trochanter in patients with hip replacement

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A B S T R A C T

Background: Fixation of the greater trochanter with total hip replacement is challenging and associated with short- and long-term complications. Locking plate technology has been used for fixation of other bones and may be applied successfully in trochanteric fixation. The purpose of this retrospective study was to analyze the utility of the use of trochanteric locking plates in total hip arthroplasty (THA) patients.
Methods: From 2004 to 2014, 32 procedures were performed to fix the greater trochanter in patients with trochanteric fracture, osteotomy, or nonunion in the setting of THA. The median age at the time of surgery was 69 years. This was a primary arthroplasty in 8 of the patients, conversion from prior hip surgery in 5, and a revision in 19. The greater trochanter was fixed with locking plate alone in 15 hips and with the addition of a single cerclage cable in 17 hips. Patients were followed clinically and radiographically until healing occurred. The median duration of radiographic follow-up was 41.6 months (range: 10-112 months).
Results: Osseous union occurred in 29 (90.6%) of 32 hips. The median Harris hip score was 94 (range 54-100, standard deviation = 10.4) at latest follow-up. Complications included broken hardware in 5 (15.6%) patients, of which 3 underwent subsequent hardware removal. Two additional patients elected hardware removal due to trochanteric pain.
Conclusions: Locking plate technology is a successful method of fixation of the greater trochanter in patients with THA. Postoperative trochanteric pain and reoperation for hardware-related issues remain a challenge.

Introduction

Fixation of the greater trochanter in total hip arthroplasty (THA) is desirable not only after osteotomy but also in many cases of acute fracture or nonunion. There are a surfeit of specific trochanteric fixation methods described in the literature, but no one method has been conclusively shown to be advantageous [1]. The method chosen should achieve the surgical goal of allowing the greatest chance of healing and at the same time be easiest for both surgeon and patient. Stable, reliable fixation should be attained with earliest possible full weight bearing and active abduction. In addition, minimizing or eliminating the use of multistrand metallic cables is desirable [2-4].

There are a number of short- and long-term complications associated with traditional greater trochanteric fixation including trochanteric pain syndrome, nonunion, Trendelenburg limp, THA instability, generation of third body debris in the joint, and bone loss from metallic and secondary polyethylene debris [1-5]. Locking plates were introduced as an alternative method of fracture fixation elsewhere in the body in the late 1990s [6,7] and allow screws to lock into the plate, enhancing stability even with unicortical fixation [7]. Locking plates were first reported for trochanteric fixation in 2009 [8], and this study reports the first complete case series.

Our central research question focuses on the success of locking plate technology in greater trochanteric fixation. The primary outcome measure was trochanteric union. Secondary measures

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were pain, presence of a limp, hip function, and complications, including those specifically related to the hardware.

We included all locking plates used for trochanteric fixation in this study because of the relative rarity of this surgery; prior to the availability of a specifically designed trochanteric plate, we used a tibial locking plate. Results for both plates are examined and considered individually and together.

Material and methods

Patients

Our institutional review board approved this study. All patients requiring trochanteric fixation by the senior author (BJM) between November, 2004, and July, 2014, who were followed for a minimum of 10 months were included. The patient group consisted of 10 males and 22 females. The median age at the time of trochanteric fixation was 69 years (average 68.4, range 47-85 years, standard deviation [SD] = 10.4 years). The median BMI was 28.3 kg/m^2 (average 26.5, range 18-39 kg/m^2, SD = 5.5 kg/m^2). Eighteen procedures were on the left hip and 14 were on the right.

There were 8 primary hip replacements, 5 conversions, and 19 revision hip replacements. Eleven surgeries were indicated for treatment of trochanteric fractures, 6 for trochanteric osteotomy, and 15 for trochanteric nonunion in the setting of failed THA.

Patients requiring trochanteric fixation were identified by clinical presentation and radiographic findings on plain anteroposterior and lateral hip radiograph. Fractures (11/32) fell in 2 categories: trochanteric periprosthetic with a prior THA (Vancouver [9] A_G, n = 9) and trochanteric periprosthetic in patients during THA (Vancouver [9] A_G, n = 2). Periprosthetic fracture patients with prior THA (9/32) were offered fixation only after failing nonsurgical management with an abductor brace and touch-down weight bearing. Despite this treatment, progressive migration of greater than 2 centimeters, continued significant pain and/or limp, or THA instability occurred. Intraoperative fracture patients (2/32) had a large trochanteric fragment that could not be treated with cerclage fixation alone and excluded minor trochanteric tip or calcar fractures. Osteotomy patients (6/32) included 1 who underwent trochanteric advancement and 5 who has standard trochanteric osteotomies for exposure. This group did not include extended trochanteric osteotomies, where simple cerclage wire fixation was thought to be adequate. For patients with trochanteric nonunion (15/32), the decision to proceed with fixation of the greater trochanter was determined by proximal trochanteric migration of greater than 2 centimeters, significant pain and/or limp, or THA instability. Fixation was also considered in cases of nonunion at the time of THA revision for other reasons.

Operative technique

All patients were positioned in the lateral decubitus position on a standard operating room table, and a posterior approach was used. The pelvis was stabilized by a Wixson 2 hip positioner (Innomed, Inc., Savannah, GA), and all patients received preoperative antibiotics. The entire extremity was draped using sterile technique, with skin barrier placed to the knee. The incision was extended laterally so that the vastus lateralis muscle could be reflected anteriorly.

Fixation technique has been previously described [10]. Briefly, the origin of the vastus lateralis was dissected from the trochanteric vastus ridge and the epimysium of the muscle incised 0.5-1.0 cm anterior to the intermuscular septum posteriorly. The muscle belly was then reflected anteriorly, with care not to devitalize the muscle. The bone was then prepared after exposure and provisional fixation achieved. Since it has become commercially available, a Zimmer NCB (Zimmer, Inc., Warsaw, IN) periprosthetic trochanteric extension plate and short femur plate assembly have been used (10/32 plates in this study; Fig. 1). The proximal plate was placed directly over the tendinous attachment of the abductor muscles. Distally, the plate was placed directly over the lateral femoral cortex. After the plate was prepared by linking the trochanteric attachment to the NCB (Zimmer, Inc.) plate, anteroposterior coverage was maximized proximally and distally. Multiple proximal locking 3.5 screws were placed in the trochanter, alternating anterior and posterior location to maximize host/plate contact. Alternatively, a nonlocking screw may be used to compress the plate against bone prior to locking screw placement. Next, a compression (distal) or interfragmentary screw (proximal to distal) was placed, followed by the distal locking screws. Of note, the screw placement distally (anteriorly or posteriorly to the prosthesis) is facilitated by multiaxial (30 degrees) placement options. Specialized drills may also be used without risk of compromising the mechanical integrity of the cement mantle, if the reconstruction is cemented [11]. An intraoperative anteroposterior radiograph of the femur was obtained after fixation; fluoroscopic images were not required. After intraoperative radiographs confirmed satisfactory fixation, locking caps were placed over the distal polyaxial screws to convert them to locking mode.

Bone grafting was considered if appropriate: bulk allograft was considered for proximal screw fixation if severe osteolysis was present in the trochanter (4 cases) [8]; autograft from reamings was used at the fixation site if available (8 cases). No allograft struts were used, as we did not wish to impede vascularity at the junction of the trochanter and femoral bone. The vastus lateralis was then draped over the plate and the epimysium repaired posteriorly. The origin was sewn down proximally anteriorly and posteriorly to the plate with interrupted absorbable sutures.

Although ideal screw number has not been established, we currently use maximal fixation in the proximal trochanteric fragment and distal fixation with a minimum of 3 bicortical and 1 unicortical screw. Cable augmentation is not necessary with this construct, in our experience.

Earlier in the case series, a tibial locking plate with cable augmentation distally was used [12]. We no longer use this plate (we exclusively use the NCB plate with trochanteric extension [Zimmer, Inc.]) but believe that both types of plate should be evaluated in this review; as locking plate trochanteric fixation is a unique concept and this is the first comprehensive analysis of this technique. We feel that the NCB (Zimmer, Inc) plate construct is superior to usage of the tibial plate because: (1) it is contoured to fit the femur; (2) it is thicker and therefore more stiff (allowing for avoidance of cable augmentation and enhanced locking fixation with larger locking screws); and (3) it has the capability for wide and narrow trochanteric plates, right and left sides, and variable lengths.

Postoperative care and follow-up

Postoperatively, patients maintained touch-down weight bearing for 4 weeks, followed by partial weight bearing for 2 weeks. Active abduction exercises were avoided for 6 weeks.

Clinical follow-up intervals were 1 month, 2 months, 1 year, and every 5 years for prosthesis surveillance. Radiographic follow-up, specifically anteroposterior and lateral hip radiographs, was obtained at 1 month, 1 year, and every 5 years thereafter. In some cases in the present cohort, more frequent follow-up was obtained if symptoms or radiographic changes warranted.

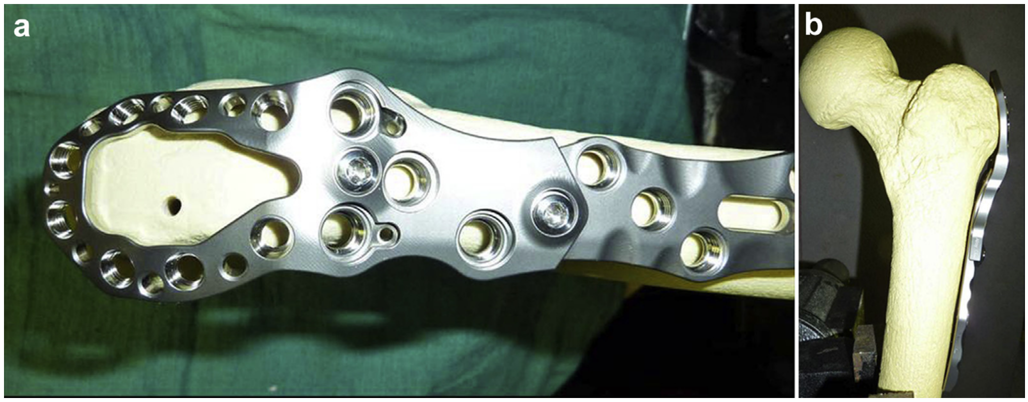

Figure 1. Zimmer NCB (Zimmer, Inc., Warsaw, IN) periprosthetic trochanteric plate and short femur plate assembly, photographed on plastic femur model. (a) Front view. (b) Side view.

Methods of evaluation

The primary postoperative assessment was evidence of osseous consolidation on plain anteroposterior and lateral radiographs. Union was considered present if there was osseous continuity between the greater trochanter and the femur and if there was no evidence of trochanteric migration or broken hardware [13]. Union was considered absent if there was no osseous continuity between the greater trochanter and the femur or if there was evidence of any trochanteric migration. Fibrous union was present if there was radiographic evidence of nonunion without migration over time and minimal or absent symptoms of pain, limp, or instability. All radiographs were reviewed by both authors, and consensus was reached for each patient.

Hip function was graded using the modified Harris hip score (HHS) [14], which was collected as a patient-reported outcome. With this tool, functional status can be categorized as excellent (90-100 points), good (80-89 points), fair (70-79 points), or poor (<70 points). Physical exam was assessed for range of motion, presence of limp, hip abduction strength (tested standing and manually in the lateral decubitus position), and presence of trochanteric pain or crepitation on palpation.

Hip scores were collected prospectively by the surgeon or physician assistant at the time of regular follow-up and retrospectively abstracted from the charts for this study by the first author (AKT). Preoperative and follow-up radiographs were reviewed by both authors, and consensus was achieved on union status.

Radiographic and clinical outcomes were then compared between diagnoses groups (nonunion, fracture, osteotomy) and also fixation method (modified Zimmer tibial locking plate vs Zimmer NCB periprosthetic trochanteric plate [Zimmer, Inc]). The comparison statistic for plate types was a chi-square test with 2-tailed P value. A cutoff of $P < .05$ was used to demonstrate statistical significance.

Results

From September 2005 to July 2014, 32 consecutive procedures were performed for patients requiring trochanteric fixation in the setting of primary or revision, THA. Indications for fixation included osteotomy, displaced or symptomatic fracture, or trochanteric nonunion.

Primary outcome measure

Twenty-nine of 32 trochanters (90.6%) achieved osseous union (Fig. 2). The median duration to follow-up was 42 months, with an average of 41.6 months (range 10-112 months). There were 2 hips (6.2%) with stable fibrous nonunion and 1 hip with trochanteric nonunion and proximal migration (3.1%). For the 22 hips fixed with tibial locking plates, 19 healed with osseous union, for a fixation rate of 86.4%. All the 10 hips that were fixed with a specifically designed trochanteric locking plate achieved osseous union, although with our cohort size this union rate was not significantly different than the tibial locking plates ($P = .536$). Results by diagnosis are presented in Table 1.

Clinical outcome

In all patients, the median postoperative HHS was 94 points (average 91.6, range 54-100 points, SD = 10.4). Twenty-one patients were categorized as excellent hip function (90-100 points), 6 categorized as good (80-89 points), 4 hips as fair (70-79 points), and 1 as poor (<70 points). The average preoperative HHS for patients with trochanteric nonunion was 43.6 points (range 27-76 points, SD = 15.5, n = 15). The average preoperative HHS for patients with acute periprosthetic trochanteric fracture was 47 points (range 17.7 points, SD = 20.7, n = 9). Preoperative HHS was not relevant for intraoperative fractures or osteotomy.

Eleven of 32 patients (34.4%) had a limp postoperatively, 9 of which were slight and 2 were moderate. Twenty-five patients (78.1%) reported no pain in their hip; 5 reported slight, occasional pain; 1 had mild pain; and a single patient had moderate pain. Eight patients (25%) required support for walking, with 2 using a cane full time, 4 using a cane for long walks, and 2 using a walker. Twenty-two of 32 patients (68.8%) could walk unlimited distances, 4 were able to walk 6 blocks, 5 were able to walk 2-3 blocks, and 1 was limited to walking indoors only. One patient had a positive Trendelenburg sign and 2 patients had weakness (less than full strength against resistance) in side-lying abduction testing. Clinical data is summarized in Table 2.

Factors associated with nonunion

Two patients (6.3%) had stable fibrous nonunion and 1 (3.1%) had nonunion with trochanteric migration. Of these 3, 1 had trochanteric nonunion after prior fixation with a claw plate, 1 had a trochanteric osteotomy to remove infected hardware, and 1 had a trochanteric fracture in the setting of failed THA with eccentric poly wear and marked femoral and acetabular osteolysis. All 3 hips were fixed with tibial locking plates. Using the HHS, 2 patients were categorized as fair hip function and 1 with good hip function. The mean postoperative HHS for these 3 patients was 81.7 (SD = 5.2), which is not significantly lower than the mean for the group with

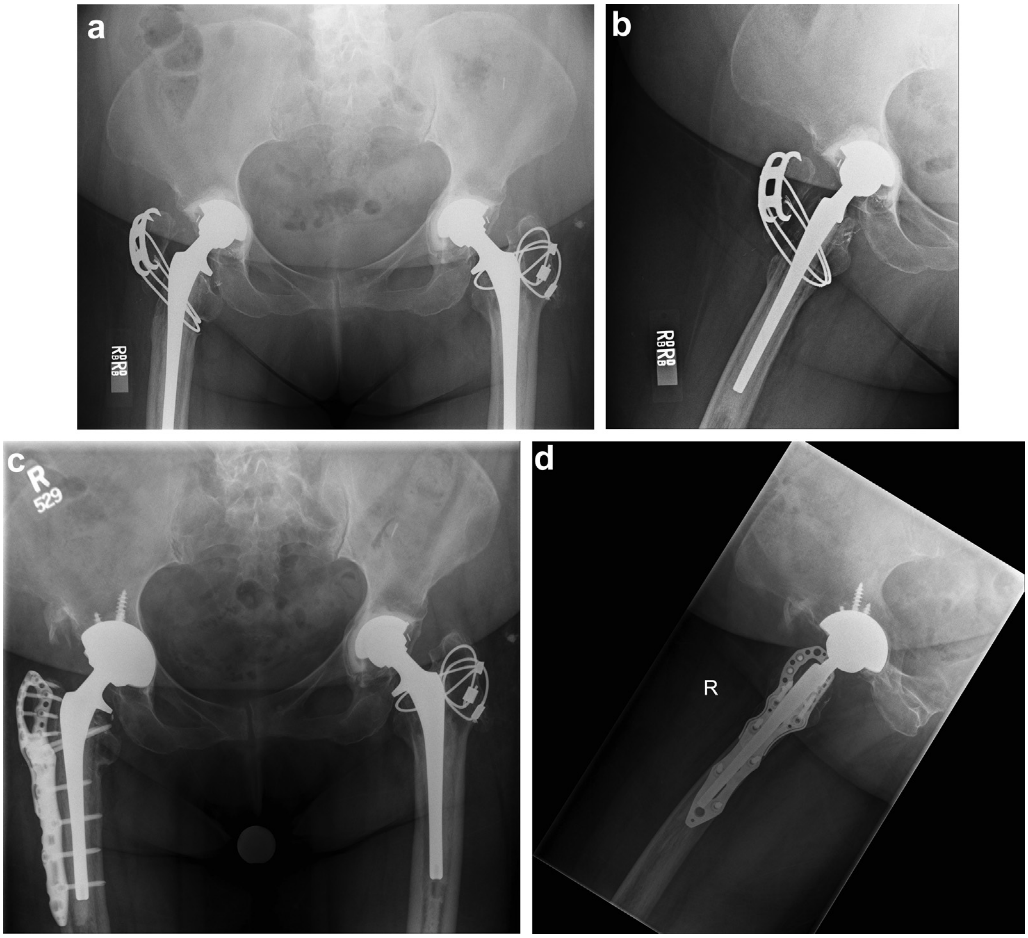

Figure 2. Anteroposterior pelvis (a) and lateral right hip (b) radiographs of patient with aseptic acetabular loosening of revision total hip replacement and concomitant painful trochanteric nonunion. The patient had significant Trendelenberg lurch and had failed prior attempts at trochanteric fixation. Anteroposterior pelvis (c) and lateral right hip (d) radiographs of patient arthroplasty revision and trochanteric fixation with a Zimmer NCB (Zimmer, Inc., Warsaw, IN) periprosthetic trochanteric plate and short femur plate assembly at 27 months. The patient had no limp and Harris hip score [14] of 94.

trochanteric union, for which mean HHS was 92.6 (SD = 10.2) (*P* value = .080). In these 3 patients without bony healing, all demonstrated broken hardware on radiographic follow-up and 2 had subsequent hardware removal. Two of the 3 patients also reported trochanteric pain.

Complications

The most common complication associated with trochanteric fixation was trochanteric pain, which occurred in 6 of 32 patients (18.8%). Overall, there were 5 patients with hardware complications: 2 had fractures of the distal-most screw, 1 had cable breakage, 1 had screw dissociation and a fifth had nonunion with proximal fragment migration and failure of distal fixation. Five patients (15.6%) had repeat surgery to remove hardware: 3 for pain alone and 2 for hardware removal because of breakage.

A single patient experienced a posterior hip dislocation on postoperative day 4 and was treated with hip precautions for 6 weeks. She had no further instability at 7 years.

Table 1
Results of trochanteric fixation with locking plate by diagnosis.

Diagnosis	N	Follow-up, mean (range [mo])	Union, n (%)
Fracture	**11**		
Intraoperative	2	32.5 (15-41)	2 (100)
Periprosthetic	9	55 (12-112)	8 (88.9)
Nonunion	**15**		
Fracture	13	32 (10-102)	12 (92.3)
Osteotomy	2	55 (40-70)	2 (100)
Trochanteric osteotomy	**6**	43 (12-60)	5 (83.3)
Total	32	41.6 (10-112)	29 (90.6)

Bold numbers represent the sum of the patients in the subcategories indented below each bolded number.

Discussion

Fixation of the greater trochanter in THA is imperative after osteotomy and also desirable in cases of displaced or symptomatic fracture or nonunion. Of these indications, nonunions are most difficult to treat because of bone loss, soft-tissue scarring and traction, and poor bone viability [15]. Locking plate technology has revolutionized fracture care but has only recently been suggested for fixation of the trochanter in THA [1,8,10]. This study is the only case series for this type of fixation and provides complete follow-up for previously cited patients [8,10].

Difficulties previously noted in the literature with other forms of trochanteric fixation include nonunion, malunion, pain, Trendelenberg gait, functional limitations, technique complexity, hardware failure, third body debris, THA instability, and secondary osteolysis [1,2,16]. Further, complications associated with these

Table 2
Patients in this study, with major outcome parameters.

Patient	Diagnosis	Follow-up (mo)	Plate	Preoperative limp	HHS	Postoperative Limp	HHS	Union	Complication	Reoperation
1	NU	12	NCB	Moderate	42	None	100			
2	NU	12	NCB	Severe	37	None	98			
3	TO	41	Tibial	Moderate	45	Slight	93		Troch pain	Removal
4	TO	19	NCB	Severe	14	Slight	81			
5	FX	77	Tibial	Severe	42	None	93		Troch pain	
6	TO	60	Tibial	Severe	14	None	100			
7	NU	10	NCB	Moderate	40	None	90			
8	TO	57	Tibial	Severe	14	Moderate	78	NU	BH	Removal
9	NU	51	Tibial	Severe	66	None	100			
10	NU	70	Tibial	None	76	Slight	85		Troch pain	
11	NU	53	Tibial	Severe	27	None	86		BH	
12	TO	25	NCB	Slight	65	None	92			
13	FX	16	NCB	Severe	18	None	81			
14	NU	112	Tibial	Moderate	NA	None	79			
15	NU	11	NCB	Severe	18	Slight	78			
16	TO	45	Tibial	Slight	66	None	100		BH	Removal
17	NU	47	Tibial	Slight	58	Slight	78	NU (FU)	BH	Removal
18	FX	36	Tibial	Moderate	51	None	100			
19	FX	60	Tibial	Moderate	53	None	98			
20	FX	17	NCB	Moderate	36	None	90			
21	NU	44	Tibial	Severe	44	Moderate	54		Troch pain	
22	NU	12	NCB	Severe	27	Slight	97			
23	FX-IO	12	Tibial	Slight	54	None	98			
24	FX	14	Tibial	Severe	70	None	89	NU (FU)	BH	
25	NU	10	Tibial	None	53	Slight	88			
26	NU	43	Tibial	Slight	39	None	100			
27	FX	88	Tibial	Moderate	62	None	100		Troch pain	Removal
28	FX	109	Tibial	None	74	None	100			
29	FX-IO	14	Tibial	Slight	64	None	100			
30	NU	27	NCB	Moderate	42	Slight	94			
31	NU	74	Tibial	Moderate	41	Slight	93		Posterior dislocation	
32	FX	81	Tibial	Severe	17	None	98			

BH, broken hardware; FX, fracture; FX-IO, intraoperative fracture; HHS, Harris hip score; NCB, Zimmer NCB plate; tibial, Zimmer tibial locking plate; NU, nonunion; NU (FU), nonunion/fibrous union; TO, trochanteric osteotomy; troch, trochanteric.

attempts make analysis of locking plate technology important when applied to the greater trochanter.

We demonstrate in this cohort of patients that locking plates used for trochanteric fixation yield a high union rate with an acceptable rate of complications. Our results of 91 percent union compare favorably with those reported for cable devices (21%-38% nonunion, 33%-43% breakage [17,18]), noncable devices (3%-11% nonunion [19]), and wiring techniques (9% nonunion, 4% migration prior to union [20]). Although there is a paucity of contemporary studies assessing trochanteric fixation, and direct comparisons of such studies are difficult because of varying inclusion criteria, our results match up in regard to both union rate and reoperation for hardware issues (Table 3). We think that the biomechanical advantage of the locking plate construct is superior in resisting trochanteric forces during healing [27], but this theory needs scientific confirmation.

Allogeneic structural bone graft augmentation may be used in selected instances of severe trochanteric osteolysis [8], but we utilize this technique infrequently (4/32 patients). This technique was used when there was a large, cystic osteolytic lesion in the greater trochanter. A crescent of bulk allograft bone was placed in the defect after debridement. The bulk allograft bone acts to engage the locking screws, but further studies are warranted to determine if this is necessary. Autograft from acetabular or femoral reamings was used at the fixation site if available (8 cases). We feel strongly that allograft strut bone graft will impede vascularity at the junction of the trochanter and femoral bone and do not use this technique.

The current study has several shortcomings. As a retrospective study of a relatively rare problem, a comparison group was not available, and historic data were used for assessment. Even so, contemporary comparison studies are rare and include extended trochanteric osteotomies or different proprortions of nonunions and trchanteric osteotomies (and therefore it is difficult to draw direct comparisons to this study). Further analysis of locking plate technology for trochanteric fixation should include multicenter

Table 3
Comparison with historic results (last 10 years) of trochanteric fixation with various techniques diagnosis.

Author	Fixation method	Union, n (%)	Hardware-related reoperation	Notes
This study	Locking plate	29/32 (90.6%)	5/32 (15.6%)	
Ozan et al., 2014 [21]	Cable System	14/32 (43.7%)	Not reported	Partial hip arthroplasty
Patel et al., 2012 [22]	Cable plate	44/46 (95.6%)	2/46 (4.3%)	1 patient died early; study included ETO
Lakstein et al., 2010 [23]	2-3 2× looped cerclage wires	70/83 (84.4%)	5/83 (6.0%)	Sliding osteotomy; prior osteotomy, NU, fx excluded
Zarin et al., 2007 [24]	Wire claw plate	28/31 (90.3%)	3/31 (9.7%)	
Bal et al., 2006 [25]	Wires	67/73 (91.8%)	20/73 (27.4%)	Slide osteotomy only
Barrack & Bultler 2005 [26]	Cable plate	35/42 (83.3%)	Not reported	8/42 (19%) broken hardware

ETO, extended trochanteric osteotomy; NU, nonunion.

studies to allow for larger patient numbers and multiple surgeon experience, possibly randomizing against traditional techniques. Next, several diagnoses were included in our cohort, again because of small numbers of patients requiring fixation of the trochanter. We did evaluate each diagnosis individually, but, again, larger numbers would have been helpful. Finally, 2 styles of locking plate were evaluated. We think that both should be included in our study, as this technology has not been evaluated in relation to trochanteric fixation. We prefer the specifically designed NCB plate with trochanteric extension for the reasons previously outlined in the manuscript. Finally, cadaveric biomechanical studies would also be very useful to corroborate our clinical experience (Lenz).

Based on our single-surgeon, single-institution results, we currently prefer locking plates to other forms of fixation for standard trochanteric osteotomy fixation, displaced and symptomatic Vancouver [9] A_G trochanteric periprosthetic fracture fixation, and surgically treated trochanteric nonunions after THA.

Conclusions

Locking plate fixation of the greater trochanter in patients with trochanteric fracture, osteotomy, or nonunion in the setting of THA is successful. Osseous union occurred in 30 (90.9%) of 33 hips and HHS was 91.6 (range 54-100, SD = 10.4) at latest follow-up in this cohort. Complications included broken hardware in 5 (15.2%) patients, of which, 2 underwent subsequent hardware removal. Three additional patients elected hardware removal due to trochanteric pain. The newer NCB locking plate with trochanteric attachment (Zimmer, Inc), specifically design for trochanteric fixation, is promising and does not require cable fixation.

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