The effect on outcomes of the application of circumferential cerclage cable following intramedullary nailing in reverse intertrochanteric femoral fractures

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Abstract

Introduction The aim of this study was to evaluate the effect on union results of the application of cerclage cable around the lateral femoral wall (LFW) in postoperative fracture displacement.

Patients and methods A retrospective evaluation was made of all the cases of reverse intertrochanteric fractures over a 7-year period in a trauma center. The study included 69 fractures treated with intramedullary nailing. The age of the patients, postoperative reduction quality and complications such as mechanical failure and non-union (1.4%) were obtained from the medical records. Changes in the neck-shaft angle, the amount of LFW displacement and telescoping of proximal femoral nail antirotation blades and lag screws were measured on anteroposterior and lateral radiographs. The functional evaluation of the Harris Hip Score was recorded at the final follow-up examination.

Results The mean age of the patients was 56.31 years (range 18–93 years). Closed reduction was applied in 37 (53.7%) cases, open reduction in 10 (14.5%) and with cerclage cable in 22 (31.8%). Mechanical failure developed in 8 (11.5%) cases where cerclage cable was not used. In 2 of these 8 cases, open reduction was successful. In the patients where cerclage cable was applied, no mechanical failure developed and no case underwent revision surgery. In the cases where cerclage cable was not used, a significantly higher rate of telescoping was found. ($p = 0.001$). The application of cerclage cable was seen to significantly reduce the amount of LFW displacement (2.23 mm vs 8.86 mm) and shorten the time to partial weight bearing ($p = 0.000$).

Conclusion In reverse intertrochanteric fractures, the application of circumferential cerclage cable with cephalomedullary nailing contributes to primary stability and accelerates mobilization. Therefore, it can be considered a good option. It reduces the risk of failure internal fixation for intertrochanteric fracture.

Keywords Intertrochanteric fracture · Cable · Intramedullary nailing

Introduction

Reverse intertrochanteric fractures are less common than other (AO/OTA 31-A1 and A2) intertrochanteric fractures and are estimated to constitute approximately 2% of all hip fractures [1]. These fractures are classified in the Orthopaedic Trauma Association system as AO/OTA 31-A3. There are two known deforming forces on these fractures. The first is that due to shear forces formed of the iliopsoas and adductor muscles, there is a tendency for shaft medialization and shortening in the fracture area. The second is that the deforming force of the hip abductors which tends to move the proximal fragment to varus and external rotation [2]. Due to these high tensile and compressive forces working in different directions, it is difficult to prevent

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fracture displacement and provide recovery. Furthermore, calcar support is lost because of the fractured large posteromedial fragment. Thus, there is a tendency of implant failure with axial loading. Therefore, the optimal device for stabilization of these fractures would be an implant that resists the tendency for shaft medialization, rotation and varus [3]. Intramedullary nails can more reliably resist the relatively high axial forces across the medial calcar that are typically borne by the implant in an reverse fracture and owing to this feature it allows to early partial weight bearing [1–3].

In addition, a specific feature of 31-A3 fractures is the extension to the lateral femoral wall (LFW) [4, 5]. The LFW represents a region from the vastus corner of the trochanter extending distally along the lateral femoral cortex, which prevents the sliding of the proximal fragment [6, 7]. Although seen more often in A3.3 fractures in particular, in fractures which extend to the trochanter major, there may be free proximal fracture fragments in the anterior or posterior and free posteromedial fragment [8].

These fractures where the integrity of the lateral wall is impaired are repaired much better with intramedullary nailing than with dynamic hip screw. In addition, sufficient fixation may not be able to be provided with nailing alone because of the fracture of the LFW and the associated free fragments and therefore the fracture may remain displaced [8–10]. The use of circumferential cable provides bone contact and may be useful in avoiding postoperative lateral migration and angulation due to pulling of abductor arm to proximal fragment [11]. There are several studies in literature which state that the application of circumferential cerclage cable as support to intramedullary nailing provides better functional results in trochanteric region fractures [11–13]. However, to the best of our knowledge, there is no study in literature which has compared the use of cerclage cable additional to nailing, specifically in reverse intertrochanteric fractures.

The aim of this study was to evaluate the effects of circumferential cerclage cable in addition to intramedullary nailing for reverse intertrochanteric fractures.

Patients and methods

A retrospective evaluation was made of consecutive patients who presented at the Our Hospital with a reverse intertrochanteric fracture (31-A3) over a 7-year period. A total of 10 patients were excluded from the study because of pathological fractures, multiple trauma, mortality in the early postoperative period, a lack of regular follow-up examinations, and cephalomedullary nailing was not used.

Surgical technique and the physical therapy protocol

At half an hour before the start of the operation, antibiotic prophylaxis (cefazolin sodium 1 g/day IV) was applied to all patients and in the postoperative period, treatment of low molecular weighted heparin (enoxaparin sodium 40 mg/0.4 mL/day) was administered. All the operations were conducted under spinal or general anesthesia. All the operations were applied in a single center with the participation of a surgical team of surgeons with at least 5 years of experience in hip surgery. Patients were positioned and rigidly fixed in the lateral decubitus position on a conventional surgery table. The fixation device was checked to determine fluoroscopic visualization. Reduction in the fracture was provided by manual longitudinal traction and internal rotation. The quality of the reduction was confirmed using an image intensifier positioned in a lateral mode to take images for both anteroposterior and lateral views. The lateral view was obtained by flexing the hip to nearly 90° and abducting to 45°. In fractures where undisplaced reduction could not be provided in complex or LFW and posteromedial fragmented fractures, an open surgical approach was used. Circumferential cerclage cable (1 or more) was applied to maintain fracture reduction or to fix the free lateral wall fragment and posteromedial fragment, usually when the clamp was removed after the nailing in patients with a free proximal fragment or with displaced trochanteric fragment or posteromedial fragment. Postoperatively, standard medical care was applied to all the patients. With the assistance of a physiotherapist in the postoperative period, partial weight-bearing mobilization was encouraged, depending on patient tolerance, biomechanical structure stability and bone quality. Toe touch with double crutches is allowed at first postoperative day. The patients were followed up regularly in the trauma clinic at 4, 6, 8 and 12 weeks 6 and 12 months. Non-union or delayed unions were controlled radiographically at 4 weeks intervals after 12 weeks.

At the 1-year follow-up examination, functional evaluation was made with the Harris Hip Score (HHS). Throughout follow-up, changes in the neck-shaft angle, time to fracture union, time to partial weight-bearing and mechanical complications such as hip screw migration, cutout, shaft fracture and non-union were reported in the radiological evaluations. Fracture union was defined as the visualization of osseous bridging in at least 3 cortices on anteroposterior and lateral radiographs and painless full weight bearing [14]. LFW displacement, reduction quality and telescoping of the lag screw and blade were also measured in all 69 patients.

Radiographic measurements

Measurements were taken using a measuring device in a digital environment on the radiographs taken on the post-operative 1st day and at 1 year. The measurements were standardized and evaluated by 2 experienced orthopedic surgeons. To prevent bias, the radiographic evaluations were completed before the evaluation of the functional results. Proportional correction was made of the measured screw size with the known screw size to eliminate radiological magnifications and differences in the measurements arising from the extremity position [9].

On postoperative day 1, plain anteroposterior and lateral radiographs were taken. The quality of the fracture reduction and the placement of the implant were analyzed. Reduction quality was classified as good, acceptable or poor [15]. LFW displacement was evaluated on the radiograph as the perpendicular distance from the apex of the lateral femoral fragment to the lateral edge of the nail (Fig. 1).

According to the Cleveland–Bosworth Quadrants, center–center and inferior–center quadrants were accepted as optimal and the remaining quadrants were accepted as suboptimal [16]. Telescoping was defined as the distance along the blade from the lateral border of the nail to the blade end (Fig. 1). Proximal fragment sliding was considered as the difference in telescoping between the postoperative 1st day radiograph and the 1st year radiograph.

Fig. 1 Measurement of LFW displacement (**a**). Telescoping (**b**)

Statistical analysis

Differences between the two techniques in respect of HHS, telescoping, neck-shaft angle changes, time to union and partial weight bearing were assessed using two-sample t tests. In the tables, data were expressed as mean ± standard deviation values. Chi-square tests were applied to evaluate the associations between the two techniques and quality of reduction, AO classification, ASA scores and implant positions in the studied patient cohorts. All statistical testing was performed with software R (www.r-project.org) [17].

Results

Of the 69 cases with reverse intertrochanteric fracture, cerclage cable was used in 22 (31.9%). Closed reduction was applied in 37 (53.7%) cases, open reduction in 10 (14.5%) and open reduction with cerclage cable in 22 (31.9%). Of the patients with open reduction, support with cerclage cable was applied in 68.7%. The demographic data of age, gender, ASA score and fracture pattern of the fractures treated with cerclage and without cerclage are presented in Table 1. There were no statistical difference in terms of age, gender, ASA score and fracture pattern variables. (t test, $p = 0.990$, Chi-square test, $p = 1.000$, Fisher's exact test, $p = 0.176$ and Chi-square test, $p = 0.763$, respectively).

The mean HHS was 84 ± 8.33 in the patients treated with cerclage cable and 79 ± 11.62 in those without cerclage cable. No statistically significant difference was determined (t test $p = 0.085$). The time to union was determined as mean 17 ± 4.92 weeks in the cerclage cable group and 17 ± 4.64 weeks in the group without cerclage cable, with no statistically significant difference ($p = 0.569$) (Fig. 2). No statistically significant difference was determined between the two groups in respect of implant placement or reduction quality (Fisher's exact test, $p = 0.440$ and Chi-square test,

Table 1 Comparison of baseline characteristics among the groups

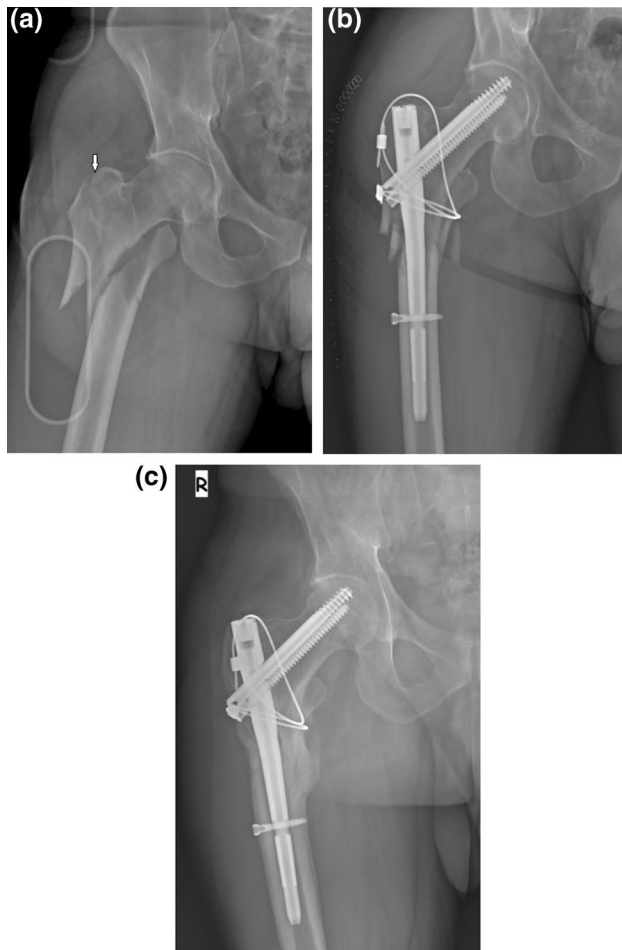| Characteristics	Cerclage cable (*n* = 22)	No cable (*n* = 47)	*p* value
Age (years) Mean (SD)	56 ± 19.92	56 ± 20.79	0.990
Sex male	13	29	1.000
AO classification			
31-A3.1	5	13	0.176
31-A3.2	2	12	
31-A3.3	15	22	
ASA score			
3 or 4	10	18	0.763
1 or 2	12	29	

Fig. 2 Extension of the main fracture to the greater trochanter (white arrow), creating a free LFW fragment (**a**) and the LFW was reduced and fixed with two cerclage cable along the lateral cortex and trochanter major (**b**). Six-month postoperative radiograph showing the stable implant with union (**c**)

$p = 1.000$). Partial weight-bearing time was significantly shorter in the cable group. ($p = 0.0001$) (Table 2).

Revision surgery was not required in any patient where cerclage cable was used. In 4 patients where cerclage cable was not used, arthroplasty was applied due to neck screw or blade cutout. In these three patients, the initial position of the implant was optimal, one was suboptimal. Erosion developed in the acetabulum in 1 patient because of protuberance of the neck screw, and total hip arthroplasty was applied. Revision surgery was necessary in 1 patient due to symptomatic non-union and in 2 patients due to severe lateral migration of the neck screw. Seven of these eight patients underwent open reduction without cable. One patient underwent closed reduction. The amount of telescoping showing shortening of the femoral neck was found to be statistically significantly high in the group without cerclage cable (*t* test, $p = 0.001$) (Table 2). The LFW displacement was determined as 2 ± 2.74 mm in the group without cerclage cable and 8 ± 6.35 mm (*t* test, $p = 0.001$) in the group where cerclage cable was used.

Discussion

Our results show that cable fixation appears to maintain good reduction, anatomic or close to anatomic reduction (Figs. 2, 3). This is often not technically possible with closed reduction alone. We believe that the good reduction not only eases the nailing procedure but also makes the entire fixation more stable, as most of the weight-bearing forces can be transferred through the aligned osseous fragments.

In 31-A3 fractures, the implant to be used must be optimal to provide anatomic reduction, to maintain the reduction until union and to allow early weight bearing. Following

Table 2 Comparison of the operating factors and the radiological and functional results of the fractures treated with and without cerclage cable

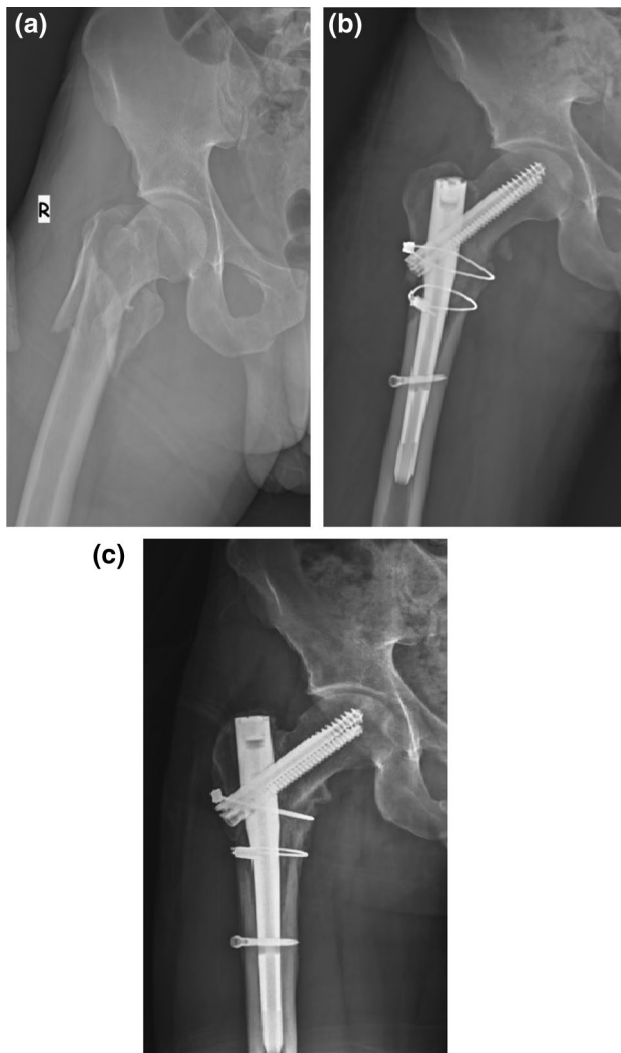| Characteristics	Cerclage cable ($n=22$)	No cable ($n=47$)	*p* value
HHS	84 ± 8.33	79 ± 11.62	0.085
Union time (weeks) (SD)	17 ± 4.92	17 ± 4.64	0.569
Partial weight-bearing (days) mean (SD)	4 ± 1.95	7 ± 3.67	0.000
Quality of reduction			
Good	18	31	0.440
Acceptable	3	11	
Poor	1	5	
Implant position			
Optimal	16	35	1.000
Suboptimal	6	12	
Nail type	10 pfna, 12 InterTan	23 pfna, 24 InterTan	0.991
Nail length long %	7 (31.8%)	13 (27.6%)	0.994
Neck-shaft angle change (degrees) (SD)	3 ± 3.21	5 ± 5.45	0.080
Telescoping [mm (SD)]	3 ± 2.80	6 ± 6.68	0.001
LDD (mm) (SD)	2 ± 2.74	8 ± 6.35	0.000

Fig. 3 Plain radiograph showing AO 31-A3.3 intertrochanteric femur fracture with four part comminution (**a**). Initial postoperative radiograph demonstrating anatomic reduction of LFW and posteromedial fragment by application of two circumferential cable (**b**). One-year postoperative radiograph showing a stable implant with union (**c**)

that as intramedullary nails functioned as support in 31-A1 and A2 intertrochanteric fractures, there was a limited effect of instability created by an unstable LFW. However, it is not clear whether or not there is any contribution to healing and stability of the support function provided by intramedullary nailing applied in these fractures which have sustained fractured and displaced LFW during the injury [4, 9, 20]. Therefore, there are no clear guidelines for the additional treatment of laterally displaced and free LFW fragments. The findings of the current study indicated that in contrast to what was assumed, there was no harmful effect of the application of circumferential cerclage cable such as infection, lateral thigh pain or delayed union.

Yun et al. [10] used supporting mini locking plates for fixation of the trochanteric major fragment in pertrochanteric fractures or for the repair of the LFW during intramedullary hip nailing. The use of these plates has been reported to be simple and allows multi-directional use. In the current study, cerclage cable can be used after nailing for the fixation of the trochanter major and repair of the LFW. Its advantages in simple, rapid and stable manipulation, as well as its ability to fulfill load bearing requirement early, can reduce complications related to long-term bed rest.

There have been reports in orthopaedic literature related to the addition of minimally invasive cerclage cable in subtrochanteric fractures exposed to forces with a similar effect as in reverse intertrochanteric fractures [24]. Cerclage cable is advocated in unsuccessful closed reduction interventions. With the assistance of a clamp, reduction combinations have been used in oblique and spiral fractures [12, 13, 25]. Following the use of cerclage cable, re-operation rates and reduction quality have been reported to be better and the amount of fracture displacement is less [12, 13]. It was also reported in another study of AO 31-A3.3 fractures that the presence of displaced LFW after closed reduction had no negative effect on the radiological healing of pertrochanteric fractures [9]. In our study, after the use of cerclage cable, better LFW reduction was seen to have been obtained.

The change in neck-shaft angle was not determined to have any effect on subsequent development of varus angulation. Furthermore, no statistically significant difference was determined between the two groups treated with or without cerclage cable in respect of the functional scores.

Although there have been low rates of open reduction reported in previously published studies, it was necessary to apply open reduction to almost half of the cases in the current series to obtain better stability and in the majority, anatomic or nearly anatomic reduction was achieved [26–28]. Despite correct technical application during nail placement, because of the difficulty in reduction in medialization of the distal fragment and abduction of the proximal fragment with the effect of the abductor arm, open reduction must be applied in some patients to determine the correct nail entry

fixation of these fractures with dynamic hip screw, complications such as implant failure and functional impairment are often seen [18]. At the same time, uncontrolled collapse of the proximal fragment is permitted following medialization of the distal femoral fragment [2, 19]. Therefore, trochanteric stabilization plates have been shown to be effective in these types of fractures in biomechanical and clinical studies [20–22]. The combination of dynamic hip screw and trochanteric stabilization plate allows for partial fixation and reduction in the trochanter major and LFW fragments. However, there is no such possibility with nailing [21, 22].

Proximal femoral nailing is the optimum treatment choice in unstable fractures, especially in reverse 31-A3 fractures with LFW fracture [3, 14, 23]. Boopalan et al. [4] reported

point and obtain anatomic or close to anatomic reduction [11, 29, 30]. The use of cerclage cable can be recommended after open reduction to obtain good primary stability and to help decrease abduction of the proximal fragment (LFW and trochanter major).

When weight bearing is applied early, to protect the reduction and reduce complication rates, it is important to provide weight transfer with the alignment of bone fragments. In our study, as there was stable reduction, the time to partial weight bearing was seen to be shorter than in without cable group. In a biomechanical study, it was reported that the wrapping of additional cerclage cable provided important posteromedial support and could reduce the risk of osteosynthesis failure in complex fractures [31]. Revision surgery was necessary because of a symptomatic nonunion in a cableless patient with poor posteromedial support (Fig. 4). No patient treated with cable in the current study required re-operation because of mechanical failure. It was also observed that good fracture repositioning was provided by the cerclage cable reducing the lateral fracture gap and provided to good posteromedial support. Other surgical

Fig. 4 **a** AP Radiograph of the left hip showing a AO/OTA 31-A3.3 fracture **b** postoperative 1 day and **c** at 11 months, a case of mechanical insufficient due to the non-union

factors such as the type and length of nail and the implant position were not found to be associated with complications.

Gao et al. [32] reported that the use of cerclage cable was a useful surgical technique for the treatment of intertrochanteric femoral fractures that could not be reduced with closed maneuvers in young patients, because the cable facilitated reaming and nailing, reduced intraoperative complications and helped to protect the reduction of the fracture. However, Ban et al. [11] applied cerclage cable additional to nailing in 35 patients with reverse fractures and reported that mobilization was accelerated in approximately three-quarters of the cases and reduction quality was increased. In our study also, no difference in reduction quality was determined between those treated with or without cerclage cable. A study by Fogagnolo et al. [33] included only 5 AO 31 A3 fractures, and fewer than half were permitted immediate weight bearing. Wei et al. [29] reported that intraoperative LFW reconstruction additional to cephalomedullary nailing for LFW integrity accelerated early mobilization. In the current study, it was also observed that the use of cerclage cable shortened the time to partial weight bearing and accelerated mobilization. Studer et al. [8] determined that the treatment of reverse pertrochanteric femoral fractures in particular with closed reduction and internal fixation with cephalomedullary nailing caused a serious loss in mobility of the displaced greater trochanteric fragment. In another study, cerclage cable applied to the LFW in reverse oblique fractures was determined to increase stability [26]. Another biomechanical study reported that the application of an auxiliary locking plate additional to nailing in intertrochanteric fractures reduced interfragmentary movement, increased the rigidity of osteosynthesis and reduced the load on the intramedullary nail [34]. Therefore, the reduced time to early weight bearing in the current study can be associated with the provision of better stability.

In our study, to prevent excessive sliding of the head and neck fragment, the application of circumferential cerclage cable additional to nailing of LFW fracture was seen to be beneficial. The rates of telescoping, which show head-neck collapse, were greater in the patients where cerclage cable was not applied. Revision with arthroplasty was applied to 2 cases because of serious lateral screw migration.

Biber et al. [35] noticed that in some cases of a series, nail gliding was blocked by cortical support below the sleeve of the lag screw on the lateral side. By removing this bone block, fracture impaction is provided along the femoral shaft axis, and with this procedure, known as "lateral notching," the risk of implant fracture has been reported to have been reduced. Lateral notching for dynamization or removal of the distal locking screw was not applied to any of the current study patients. Tomás-Hernández et al. [36] associated nail breakage primarily with fracture gaps of > 5 mm. In the current study, the reason for nail breakage in 1 case applied
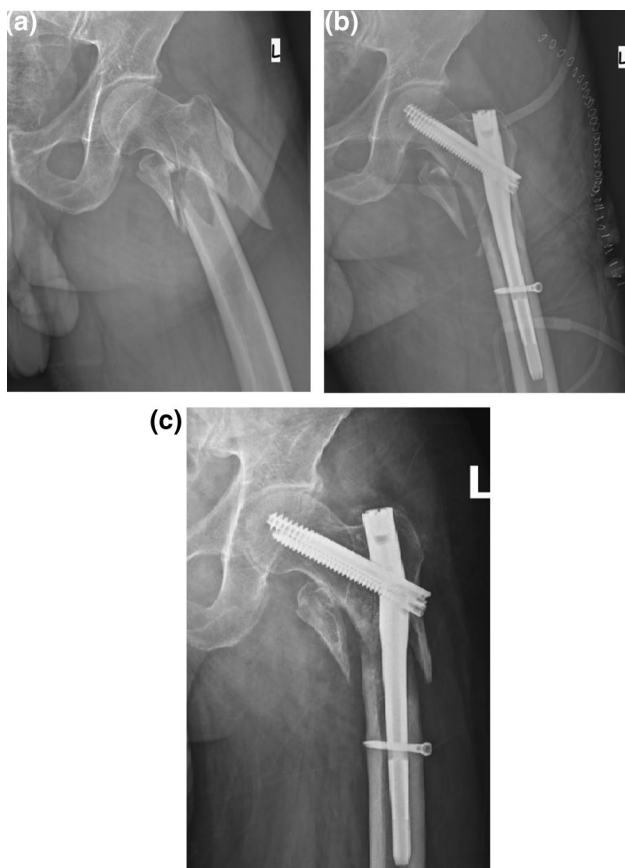
with nailing without cable was considered due to a larger medial cortical gap (Fig. 4a–c).

There is a belief that non-union is caused as a result of impaired fracture vascularity and blood support of the bone related to the use of cerclage cable [37]. This has been associated with over-dissection of the periosteal and soft tissue. If minimally invasive techniques are applied, the deterioration in soft tissue and bone vascularity is reduced [11]. In an animal model without fractures, vascular support was seen to be protected following the use of cerclage cable [38]. In the current study, there was seen to be no negative effect from the use of cerclage cable. Complete bone union was achieved in all the cases treated with cable. Kennedy et al. [25] reported no harmful effect on the time to union. In the this study, cutout developed in 4 patients who were not treated open reduction without cerclage, and revision was made with arthroplasty.

Limitations of the current study can be said to be that the study was retrospective, and as the fracture reduction in all cases was applied without the use of a fracture table, this could have affected the surgical approach rates.

Conclusion

Taking everything into consideration, the provision of stable fixation is important to reduce the risk of re-operation and obtain early mobilization. Although it cannot be recommended for routine use, the addition of cerclage cable for selected patients under optimal conditions, especially those with 31-A3.3 fractures with free, displaced LFW fracture, can be considered to increase the chance of surgical success and help to protect the reduction. This approach is an easy, safe and effective treatment for intertrochanteric fracture.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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