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Comparison of reduction methods in intramedullary nailing of subtrochanteric femoral fractures

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Objective: The aim of this study was to compare the outcomes of three reduction methods used during intramedullary nailing of the subtrochanteric femur fractures.

Methods: This study included 45 patients with subtrochanteric femur fractures who were treated with intramedullary nailing. Twenty-two patients underwent clamp-assisted reduction, 11 reduction with cable cerclage, and 12 with blocking screws. Reduction techniques were compared with respect to the early postoperative alignment, one year postoperative alignment, time to full weight-bearing, time to union, Harris hip score at one year, operation and fluoroscopy times, blood transfusion amount, complications, and additional interventions.

Results: The clamp-assisted reduction group had a statistically high mean time to full weight-bearing (p=0.038) and a low mean Harris hip score at one year (p=0.002). The blocking screw group's operation times and fluoroscopy times were statistically long. There was no statistically significant difference between the clamp-assisted reduction and cable cerclage groups in terms of operation times and fluoroscopy times. On the other hand, there were statistically significant differences between the clamp-assisted reduction and blocking screw groups (p=0.0001 and p=0.0001, respectively) and between the cable cerclage and blocking screw groups (p=0.037 p=0.0001, respectively) in terms of operation times and fluoroscopy times. There was no statistically significant difference between the clamp-assisted reduction, cable cerclage and the blocking screw groups in terms of early postoperative alignment, one year postoperative alignment, time to union, complications or additional interventions.

Conclusion: Clamp-assisted reduction leads to a longer time to weight-bearing and a poorer functional status at one year. Operation time and fluoroscopy time were longest in the blocking screw group.

Key words: Blocking screw; cable cerclage; clamp-assisted reduction; intramedullary nail; subtrochanteric fracture.

Closed intramedullary nailing is currently considered the most mechanically and biologically advantageous therapeutical modality in the treatment of subtrochanteric femoral fractures.[1-7] Subtrochanteric femoral fractures involve a high tendency towards displacement for fracture fragments due to the effects of the strong muscles adhering to the fracture site.[4,8-10] In fractures where the trochanter minor remains intact in the proximal fragment, the iliopsoas pulls the proximal fragment towards the anterior, thereby leading to a

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failure to achieve the desirable improvement by closed insertion. In such cases, closed intramedullary nailing alone may be insufficient, requiring additional methods for reduction and fixation.

One such method is cable cerclage (CC). Preferably, the CC method is only used when absolutely required as it can result in further damage to the periosteum in the soft tissue.[9] Clamp-assisted reduction (CR) is considered biologically less harmful and is performed at the lateral via a small incision and removed following the intramedullary nailing procedure.[8] A third possible method is the use of blocking screws (BS) which are not biologically harmful and applied percutaneously on the proximal fragment.

The aim of this study was to compare the efficacy of these three different reduction methods in the treatment of subtrochanteric femoral fractures with intramedullary nailing.

Patients and methods

A total of 45 patients presenting to our clinic with subtrochanteric femoral fractures between January 2005 and October 2010 were included in this study. Eleven (8 males, 3 females; mean age: 55.8 years; mean follow-up time: 24.18 months) were treated with intramedullary nailing and CC, 22 (8 males and 14 females; mean age: 55.3 years; mean follow-up time: 26.09 months) with intramedullary nailing and CR, and 12 (7 males and 5 females; mean age: 47.9 years; mean follow-up time: 21.83 months) with intramedullary nailing and BS. Patient demographics and mode of trauma are presented in Table 1 and 2, respectively.

All surgeries were performed by the same surgeon (MS) and reduction technique indications were determined by a single person. Patients were operated in a supine position on a traction table. Closed intramedullary nailing was performed using standard techniques for fractures exhibiting good alignment on bi-plane imaging under controlled traction and were excluded from the trial. Additional reduction was performed on patients in which closed reduction failed due to displacement of the proximal fragment to flexion, abduction and external rotation.

For the clamp-assisted reduction application a 5-cm-long incision was made at the lateral of the fracture site (slightly longer in over-weight people). For spiral and long fractures, a bone clamp was used to fix the fracture, intramedullary nailing was performed and the clamp removed. For transverse or short oblique fractures, the displaced proximal fragment was captured by the bone clamp and the fracture reduced; intramedullary nailing was applied while an assistant held the clamp in place. For intramedullary nailing, Synthes PFN and Synthes nails (Synthes GmbH; Zuchwil, Switzerland) or Smith & Nephew piriformis fossa-entry long nails (Smith & Nephew Inc, Memphis, TN, USA) were also used in addition to the standard PFN-A and long PFN-A (Synthes GmbH; Zuchwil, Switzerland) nails.

Table 1. Review of the groups in terms of age, follow-up time and sex.

		CR Group	CC Group	BS Group
Age (years)		55.32±23.61	55.82±19.34	47.92±20.83
Follow-up time (months)		26.09±10.88	24.18±5.78	21.83±9.69
Sex	**Male**	8	8	7
	Female	14	3	5

CC: cable cerclage, CR: clamp-assisted reduction, BS: blocking screw

Table 2. Review of the groups based on etiology of the trauma.

Etiology	CR Group	CC Group	BS Group
Pedestrian accident	1	3	1
Motor vehicle accident	4	5	2
Fall	10	3	6
Occupational accident	2	0	1
Sports injury	3	0	2
Other injuries	2	0	0

CC: cable cerclage, CR: clamp-assisted reduction, BS: blocking screw

In the CC application, an additional incision was made at the lateral of the fracture to reveal the fracture. After the fracture was reduced, a single or multiple cerclage cables (2-mm diameter; Smith & Nephew, cobalt-chromium or steel) were applied depending on the shape of the fracture followed by intramedullary nailing.

Blocking screw application was used in cases where CR application failed, particularly in Seinsheimer Type 2A, 2B and 3B fractures where the trochanter minor remained in the proximal fragment. Here, the BS indication was determined using subjective criteria based on operation conditions. A puncture was made using the drill at the posterior of the guide wire from the lateral towards the medial between the middle section and the posterior section of the bone and was followed by application of a blocking screw. In the proximal femoral external rotation, care was taken to place the screw on the frontal plane of the bone. A site of the medulla that was wide enough for the passage of the proximal thickness of the intramedullary nail was left at the anterior of the BS. In addition, a minimum 1-cm space was left between the point of the screw application and the fracture line to avoid expansion of the fracture. After the site of access in the trochanter was expanded, the nail was advanced by a few centimeters to the narrowed medulla in front of the BS. Receiving support from the blocking screw via the intramedullary nail, the proximal fragment was brought to extension and placed. As the nail was proceeded to the distal, the alignment gradually improved and the desirable placement achieved when the proximal width of the nail reached the level of the blocking screw (Figs. 1-3). In our trial, 12 patients underwent application of blocking screw from the lateral towards the medial at the posterior of the proximal fragment. Generally, a 240-mm PFN-A nail and a longer nail of the same brand was used for Seinsheimer Type 2A and Type 2B fractures and Seinsheimer Type

Fig. 1. Displacement on the lateral fluoroscopy image of a BS patient following insertion of the intramedullary guide.

Fig. 2. Fluoroscopy image during application of the BS.

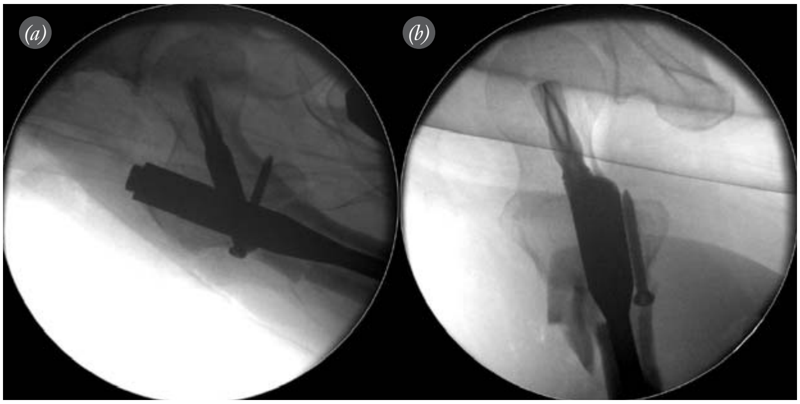

Fig. 3. **(a)** Anteroposterior and **(b)** lateral fluoroscopy images corrected after the nailing in a patient who underwent BS application.

3B fractures extending towards the diaphysis, respectively. The locking screws provided in the set were used as the blocking screws. In cases where the distal locking level of the nail used ended in the diaphysis and distal metaphysis, a single lock screw and a double lock screw was statically used, respectively.

Fractures were classified according to the Seinsheimer classification.[11] In Seinsheimer Type 2C fractures with the trochanter minor in the distal fragment and in Seinsheimer Type 3A, Type 4 and Type 5 fractures with the trochanter minor broken into a separate fragment, no marked flexion deformity occurs because there the iliopsoas has no effect on the proximal fragment. CR was used for reduction in these types of fractures. CS method was used in patients with a long oblique or spiral fracture pattern in which CR failed to achieve an adequate and permanent correction. BS was used generally in Seinsheimer Type 2A, Type 2B and Type 3B fractures with the trochanter minor remaining in the proximal fragment without breaking and with marked flexion deformity.

Drilling was done using a 4-mm diameter driller with the riffled section shortened by cutting as recommended by Krettek et al.[12]

Duration of operation was measured as the interval between the start and ending of the anesthesia (in minutes), and duration of the fluoroscopy was determined as the duration (in seconds) read on the fluoroscopy device at the end of the operation. The blood transfusions performed during or after the operation were recorded in terms of units.

All cases were mobilized using a walker on the first postoperative day and isometric exercises were initiated. Home exercises designed to increase knee and hip range of motion were begun the second postoperative week and strengthening exercises were added at the first month. After radiological bone union, full-weight bearing without assistance was permitted.

Follow-up was conducted monthly until bone union and at 6, 12 and 24 months thereafter. Early postoperative bone fracture alignment, alignment at the 1st postoperative year, time to full-weight bearing, time to bone union, Harris hips score at the end of the 1st year, complications and additional interventions were recorded. Alignment was determined by measuring the angles between the long axis of the main proximal and distal sections of the fracture using femoral anteroposterior and lateral radiographs (varus-valgus and recurvation-antecurvation angles). Non-union and delayed union were determined as the failure to achieve total or complete union on the 6th month radiograph, respectively. Patients were assessed with the Harris hip scoring system one year postoperatively.[13]

Statistical analyses were made using NCSS 2007 software. One-way variance analysis was used for intergroup comparisons and Tukey's multi-comparison test for the subgroup comparisons and the chi-square test for comparing the qualitative data. Significance level was set at $p<0.05$.

Results

There was no statistical difference between the three groups with respect to gender, age, duration of follow-up, trauma etiology, fracture type, follow-up time or time to union (Tables 1-4). The CR group had a statistically significantly higher mean time to full weight-bearing compared to the BS group ($p=0.038$), while no statistically significant difference was detected between the other groups ($p>0.05$).

Table 3. Review of the groups based on fracture type (Seinsheimer classification) and open fracture (Gustillo and Anderson classification).

Fracture type (Seinsheimer)		CR Group	CC Group	BS Group
2A		2	0	2
2B		3	0	3
2C		4	1	0
3A		4	5	0
3B		2	3	7
4		2	1	0
5		5	1	0
Open fracture (Gustillo & Anderson)	**Closed**	19	11	9
	Type 1 Open	2	0	2
	Type 3 Open	1	0	1

CC: cable cerclage, CR: clamp-assisted reduction, BS: blocking screw

Table 4. Review of the groups based on time to union, full weight-bearing and Harris hip score at Year 1.

	CR Group	CC Group	BS Group	p
Time to union (weeks)	21±9	19±8	15±6	0.170
Time to full weight-bearing (weeks)	4	5	2	
Harris hip score at Year 1	83.05±6.56	89.91±7.78	91.17±6.21	**0.002**

CC: cable cerclage, CR: clamp-assisted reduction, BS: blocking screw

There was no significant difference between the CR and CC groups for duration of operation or duration of fluoroscopy use although there was a significant difference between the BS and the CR groups (p=0.0001 and p=0.0001, respectively), and between the BS and the CC groups (p=0.037 and p=0.0001, respectively). The duration of operation and fluoroscopy was long in the BS group. There was no significant difference between the groups with respect to blood transfusions.

The multi-comparisons between the CR, CC and BS groups revealed a statistically significant difference in the mean 1st year Harris hip scores (p=0.002). The single-comparisons revealed a statistically significantly lower mean 1st year Harris hip score in the CR group relative to the CC and BS groups (p=0.024, p=0.005) while there was no significant difference between the CC and the BS groups.

The CR, CC and BS groups exhibited no statistical significance in the early postoperative and 1st year alignments. No statistically significant difference was detected between the CR, CC and BS groups in terms of complications and additional interventions (Table 5).

An 83-year-old patient with a Seinsheimer Type 2A fracture achieved bone union only at Week 32. This patient, who was able to walk with full weight-bearing using a single walking stick, was considered a case of delayed bone union. All other patients recovered without complications.

Discussion

Intramedullary nailing is considered the gold standard in the treatment of subtrochanteric femoral fractures, particularly in unstable fractures such as those due to biomechanical reasons and reverse oblique trochanteric fractures.[1-3,6,13-17] Impairment of alignment may occur during the treatment of subtrochanteric fractures with intramedullary nailing. While the CR, CC and BS methods used to eliminate the impaired alignment are individually described in the literature, no study comparing these three methods exists.

Although closed intramedullary nailing is currently the preferred therapeutical method due to its favorable mechanical and biological side effects, the adherence of the strong muscles to the femoral proximal region in closed displacement causes major issues in cases of subtrochanteric fractures.[4,8,9,18,19] The proximal fragment is displaced to the anterior by the influence of the iliopsoas muscle, to the lateral by the influence of the gluteus medius muscle and the distal fragment is displaced to the medial by the effects of the adductor longus and magnus muscles. In Seinsheimer Type 2A, 2B and 3B fractures, where the trochanter minor remains intact in the proximal fragment, the proximal fragment that is oriented towards the anterior under the influence of the iliopsoas results in flexion deformity. With femurs with a long and narrow medulla, the distal fragment can be managed using intramedullary nailing. However, the proximal fragment with a short and large medulla on flexion cannot be adequately managed by the intramedullary nail. Other applications are required to achieve reduction.

Afsari et al.[8] recommended reduction with a small incision at the lateral using a bone clamp, while Park and Young[20] recommended achieving reduction with long hemostatic forceps. Cable cerclage may be added

Table 5. Review of the groups in terms of complication and need for additional intervention.

		CR Group	CC Group	BS Group
Complication	**No**	9	7	9
	Yes	13	4	3
Additional intervention	**No**	16	8	10
	Yes	6	3	2

CC: cable cerclage, CR: clamp-assisted reduction, BS: blocking screw

to provide a more permanent effect. However, since this would warrant a larger incision and cause injury to the soft tissues and the periosteal circulation, it is not preferred. Russell et al. recommend using nail insertion methods with low tissue damage that are designed to avoid alignment impairment without biological damage (minimally invasive nail insertion technique).[21]

Blocking screws are used to constrict the intramedullry duct, thereby orienting the intramedullary nail towards the desirable direction and achieving a better fracture placement. Screws also contribute to maintaining the placement and increasing fracture fixation.[12,22,23] Blocking screws were first described for the tibial proximal and distal fractures by Krettek et al. in 1999.[12,22] Stedtfeld et al. performed a comprehensive trial on the application of blocking screws.[23] Ostrum and Maurer[24] described the treatment method for the retrograde intramedullary nailing of distal femoral fractures with BS and Ricci et al.[25] described the treatment of the proximal tibial fractures with BS. We performed our applications on subtrochanteric femoral fractures and observed beneficial results of blocking screws on achieving, maintaining and stabilizing the insertion.

In CR, there may be impairment following placement and driving of the nail, while BS provides a more lasting placement and contributes to stabilization. CC also has a lasting effect; however, it greatly damages the soft tissue and periosteal circulation. The duration of surgery and fluoroscopy use was long in the BS group. We believe the better outcomes obtained with this technique outweighs the long surgery duration and surgical staff's high exposure to radiation.

PFN-A nails have a more lateral entry compared to the nails with piriformis fossa entry and are thus considered disadvantageous with respect to avoiding varus in subtrochanteric fractures. However, they also have advantages, such as convenience of application and insertion, capacity to strongly seize the femoral head, and ability to perform distal locking with a guide for standard sizes. We did not observe any complications such as head perforation or cubitus varus that would warrant reoperation. We believe that these complications can be prevented by accurate insertion of the hip screw, appropriate selection of the entrance site and proper placement.

The most common complication associated with BS is the occurrence of a new fracture at the application site and enlargement of the existing fracture. To avoid this, the point of application should be accurately selected. The screw should be inserted close enough to the midline so that it can effectively orient the nail to the opposite side and the intramedullary nail should fit into the remaining duct. In addition, a space sufficient to prevent a new fracture should be left between the screw and the fracture line. In our study, no new fractures occurred due to BS.

Blocking screws are applied opposite to the displacement direction of the fracture. As required by the shape of the fracture, the screws may be inserted from the anterior to the posterior and in the distal fragment in subtrochanteric femoral fractures. In our cases, we applied the BS at the posterior of the proximal fragment displaced to the anterior, and from the lateral to the medial. A disadvantage of such applications is that a single blocking screw may fail to avoid displacement, such as abduction, external rotation and flexion. If a blocking screw inserted from the lateral to the medial at the posterior of the nail is placed into the proximal femoral fragment exactly at the frontal plane, it corrects the external rotation deformity together with the flexion during reduction. For abduction, a percutaneous bone skidder can be used at the lateral. As CR with incision was initially used in all these cases we had no difficulty in pushing the proximal fragment or seizing it with the bone clamp. Still, a second blocking screw can be applied from the anterior to the posterior at the medial of the nail in case of failure. We did not perform a second screw application in our series, considering the technical difficulty of application and the potentially increased risk of splitting the proximal fragment.

We did not observe any difference in the clinical assessment criteria between the BS and CC groups, with the exception of a longer time to weight-bearing and worse functional status at the end of the 1st year in the CR group. We observed a subsequent loss of alignment in a portion of the CR patients, despite proper fracture placement during the operation. Therefore, we acted more cautiously in maintaining the postoperative insertion and delayed the time to weight-bearing. We did not limit weight-bearing in the CC and BS groups as additional procedures that potentially contributed further to the fracture placement and stabilization were performed. This is reflected in our statistical data.

In conclusion, the time to weight-bearing and thus the Harris hip scores were unfavorable in the CR group which did not provide an internal fixation similar to the CC and BS methods. There was no difference between these groups in the time to bone union, alignment or complications. As for the CC and BS treated arms with more favorable results, CC has an unfavorable effect in that it results in a higher soft tissue injury and BS involves a longer duration of operation and fluoroscopy. BS applications may be preferred despite the prolonged duration of the operation and the fluoroscopy due to the permanence of the fracture placement and lesser soft tissue injury. We also began to mostly perform the BS application percutaneously without trying the CR application. However, one should consider the longer learning curve while applying this method.

Conflicts of Interest: No conflicts declared.

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