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Intramedullary fixation with minimally invasive clamp-assisted reduction for the treatment of ipsilateral femoral neck and subtrochanteric fractures: a technical trick

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Summary:
The purpose of this study is to describe a surgical technique for intramedullary fixation and minimally invasive clamp-assisted reduction with selective cerclage wiring for the management of combined ipsilateral femoral neck and subtrochanteric fractures and to present the clinical outcomes in 17 patients after treatment using this technique.

Introduction
In recent years, the incidence of proximal femoral fractures has significantly increased,[1] and the number of patients suffering from proximal femoral fractures is expected to double in the next 25 years.[2] Ipsilateral femoral neck and subtrochanteric fractures account for 1%-9% of femoral subtrochanteric fractures.[3,4] They are rare injuries, but their management presents a significant challenge to the orthopedic surgeon. The unique anatomical structure and intense concentration of the deforming forces increase the difficulty of successful treatment Moreover, femoral neck fractures are commonly associated with a higher rate of complications, including malunion, nonunion, and avascular necrosis.[5,6] It is therefore critical to obtain both an anatomical reduction and maintain effective stable fixation of both fractures.[6-8]

Treatment options for ipsilateral femoral neck and subtrochanteric fractures include a cephalomedullary “reconstruction” nail, a sliding hip screw and side plate, antegrade,or retrograde nails, or femoral plates, with adjacent femoral neck screws around the nail or plate.[8-10] However, there is no consensus on the optimal surgical treatment at present. Intramedullary nails have advantages such as superior mechanical stability and less invasiveness, and their combination with cerclage wiring contributes to better fixation stability and early mobilization in comminuted pertrochanteric fractures.[11] Furthermore, closed reduction is less harmful to femoral neck fractures, especially minimizing damage to the blood supply.The purpose of this study was to describe a surgical technique for the treatment of ipsilateral femoral neck and subtrochanteric fractures and to present the clinical outcomes in 17 patients after treatment with using this technique.

Patient Management and Surgical Technique
The patient should undergo preoperative fluoroscopy of the femur and hip joint (Fig. 1a and b) for detection of ipsilateral femoral neck and subtrochanteric fractures. A CT scan is needed for further diagnosis (Fig. 1c and d). Once the diagnosis is made, and surgery is indicated, the patient is placed on a radiolucent operative traction table in the supine position under general anesthesia. The foot of the injured lower extremity is fixed for further traction. The contralateral lower extremity is placed in the hemi-lithotomy position for easy distal locking and a proper lateral view of the injured extremity (Fig 2a). Initially, anteroposterior and lateral views of the hip joint and the subtrochanteric fracture are obtained by the image intensifier. With the assistance of the image intensifier, gradually increasing lateral traction is applied to the upper thigh, and after that additional longitudinal traction is applied to remove the impaction of the femoral neck fracture using the operative traction table. Then, the injured lower extremity is placed in an internal rotation and adduction position to reconstruct the femoral neck and achieve an optimal reduction (Fig 2b and c). Unless an anatomic reduction can be obtained by closed means on the fracture table, as verified on both the AP and lateral fluoroscopic views, an open reduction must be performed using a separate Smith-Petersen approach. The femoral neck fracture is exposed and debrided carefully after the hip capsule incision. Then, the femoral neck fracture is reduced gently with internal rotation and adduction of the upper thigh, which is followed by provisional fixation with K-wires. The K-wires are removed when the intramedullary nailing is completed.

The femoral subtrochanteric fracture site is confirmed by the image intensifier after conventional sterilization and toweling (Fig 3a). Then, a longitudinal 4-6 cm incision is performed on the lateral aspect of the femur. Fracture exposure is achieved through fascia lata incision and blunt dissection of the vastus lateralis. The soft tissue between the fracture fragments is removed completely under direct vision. A three-jaw reduction clamp is placed across the fracture site before fracture reduction, which is checked by the image intensifier. The distal femur is rotated to correct the fracture deformity to obtain an anatomic reduction. Finally, the reduction clamp is tightened to close the fracture gap, and the clamp is left in place until evaluation of fracture displacement (Fig. 3b and c).

For intramedullary nailing, a 3-5 cm longitudinal incision is made 3 cm above the greater trochanter. The apex of the greater trochanter is chosen as the entry point for intramedullary nailing after fascia lata incision. After insertion from the entry point, the guidewire should be confirmed across the fracture ends into the distal femur with the assistance of the image intensifier. Then, the intramedullary nail (InterTan; Smith Nephew, Memphis, TN) with a radiolucent proximal screw aiming device is inserted across the subtrochanteric fracture site along the guidewire after reaming the femoral canal. The lag screw hole should be confirmed on the midline of the femoral neck and femoral head. All above manipulations should be performed gently to avoid fracture displacement. The anti-rotation bar is inserted through the lower screw hole, and then the lag screw is inserted into the upper screw hole after length measurement.The compression screw is then introduced through the lower screw hole after anti-rotation bar removal. Allowing the screwhead to seat against the lateral aspect of the nail while using the intergrated screw's rack and pinion mechanism, allows up to 10 mm of fracture compression. Tightening the superior set screw will then lock the two integrated screws. Both the lag screw and compression screw are introduced with a proximal screw aiming device after femoral neck anteversion adjustment and should be inserted to reach the subchondral portion of the femoral head. Long intramedullary nails and static distal locking are recommended for ipsilateral femoral neck and subtrochanteric fractures.

For the transverse and short oblique subtrochanteric fractures, the reduction clamp was released and removed. For oblique subtrochanteric fractures, the displacement degree of femoral subtrochanteric fractures is evaluated after the release of the reduction clamp, and the clamp remains in place after release. If the fracture displacement is more than 5 mm, cerclage wiring is adopted for further fixation of the femoral subtrochanteric fracture (Fig. 3d). Otherwise, the reduction clamp is directly removed. Finally, wound closure and final fluoroscopic views are obtained (Fig. 3e, f, and g). Gradual range of motion exercises are important and encouraged in the early postoperative period. Partial weight bearing is permit after 8–12 weeks non-weight-bearing activities postoperatively. Full weight bearing is permit only after radiological union (appearance of callus continuity across fracture site on AP and lateral radiographs) or clinical union. Routine radiological and clinical assessment was performed every 1 month until presence of radiological consolidation, and then every 3 months thereafter.

Clinical Cases

From June 2012 to June 2015, a total of 17 patients underwent surgical treatment for ipsilateral femoral neck and subtrochanteric fractures in our level I trauma center (Table 1). Patients who had complications of open fractures, prior fractures of the ipsilateral femur, concomitant fractures of the ipsilateral extremity, pathological fractures, multiple trauma, malignancy related fractures, severe systemic disease, or severe hematological diseases were excluded. All patients who met these criteria had the above-described surgical treatment performed. Informed consent was provided prior to participation. The study protocol and amendments were approved by the local institutional review boards. The operative time, fracture healing time, and postoperative complications were recorded. The tip apex distance (TAD) and fracture displacement were evaluated with fluoroscopy 1 month postoperatively. The Harris Hip Score

and visual analog score were recorded for evaluation of hip function at the final follow-up. Length discrepancy of the injured lower extremity was defined as shortening of more than 2 cm compared with the contralateral extremity.

The 17 patients in the study (4 men and 13 women) had an average age of 51.47±11.16 years, and all patients completed a minimum of 12 months of follow-up. The mean follow-up time and mean operative time were 14.29±2.26 months and 81.24±17.45 minutes, respectively. Sixteen of the 17 ipsilateral femoral neck and subtrochanteric fractures were caused by a high-energy mechanism (14 automobile accidents and 2 motorcycle accidents), and the remaining fractures were caused by a lower-energy mechanism. Twelve fractures occurred on the right side and 5 on the left side. According to Garden classification, there were 7 type II, 7 type III, and 3 type IV femoral neck fractures. Femoral subtrochanteric fractures were classified by Seinsheimer classification, with 9 type II, 4 type III, 2 type IV, and 2 type V recorded (Table 1).

All patients achieved bone union with a mean fracture healing time of 26.65±6.22 weeks. The mean Harris Hip Score was 84.71±7.32 at the final follow-ups. Fourteen of the 17 patients (82.4%) obtained satisfactory hip function. Sixteen of the 17 patients (94.1%) believed they had recovered preoperative function at the final follow-up. Four patients (23.5%) complained of mild postoperative pain, which did not influence normal life. The mean TAD was 15.53±4.14 mm at the final follow-up. During the follow-up period, there was no obvious fracture displacement, osteonecrosis, or nonunion. Only 1 mild hip varus was observed due to femoral neck displacement, which finally achieved bone union. In addition, there was no screw cut-out, implant failure, loosening of cerclage wiring, or length discrepancy of the injured lower extremity.

Discussion

Although ipsilateral femoral neck and subtrochanteric fractures are uncommon, they present various challenging problems for fracture management.[12] At present, there is no consensus on the optimal treatment of ipsilateral femoral neck and subtrochanteric fractures. Intramedullary and extramedullary fixation are the main treatment methods.[13] One study applied plate fixation and femoral neck screws for ipsilateral femoral neck and subtrochanteric fractures, and they reported 5 (10.6%) instances of shaft nonunion.[10] Several studies have verified the efficacy of intramedullary nails for the treatment of these fractures.[14,15] Intramedullary nails have excellent mechanical stability and contribute to early mobilization, which are more important for subtrochanteric fractures without medial column support. However, a higher nonunion rate of femoral neck fractures was also reported for ipsilateral femoral neck and subtrochanteric fractures treated with a combination of antegrade intramedullary nailing and lag screws.[16]

The shape and combination of InterTan proximal screws increase the fracture stability and resistance of screw cut-out,[6-8] and its unique linear compression technique and anti-rotation characteristics have been verified to have good efficacy in the fixation of femoral neck fractures.[2] In our study, ipsilateral femoral neck and subtrochanteric fractures were treated with minimally invasive clamp-assisted reduction, intramedullary nails, and selective cerclage wiring. We found that 14 of 17 patients (82.4%) obtained satisfactory hip function. There was only 1 incidence of mild hip varus, which finally achieved bone union. Moreover, no osteonecrosis, nonunion, or implant failure was observed.

When evaluating long-term outcomes, femoral neck fractures are recommended to be managed first.[17] It is critical to obtain anatomical reduction of the femoral neck to decrease the incidence of osteonecrosis, implant failure, and other complications.[11,15] Moreover, Gotfried et al.[18] proposed a novel closed reduction method of femoral neck fractures to achieve stable fixation through constructing positive support, and they reported a satisfactory outcome through the above method. For subtrochanteric fractures, Afsari et al. [19] found that intramedullary nails and clamp-assisted reduction with cerclage wiring contributed excellent reduction and a high union rate, which had a similar union rate to our results (43/44 vs. 17/17). Yoon et al. [20] performed a pointed clamp reduction for spiral subtrochanteric fractures, and 1

instance of loss of reduction was observed after release of the reduction clamp. Therefore, cerclage wiring for additional fixation should be provided when loss of fracture reduction occurs after clamp removal. Moreover, minimally invasive clamp reduction for femoral subtrochanteric fractures is mandatory to achieve good outcomes, and careful attention should be paid to minimize damage to the soft tissues.[21]

Anatomical reduction of subtrochanteric fractures is key to successful bone union, and cerclage wiring is effective in maintaining fracture reduction.[22,23] A mechanical study supported that cerclage wiring provided effective support of the medial cortex to reduce implant failure.[8] Moreover, Ban et al. [24] demonstrated that cerclage wiring was an adjunctive method of increasing fracture stability and did not increase the incidence of bone nonunion. However, several studies suggested that cerclage wiring might compromise periosteal blood supply and had a negative effect on bone union.[21, 25, 26] They believed that more soft tissue dissection, potential increase of operative time, and risk of surgical infections were the main disadvantages.[21,26] In our study, cerclage wiring was selectively used for fixation of femoral subtrochanteric fractures after evaluation of the displacement degree. All subtrochanteric fractures finally achieved anatomical reduction and bone union. We recommend the selective application of cerclage wiring for adjunctive fixation of subtrochanteric fractures when patients have an unsatisfactory reduction after intramedullary nailing.

In summary, intramedullary nailing with minimally invasive clamp-assisted reduction is effective for the treatment of ipsilateral femoral neck and subtrochanteric fractures by stable fixation. Selective cerclage wiring can provide an additional fixation for subtrochanteric fractures to maintain satisfactory reduction.

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Figure 1. a. preoperative hip fluoroscopy; b. preoperative femur fluoroscopy; c. a femoral neck fracture with CT scan; d. a subtrochanteric fracture with CT scan.

Figure 2. a. surgical posture; b. femoral neck fracture after closed reduction; c. femoral subtrochanteric fracture after closed reduction.

Figure 3. a. location of subtrochanteric fractures; b. a subtrochanteric fracture reduction after minimally invasive clamp-assisted reduction; c. a reduced subtrochanteric fracture under fluoroscopy; d. a reduced subtrochanteric fracture fixed with cerclage cable; e. lateral view of proximal femoral portion; f. antero-posterior view of proximal femoral portion; g. distal locking of intramedullary nail

Table 1. The baseline demographics of participants and follow-up results

Table 1 The baseline demographics of participants and follow-up results

No.	Sex	Age (years)	Follow-up (months)	Garden Classifications	Seinsheimer Classifications	Operative time (minutes)	TAD (mm)	Time union (weeks)	Severe complications	Harris Hip Score	VAS
1	F	60	12	III	IIIB	75	14	18	/	95	0
2	F	37	17	IV	IIB	85	13	20	/	92	0
3	M	43	12	III	IIC	79	18	24	/	93	0
4	F	42	14	II	IV	70	22	31	/	87	0
5	F	48	14	II	IIIA	69	11	27	/	89	0
6	F	77	13	II	IIC	74	17	22	/	86	0
7	M	49	15	III	IIA	84	23	24	/	79	2
8	F	58	14	II	IIC	65	19	25	/	84	0
9	F	35	13	IV	IIIA	64	10	30	/	80	1
10	F	49	15	II	IIC	82	17	28	/	92	0
11	M	53	15	III	IIIA	91	21	30	/	83	0
12	F	40	18	III	V	125	12	29	/	83	0
13	F	54	14	II	IIB	77	14	21	/	90	0
14	F	58	12	III	IIC	72	15	26	/	81	0
15	M	55	13	III	IV	99	16	35	/	77	1
16	F	47	20	IV	V	112	9	42	Mild varus	69	3
17	F	70	12	II	IIA	58	13	19	/	85	0

Figure 1

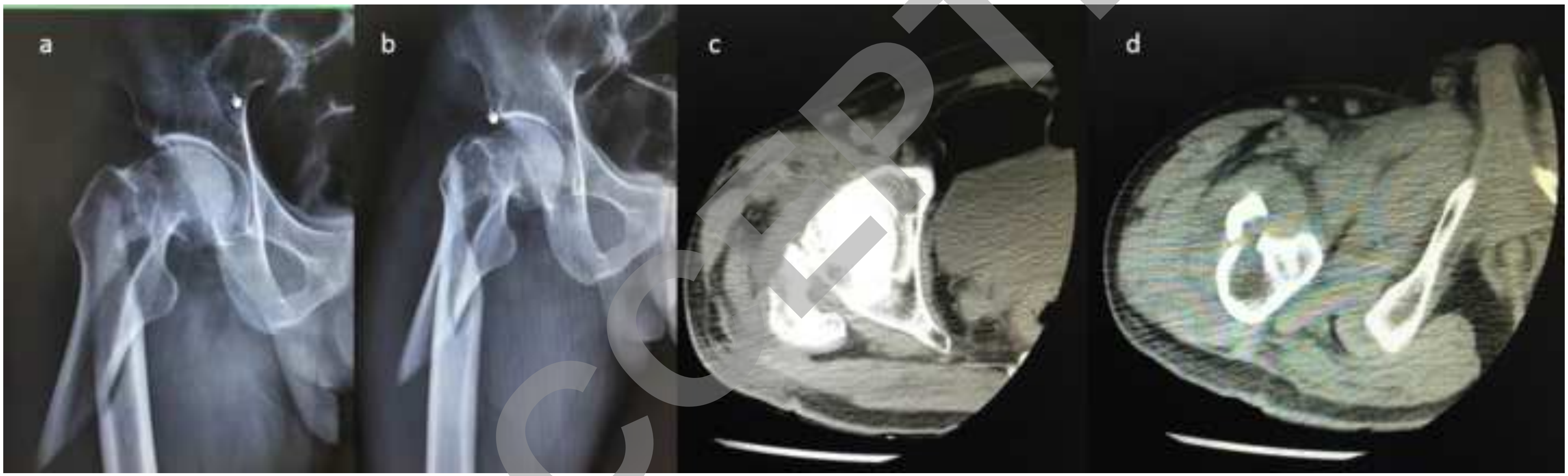

Figure 2

Figure 3