Loss of the posteromedial support: a risk factor for implant failure after fixation of AO 31-A2 intertrochanteric fractures

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Abstract

Background: The purpose of this study was to analyze cases of AO31-A2 intertrochanteric fractures (ITFs) and to identify the relationship between the loss of the posteromedial support and implant failure.

Methods: Three hundred ninety-four patients who underwent operative treatment for ITF from January 2003 to December 2017 were enrolled. Focusing on posteromedial support, the A2 ITFs were divided into two groups, namely, those with (Group A, $n = 153$) or without (Group B, $n = 241$) posteromedial support post-operatively, and the failure rates were compared. Based on the final outcomes (failed or not), we allocated all of the patients into two groups: failed (Group C, $n = 66$) and normal (Group D, $n = 328$). We separately analyzed each dataset to identify the factors that exhibited statistically significant differences between the groups. In addition, a logistic regression was conducted to identify whether the loss of posteromedial support of A2 ITFs was an independent risk factor for fixation failure. The basic factors were age, sex, American Society of Anesthesiologists (ASA) score, side of affected limb, fixation method (intramedullary or extramedullary), time from injury to operation, blood loss, operative time and length of stay.

Results: The failure rate of group B (58, 24.07%) was significantly higher than that of group A (8, 5.23%) ($\chi^2 = 23.814$, $P < 0.001$). Regarding Groups C and D, the comparisons of the fixation method ($P = 0.005$), operative time ($P = 0.001$), blood loss ($P = 0.002$) and length of stay ($P = 0.033$) showed that the differences were significant. The logistic regression revealed that the loss of posteromedial support was an independent risk factor for implant failure (OR = 5.986, 95% CI: 2.667–13.432) ($P < 0.001$).

Conclusions: For AO31-A2 ITFs, the loss of posteromedial support was an independent risk factor for fixation failure. Therefore, posteromedial wall reconstruction might be necessary for the effective treatment of A2 fractures that lose posteromedial support.

Keywords: Intertrochanteric fractures; AO 31-A2; Loss of posteromedial support; Implant fixations; Implant failure

Introduction

There is an increasing incidence of hip fractures, and new epidemiological data have shown that the number of patients could reach up to 6.3 million per year in 2050.[1] Intertrochanteric fracture (ITF) accounts for half of hip fractures, and the preferred treatment is internal fixation and early mobilization.[2,3] With the development of therapy methods, the rate of failure is decreasing, but numbers are still growing, especially for unstable fractures. Failure can result in great damage to an elderly person's health and is sometimes deadly. Therefore, it is extremely urgent for us to identify the risk factors of failure pre-operatively and avoid them as much as possible.

Previous study has reported the parameters that suggest instability and failure of fixation, such as

1) loss of posteromedial support,
2) severe comminution at the greater trochanter leading to difficulty in passing an intramedullary nail,
3) subtrochanteric extension of fracture,
4) reverse oblique fracture pattern,
5) burst lateral wall,
6) posterior wall fracture/coronal split,
7) extension into the femoral neck area/piriformis fossa, and
8) poor bone quality.[4]

Though the loss of posteromedial support, including the lesser trochanter (LT), has been widely considered as one of the factors of instability, most surgeons do not fix the fragment in clinical practice due to technical restrictions and the price of reduction.[5,6] In the early stages, Evans[7]

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identified the key function of the posteromedial cortical continuity and stressed the importance of the bone-to-bone buttress in the inner side of ITF treatment. Recently, increasing numbers of researchers have paid attention to the role of the posteromedial support. Futamura *et al*[8] suggested that even though reduction of the medial displacement was technically difficult, special attention should be paid to it. Apel *et al*[9] conducted a biomechanical experiment and suggested that the size of the posteromedial fragment was important in fracture stability and considered the posteromedial cortex as the keystone of the stability. A recent biomechanical study also suggested that the increasing comminution of the LT could cause instability in A2 ITF.[10] A biomechanical assessment by Zhang *et al*[11] revealed that the medial buttress could make a difference in the stability of ITF. The surgical treatments for ITF include intramedullary and extramedullary fixation. Previous studies have stated that in unstable ITFs, an intramedullary implant was better than an extramedullay one.[12,13] In their biomechanical experiment, Marmor *et al*[10] determined that when a medial defect existed, an extramedullary implant was more vulnerable than an intramedullary one. Even though surgeons are beginning to be aware of the importance of the posteromedial cortex, there is still no consensus on whether the fragment should be fixed or not, let alone a standardized repair procedure.

The purpose of this study was to retrospectively analyze the cases of AO31-A2 ITFs in our hospital and to identify whether the loss of posteromedial support would add to the risk of fixation failure.

Materials and methods

Patient data

This study was a retrospective analysis, and approval was obtained from the Institutional Ethics Committee of the Peking University Third Hospital. All the patients were selected from the database of the ITF patients treated in our hospital from January 2003 to December 2017. The inclusion and exclusion criteria were as follows.

Inclusion criteria: (1) AO31-A2 ITFs; (2) fresh closed fractures underwent close reduction and internal fixation; (3) American Society of Anesthesiologists (ASA) score not more than 3; (4) regular radiological review until bone union unless failure; and (5) a minimum of 1 year of follow-up unless failure. Exclusion criteria: (1) open fracture; (2) multiple injuries to the same leg; (3) pathological fracture; (4) patients with subtrochanteric fracture; (5) ASA score more than 3; (6) walking disability before injury; (7) fracture of AO31-A1 and A3; (8) bilateral ITF; (9) opposite ITF during follow-up; and (10) patients without complete follow-up statistics.

Overall, 394 patients were enrolled into the study. They were allocated into two groups: those with (Group A, $n = 153$) or without (Group B, $n = 241$) posteromedial support in the inner side post-operation [Figure 1]. All the patients were treated with closed reduction and internal fixation (intramedullary or extramedullary) by experienced orthopedic trauma surgeons. The loss of posteromedial support was defined according to the post-operative radiograph, and those with a bone-to-bone defect in the inner side met our criterion. The following features suggested the existence of posteromedial support: (1) avulsion fractures of the LT; (2) insert fracture of the two fracture sites; and (3) wire binding of the LT fragment during operation [Figure 2].

The primary outcome we focused on was the radiological failure post-operatively, which was defined as: (1) varus deformity (judged by the neck-shaft angle variation); (2) cut-out and movement of the lag screw, Z-effect; (3) breakage of the plate, screw and even the nail; (4) periprosthetic fracture; and (5) malunion, delayed union and nonunion [Figure 3]. All the above results were identified in the anteroposterior radiological film during the follow-up review. Other clinical characteristics were recorded, including the age, gender, mechanism of injury, fixation method (intramedullary or extramedullary), ASA score, the side of the affected limb, time from injury to operation, blood loss, operative time and the length of stay. A successful outcome was defined as a fracture with normal union without any discomfort symptoms; those with radiologically abnormal features but free from any clinical discomfort symptoms were considered as failure cases. Based on the final outcomes (failed or not), we allocated all of the patients into two groups: failed (Group C, $n = 66$) and normal (Group D, $n = 328$). We separately analyzed each dataset to identify the factors that exhibited statistically significant differences between the groups and then performed a logistic regression to identify the significant factors for implant failure.

Operative protocol

All of the cases were included in pre-operative discussions by more than four experienced orthopedic trauma surgeons for surgical procedures. The operations were conducted by skilled surgeons under the condition of general anesthesia and fluoroscopy control on a radiolucent fracture table. After satisfying anesthetized and closed reduction to anatomical position, the implants were precisely inserted under the control of radiological imaging. There were no intraoperative complications.

Statistical analysis

We used Shapiro-Wilk test to test the normality of the continuous data, if the data obey to normal distribution, a student's t test was used to analyze. The Mann-Whitney U test was performed to test the non-normal distribution data. The Chi-square test was used to analyze the ranked data. All of the factors with significant differences or the risk factors were analyzed by logistic regression, and $P < 0.05$ was considered statistically significant. All of the analysis procedures were performed with SPSS Statistics (version 24.0; IBM Corp., Armonk, NY, USA).

Results

The Shapiro-Wilk test turned out that all the continuous data were non-normal distribution; therefore, we dealt them with Mann-Whitney U test. The average age of these

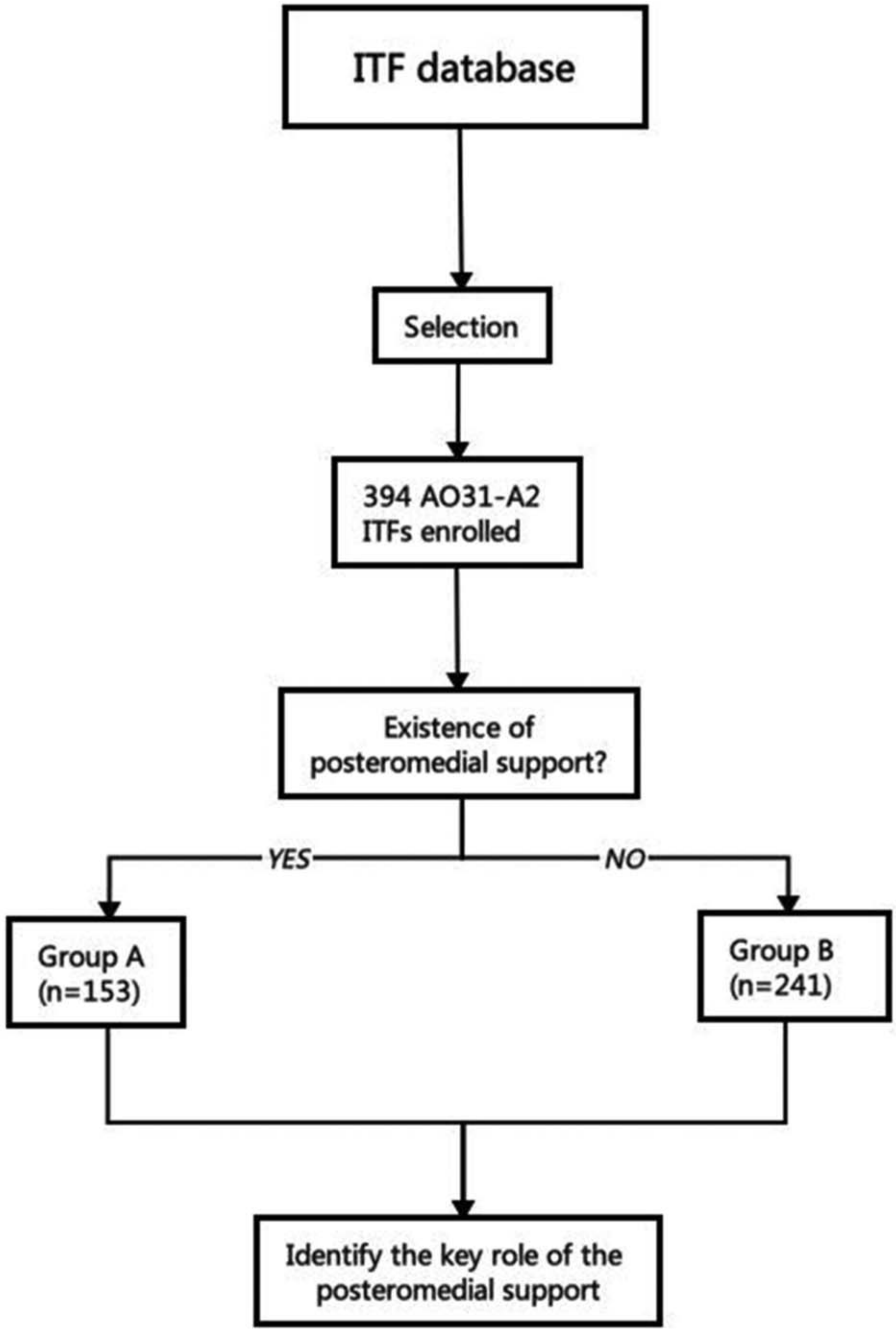

Figure 1: Flow diagram showing the study methodology. ITF: Intertrochanteric fracture.

394 patients was 76.36 years (range from 27 to 95 years), and the patients included 131 men and 263 women and 209 left and 185 right femoral ITFs. The mean follow-up period was 28.4 months. All fractures were caused by low-energy damage, and 362 patients were fixed with intramedullary implants, while the others were fixed with extramedullary implants. The number of patients evaluated as ASA scores I, II, and III were 71, 220 and 103, respectively. There were no significant differences in age, gender, affected side and ASA scores between Groups A and B ($P > 0.05$) [Table 1]. Regarding the parameters related to the operation, there were no statistically significant differences in the time from injury to operation, blood loss, operative time, length of stay and fixation method of the two groups ($P > 0.05$). The failure rate of Group B (58, 24.07%) was significantly higher than that of Group A (8, 5.23%) ($\chi^2 = 23.814$, $P < 0.001$) [Table 2]. The most common failures were varus (28, 48.28%) and cut-out (10, 17.24%) complications.

For Groups C and D, the differences in gender, affected side, ASA score, age, length of stay and the time from injury to operation between the two groups had no significant differences (all $P > 0.05$). The variance in blood loss was uneven, so we conducted a Mann-Whitney U test. The comparisons of the fixation method ($P = 0.005$),

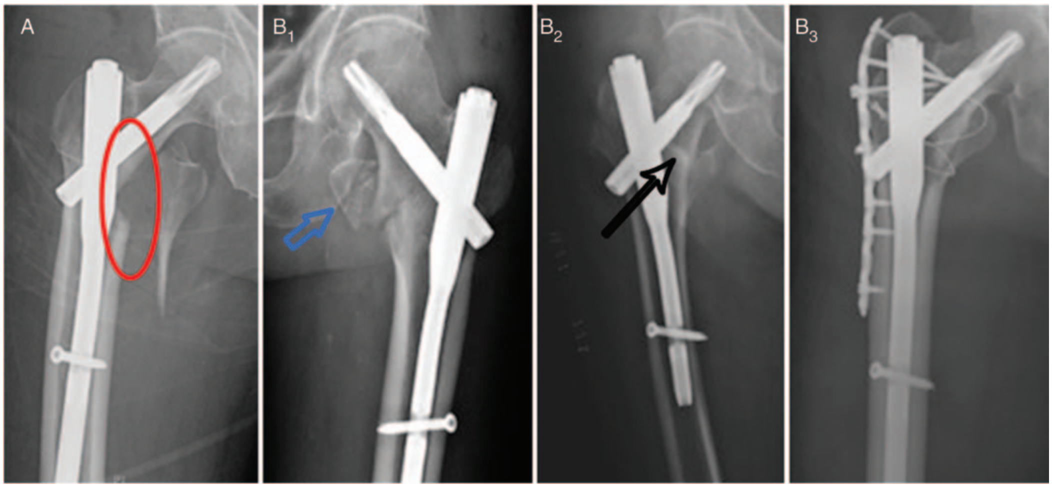

Figure 2: Images showing the loss support of the posteromedial cortex (A, red circle) and the existence of posteromedial support: avulsion fracture of LT (B_1, the blue arrow), insert fracture of the inner side (B_2, black arrow) and the wire binding of the LT (B_3). LT: Lesser trochanter.

operative time ($P = 0.001$), blood loss ($P = 0.002$) and the length of stay ($P = 0.033$) showed that the differences were significant [Tables 3 and 4].

We included the factors with significant differences (fixation method, operative time, blood loss, the length of stay and posteromedial support or not) into a logistic regression for analysis. The results revealed that in the AO31-A2 ITFs, the loss of posteromedial support could be an independent risk factor for fixation failure, and when compared with the cases with posteromedial support, the risk of failure increased (OR = 5.986, 95% CI: 2.667–13.432) ($P < 0.001$) [Table 5].

Discussion

As commonly known, the femoral calcar is a compact bone that connects the posteromedial cortex of the femoral neck and shaft and transmits the load to the lower extremity together with the LT. Therefore, once the calcar and the LT were broken and could not be reduced post-operatively, the cases were defined as without posteromedial support. The above results suggested that we should assess the integrity of the posteromedial cortex in the radiological film pre-operatively. If the posteromedial wall is broken, perhaps we should try to reduce the fragment and rebuild the bone-to-bone contact to reduce the possibility of implant failure.

Many previous studies have reported the same opinion as ours. Parker *et al*[14] stated that the failure of bone-to-bone contact in the fracture site might lead to poor bone healing, which is consistent with our view that the defect of the posteromedial cortex can lead to failure. Chang *et al*[15] suggested that rebuilding the medial cortical support was key in treating unstable ITF. Based on this perspective, Zhang *et al*[11] placed a plate in the medial side of the ITF to serve as a buttress defending against the transmitted load and revealed that the sustained medial stability was meaningful in ITF. Han *et al*[16] also stated that the intactness of the continuity of the posteromedial cortex was a critical factor in determining the stability of ITF. Moreover, several mechanical research studies all proved that the loss of posteromedial support could increase the load of internal fixation and reduce the maximum load of the device.[8,10,11,17,18,19]

Varus deformity was the major manifestation of these failure cases. Marmor *et al*[10] stated that the cortex of the posteromedial wall represented as the calcar region. It is commonly recognized that the femoral calcar is the compact cortical region connecting the neck and shaft of the femur and buttresses the load passed from the femoral neck. The key point of hemiarthroplasty is the reestablishment of the femoral calcar, which also proved the importance of the region. Based on the bone-to-bone connection theory mentioned above, we assumed that once the calcar region (posteromedial wall) was broken, the effect of the transmission load would compress the sites of the fracture line in the inner side to achieve a bone-to-bone attachment again, after which varus deformity occurred. The mechanical experiment conducted by Liang *et al*[18] also proved our initial supposition; their study revealed that the highest point of the stress in the femur was the medial femoral calcar and that once the cortex was broken, the concentrated stress could lead to varus deformity. Recently, many doctors attempted to fix the LT for posteromedial support and determined that the incidence of varus deformity was decreased with LT fixation.[11,20,21,22,23]

The second most common complication was the cut-out of the screw. We discovered that the cut-out always accompanied varus deformity. Liang[18] experiment determined that in addition to the calcar region, another high-stress area was the cancellous bone on the top of the lag screw tip. Once the calcar was broken, this area became the highest-stress one. Continual microfracture would occur due to concentrated pressure and might lead to displacement or cut-out of the screw. Previous reports also stressed that the bone-to-bone contact could reduce the tensile stresses imposed on the implant and provide the most

Figure 3: Features of fixation failure. A. varus deformity; B. cut-out; C. cut through to the hip joint; D. breakage of the screw; E. breakage of the plate; F. breakage of the nail; G. Z-effect; H. periprosthetic fracture; I. non-union; J. mal-union.

Table 1: Comparisons of the basic information of A2 intertrochanteric fracture groups (Groups A and B).

Groups	Number	Age (years)*	Gender (M/F)†	Affected Sides (L/R)†	ASA Score (I/II/III)†
A	153	76.02 ± 10.78	59/94	89/64	24/88/41
B	241	76.57 ± 9.96	72/169	120/121	47/132/62
Z or χ2		−0.761	3.182	2.637	0.924
P		0.447	0.074	0.104	0.630

Data are shown as mean ± standard deviation, *n*, or otherwise noted. *Mann-Whitney *U* test. †Chi-square test; M: Male; F: Female; L: Left; R: Right.

Table 2: Comparisons of the parameters relative to the operation (Groups A and B).

Parameters	Group A	Group B	*P*
Time from injury to operation (days)*	4.92 ± 3.93	4.66 ± 4.84	0.359
Blood loss (mL)*	96.43 ± 73.65	112.10 ± 86.56	0.091
Operative time (min)*	82.73 ± 49.15	85.08 ± 53.04	0.706
Length of stay (days)*	6.96 ± 4.28	7.43 ± 4.39	0.156
Fixation (In/Ex)†	138/15	224/17	0.330
Failure†	8 (5.23)	58 (24.07)	<0.001

Data are shown as mean ± standard deviation, *n* or *n* (%). *Mann-Whitney *U* test. †Chi-square test.

Table 3: Comparisons of the ranked data of Groups C and D.

Groups	Number	Gender (M/F)	Affected Sides (L/R)	ASA Score (I/II/III)	Fixation method (In/Ex)
C	66	23/43	33/33	6/40/20	55/11
D	328	108/220	176/152	65/180/83	307/21
χ^2		0.091	0.295	4.356	7.757
P		0.762	0.587	0.113	0.005

Data are shown as *n*, or otherwise noted. All of the above factors were compared by the Chi-square test. M: Male; F: Female; L: Left; R: Right; In/Ex: Intramedullary fixation/extramedullary fixation.

Table 4: Comparisons of the continuous data of Groups C and D.

Parameters	Group C	Group D	*Z*	*P*
Age (years)	77.74 ± 8.70	76.08 ± 10.77	−0.964	0.335
Blood loss (mL)*	–	–	−3.029	0.002
Operative time (min)	109.46 ± 81.45	79.29 ± 41.91	−3.360	0.001
Length of stay (days)	7.98 ± 4.80	7.10 ± 4.24	−1.490	0.136
Time from injury to operation (days)	4.07 ± 3.53	4.73 ± 3.52	−2.135	0.033

Data are shown as mean ± standard deviation. *The data of the 2 groups had uneven variances. All the above factors were compared by Mann-Whitney *U* test.

Table 5: Logistic regression of the potential risk factors.

							95% confidence interval for EXP (B)	
Parameters	B	S.E.	Wald	df	Sig.	Exp (B)	Lower	Upper
Loss of the posteromedial support	1.789	0.412	18.827	1.000	0.000	5.986	2.667	13.432
Fixation method	0.514	0.554	0.862	1.000	0.353	1.672	0.565	4.953
Blood loss	0.001	0.001	0.170	1.000	0.680	1.001	0.998	1.003
Length of stay	0.008	0.035	0.053	1.000	0.819	1.008	0.941	1.079
Operative time	0.007	0.004	2.979	1.000	0.084	1.007	0.999	1.015
Constant	−3.807	0.519	53.736	1.000	0.000	0.022		

resistance to cut-out.[24,25] Therefore, the absence of the posteromedial support in Group B promoted the potential of cut-out. Jung-Hoon *et al*[17] also testified in their mechanical study that in a posteromedial defect model, the second most common failure of the implant was the cut-out. Therefore, perhaps we should pay more attention to avoiding accidental cut-out when we are treating ITF, especially for patients with osteoporosis.

A previous laboratory study conducted by Jacobs *et al*[26] showed that the transmitted load was shared between implant and bone, which indicated that once the posteromedial cortex was broken, the load on the implant would increase. When the increasing load reaches the fatigued threshold of the implant, implant breakage (ie, breakage and movement of the screw, nail and plate) occurs. Marmor[10] and Jung-Hoon *et al*[17] both testified that as the size of the posteromedial defect increased, the maximum load causing the implant collapse decreased. Liang[18] mechanical experiment pointed out that the highest stress area of the intramedullary implant was the inferomedial junction of the nail and screw. The inferomedial junction and the posteromedial cortex shared the transmitted load together. Under the circumstance of the posteromedial cortex defect, the pressure of the inferomedial junction and the tensile force of the outer side of the implant increased; therefore, the implant was more likely to break down. The extramedullary device serves as a tension band to transmit more force through the bone in a stable fracture. However, when the medial support disappeared, the load would be shouldered by the implant. The increasing load would accelerate the fatigue of the implant and increase the possibility of breakage. Marmor *et al*[10] not only worked out that the loss of the medial cortex could add the risk of collapse of extramedullary fixation but also determined that when a medial defect existed, an extramedullary implant was more vulnerable than an intramedullary one. These findings were inconsistent with our result; perhaps further research is needed to classify the better fixation method.

In our analysis, the two cases of periprosthetic fractures were both in Group B and were treated with PFNA. From analyzing the design, PFNA has a medial-lateral angle of 6°, and the diameter from the angle to the distal tip is uniform, which both cause the contact of the nail with the bone from the LT to the isthmus to become nonuniform. Moreover, the distal tip of the nail is biased to the inner cortex.[27,28] These features lead to concentration of the stress in the close contact point, and this concentration makes these points more vulnerable. The loss of posteromedial support could add extra load to the implant, which would certainly increase the stress in the close contact points. In these two cases, the stress exceeded the rigidity of the bone, and periprosthetic fracture occurred.

However, our discovery was different from those of some previous studies. Laros *et al*[29] found no significant correlation between the lesser trochanteric fragment and complications of fixation in 101 patients with intertrochanteric fractures; the difference was mainly due to the average length of follow-up in their study, which was less than a year. Liu *et al*[6] also failed to identify the influence of the integrity of LT on the surgical outcome, probably because of the short follow-up and the small number of included cases. A recent study conducted by Sharma *et al*[30] determined that neither fragmentation of the posteromedial fragment nor the size of the lesser trochanter fragment could be used to predict the stability in ITF; however, the mere 37 cases involved in the study made the conclusions controversial.

Our study was the first to use a logistic regression to adjust the influences of other potential risk factors and finally determined that the loss of posteromedial support was an independent risk factor. Additionally, the number of cases involved was more than previous studies. However, our study had several limitations. First, it was a retrospective study, and therefore had inherent bias. Second, few cases had a pre-operative CT scan; some cases with inner side defects might be neglected by having only an X-ray. Third, the number of cases treated with wire binding to rebuild the posteromedial support was small.

Conclusion

In AO31-A2 ITFs, the loss of posteromedial support was an independent risk factor for fixation collapse. Therefore, further research is needed to determine whether we should try to reduce and fix the LT to rebuild the inner side support during the operation if the posteromedial support is broken. If necessary, a standard procedure of the LT fixation should be established.

Conflicts of interest

None.

References

1. Friedman SM, Mendelson DA. Epidemiology of fragility fractures. Clin Geriatr Med 2014;30:175–181. doi: 10.1016/j.cger.2014.01.001.
2. Anglen JO, Weinstein JN. American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of orthopedic surgery database. J Bone Joint Surg Am 2008;90:700–707. doi: 10.2106/JBJS.G.00517.
3. Lorich DG, Geller DS, Nielson JH. Osteoporotic pertrochanteric hip fractures: management and current controversies. Instr Course Lect 2004;53:441–454. doi: 10.1016/S0883-5403(03)00407-8.
4. Kulkarni GS, Limaye R, Kulkarni M, Kulkarni S. Intertrochanteric fractures. Indian J Orthop 2006;40:16–23. doi: 10.4103/0019-5413.34069.
5. Sarathy MP, Madhavan P, Oomen M. Modified medial displacement and valgus osteotomy for unstable intertrochanteric fractures. Injury 1997;28:601–605. doi: 10.1016/s0020-1383(97)00098-3.
6. Liu X, Liu Y, Pan S, Cao H, Yu D. Does integrity of the lesser trochanter influence the surgical outcome of intertrochanteric fracture in elderly patients? BMC Musculoskelet Disord 2015;16:47. doi: 10.1186/s12891-015-0492-7.
7. Evans EM. The treatment of trochanteric fractures of the femur. J Bone Joint Surg Br 1949;31B:190–203. doi: 10.1002/bjs.18003614433.
8. Futamura K, Baba T, Homma Y, Mogami A, Kanda A, Obayashi O, *et al*. New classification focusing on the relationship between the attachment of the iliofemoral ligament and the course of the fracture line for intertrochanteric fractures. Injury 2016;47:1685–1691. doi: 10.1016/j.injury.2016.05.015.
9. Apel DM, Patwardhan A, Pinzur MS, Dobozi WR. Axial loading studies of unstable intertrochanteric fractures of the femur. Clin Orthop Relat Res 1989;156–164. doi: 10.1097/00003086-198909000-00025.
10. Marmor M, Liddle K, Pekmezci M, Buckley J, Matityahu A. The effect of fracture pattern stability on implant loading in OTA type 31-A2 proximal femur fractures. J Orthop Trauma 2013;27:683–689. doi: 10.1097/BOT.0b013e31828bacb4.
11. Zhang R, Luo P, Hu W, Ke C, Wang J, Guo X. Biomechanical assessment of newly-designed proximal femoral medial buttress plate for treatment of reverse oblique femoral intertrochanteric fracture. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2017;31:165–170. doi: 10.7507/1002-1892.201609103.
12. Zhang WQ, Sun J, Liu CY, Zhao HY, Sun YF. Comparing the intramedullary nail and extramedullary fixation in treatment of unstable intertrochanteric fractures. Sci Rep 2018;8:2321. doi: 10.1038/s41598-018-20717-2.
13. Li AB, Zhang WJ, Wang J, Guo WJ, Wang XH, Zhao YM. Intramedullary and extramedullary fixations for the treatment of unstable femoral intertrochanteric fractures: a meta-analysis of prospective randomized controlled trials. Int Orthop 2017;41:403–413. doi: 10.1007/s00264-016-3308-y.
14. Parker MJ. Trochanteric hip fractures. Fixation failure commoner with femoral medialization, a comparison of 101 cases. Acta Orthop Scand 1996;67:329–332. doi: 10.3109/17453679609002325.
15. Chang SM, Zhang YQ, Ma Z, Li Q, Dargel J, Eysel P. Fracture reduction with positive medial cortical support: a key element in stability reconstruction for the unstable pertrochanteric hip fractures. Arch Orthop Trauma Surg 2015;135:811–818. doi: 10.1007/s00402-015-2206-x.
16. Han SK, Lee BY, Kim YS, Choi NY. Usefulness of multi-detector CT in Boyd-Griffin type 2 intertrochanteric fractures with clinical correlation. Skeletal Radiol 2010;39:543–549. doi: 10.1007/s00256-009-0795-6.

17. Do JH, Kim YS, Lee SJ, Jo ML, Han SK. Influence of fragment volume on stability of 3-part intertrochanteric fracture of the femur: a biomechanical study. Eur J Orthop Surg Traumatol 2013;23:371–377. doi: 10.1007/s00590-012-0983-2.
18. Liang C, Peng R, Jiang N, Xie G, Wang L, Yu B. Intertrochanteric fracture: association between the coronal position of the lag screw and stress distribution. Asian J Surg 2018;41:241–249. doi: 10.1016/j.asjsur.2017.02.003.
19. Nie B, Chen X, Li J, Wu D, Liu Q. The medial femoral wall can play a more important role in unstable intertrochanteric fractures compared with lateral femoral wall: a biomechanical study. J Orthop Surg Res 2017;12:197. doi: 10.1186/s13018-017-0673-1.
20. Kim GM, Nam KW, Seo KB, Lim C, Kim J, Park YG. Wiring technique for lesser trochanter fixation in proximal IM nailing of unstable intertrochanteric fractures: a modified candy-package wiring technique. Injury 2017;48:406–413. doi: 10.1016/j.injury.2016.11.016.
21. Puram C, Pradhan C, Patil A, Sodhai V, Sancheti P, Shyam A. Outcomes of dynamic hip screw augmented with trochanteric wiring for treatment of unstable type A2 intertrochanteric femur fractures. Injury 2017;48 (Suppl 2):S72–S77. doi: 10.1016/S0020-1383(17)30498-9.
22. Cho SH, Lee SH, Cho HL, Ku JH, Choi JH, Lee AJ. Additional fixations for sliding hip screws in treating unstable pertrochanteric femoral fractures (AO Type 31-A2): short-term clinical results. Clin Orthop Surg 2011;3:107–113. doi: 10.4055/cios.2011.3.2.107.
23. Ye F, Zhang LJ, Li YZ, Zheng XD, Wang X, Yang YB, *et al*. Design of the reduction fixator and its clinical application in treating fracture of lesser trochanter of femur. Zhongguo Gu Shang 2015;28:726–729.
24. Chua IT, Rajamoney GN, Kwek EB. Cephalomedullary nail versus sliding hip screw for unstable intertrochanteric fractures in elderly patients. J Orthop Surg (Hong Kong) 2013;21:308–312. doi: 10.1177/230949901302100309.
25. Norris R, Bhattacharjee D, Parker MJ. Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. Injury 2012;43:706–711. doi: 10.1016/j.injury.2011.10.027.
26. Jacobs RR, McClain O. In vitro strain patterns in "intertrochanteric fractures" internally fixed with nail-plate or compression screw-plate. Surg Forum 1976;27:511–514. doi: 10.3109/14017437609167805.
27. Mereddy P, Kamath S, Ramakrishnan M, Malik H, Donnachie N. The AO/ASIF proximal femoral nail antirotation (PFNA): a new design for the treatment of unstable proximal femoral fractures. Injury 2009;40:428–432. doi: 10.1016/j.injury.2008.10.014.
28. Zhang S, Zhang K, Jia Y, Yu B, Feng W. InterTan nail versus Proximal Femoral Nail Antirotation-Asia in the treatment of unstable trochanteric fractures. Orthopedics 2013;36:e288–e294. doi: 10.3928/01477447-20130222-16.
29. Laros GS, Moore JF. Complications of fixation in intertrochanteric fractures. Clin Orthop Relat Res 1974;110–119. doi: 10.1016/0020-1383(73)90017-X.
30. Sharma G, Gn KK, Khatri K, Singh R, Gamanagatti S, Sharma V. Morphology of the posteromedial fragment in pertrochanteric fractures: a three-dimensional computed tomography analysis. Injury 2017;48:419–431. doi: 10.1016/j.injury.2016.11.010.

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