ORIGINAL ARTICLE

Use of Additional Locking Plate-derived Poller Screws for Treatment of Femoral Non-union after Intramedullary Nailing

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ABSTRACT

Objective: *To evaluate the efficacy of using additional locking plate-derived Poller screws to treat post-intramedullary nailing for femoral non-union was investigated.*

Methods: *Between January 2009 and April 2012, six patients who underwent post-intramedullary nailing for femoral non-union were studied. Three, one, and two patients had femoral fractures in the proximal one-third, middle third and distal third, respectively. While the original intramedullary nails were retained, eight-to-nine hole locking plates were used for fixation and two-to-three cortical bone screws were applied to both sides of the fracture to ensure the stability of the intramedullary nail sagittal plane. One-to-two pieces of locking nails were inserted tightly next to the intramedullary nails to ensure a stable coronal plane. Autologous iliac bone grafts were performed around the fractures in all cases.*

Results: *Follow-up evaluations were conducted between 10 and 17 months (mean, 13.8 months). The operative time was 110–160 minutes and the blood loss was 300–500 mL. Bone pain was relieved in 1 month. Continuous callus was observed after 4–6 months (mean, 4.83 months) based on imaging. There were no infections, loosening of internal fixation, or rupture. All patients were able to walk bearing weight within 3 months.*

Conclusion: *An additional locking plate and the derived Poller screw technique effectively improved local rotation instability and is an effective and simple treatment method for femoral non-union after intramedullary nailing.*

Keywords: Blocking screws, femoral fracture, fracture non-union, intramedullary, locking plate

INTRODUCTION

Due to good biomechanical advantages and nearly 99% healing rate, interlocking intramedullary nails are widely used as the gold standard in the treatment of femoral shaft fractures (1); however, there is a report that (2) the long bone fracture non-union rate after intramedullary nailing is 1.8%–7%. For this type of fracture non-union, reaming followed by replacement with a thicker intramedullary nail (3) has become the standard treatment. Indeed, it has been suggested that this method is the ideal treatment (4); however, others have reported (5) that this method only has a 53% success rate. In recent years, supplementing the original intramedullary nailing with a plate fixation technique has been reported (6, 7) to have a high success rate. By improving this technique, we applied locking plate-derived blocking screws (Poller screws) in six such cases. We showed high efficacy as all the fractures had united.

SUBJECTS AND METHODS

Clinical data

This retrospective analysis included six patients with femoral non-union after undergoing intramedullary nailing in our Department between January 2009 and April 2012. The patients were 23–61 years of age (mean, 36.9

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years). Three, one, and two fractures were located in the proximal one-third, middle third and distal third, respectively. Five and one non-union types were atrophic and hypertrophic, respectively. Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification was as follows: type A in three patients; type B in two patients and type C in one patient. Two patients had open fractures (one Gustilo I and one Gustilo II). Both patients with open fractures had non-reamed intramedullary nailing following emergency debridement. The remaining four patients with closed fractures underwent anterograde reamed intramedullary nailing. The fracture non-union time was 8–14 months (average, 10.7 months). All of the patients had C-reactive protein and erythrocyte sedimentation rate testing; both results were in the normal range, thus excluding infectious non-union.

The diagnosis basis of fracture non-union

Eight months after long bone fracture interlocking intramedullary nailing, there were no signs of increased callus formation during the last 3 months. There was pain at the fracture site and local pain worsened after activity or weight-bearing ambulation. Fracture site tenderness or percussion pain was reported, and there were no significant axial abnormalities. An X-ray showed abundant callus in the area of bone non-union and sclerosis; however, there was no continuous callus through the fracture space and no continuous callus on at least three lateral cortices. Fracture end atrophy, bone loss and bone defects were also observed. There were no main nail fractures or fixation failures.

METHODS

Surgical methods

After conventional lateral exposure, the cortical bone stripping technique was used to ring exposed fracture ends and the surrounding 2–3 cm area. Then, periosteal stripper was used to strip soft tissue towards both sides for the steel plate attachment. All non-union cases had rotational instability and axial stability. The fracture site was filled with a large amount of fibrous connective tissue. In the hyperplastic non-union cases, there was considerable callus growth, but the bones were not united between the ends. In the cases with atrophic non-union, no callus growth was noted around the ends, and both fractured ends were absorbed, defective or underwent atrophy. The fibrous connective tissues between the fractured ends were completely removed, and the fractured ends were cut off until the bone began to ooze blood. Both the callus and the original intramedullary nail were retained.

Centring on the fracture ends, rotation deformity was corrected while maintaining normal bone length. Straight locking plates with at least eight holes were selected for placement at the lateral side of the bone. To avoid inserting double cortical screws into intramedullary nails, the locking plate can be placed towards the front or back. The exact location of the plate can be determined by pre-operative standard lateral X-ray (Fig. 1A, 1B) and the position of the exposed intramedullary nails during the procedure. First, two to three pieces of 4.5-mm double cortical bone screws were inserted on both sides (Fig. 2-1). Screws were inserted immediately next to the intramedullary nails to minimize the likelihood of failure. Subsequently, one to two locking screws were inserted on both sides (Fig. 2-2). The key is to assure that the length of the locking screws is 2–4 mm longer than the measured depth. The exact additional length can be determined by pre-operative X-ray and the available space around the intramedullary nails. In the anteroposterior X-ray, the intramedullary nail should be squeezed to one side after fixation (Fig. 2-3). After examining fixation security (mainly rotation stability), autologous iliac bone was cut into a match stick-like shape and grafted between the fracture ends and the 2–3 cm area. If bone deficiency between the fracture ends existed, high-quality three-sided cortical bone filling was used for support first followed by placing the iliac bone sticks.

To prevent fracture of drilling bits intra-operatively when inserting double cortical bone screws and to prevent drilling bits from damaging intramedullary nails, 3.0-mm Kirschner wire was used (8, 9), followed by

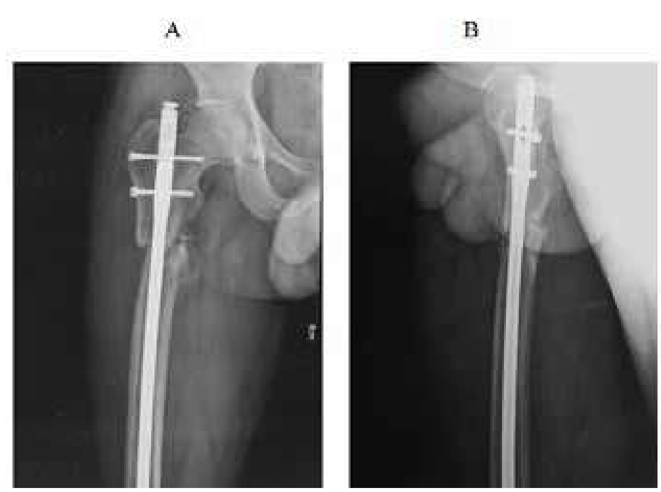

Figure 1: Non-healing X-ray films after intramedullary nail fixation for proximal-segment femoral fracture: positive position (A) and lateral position (B).

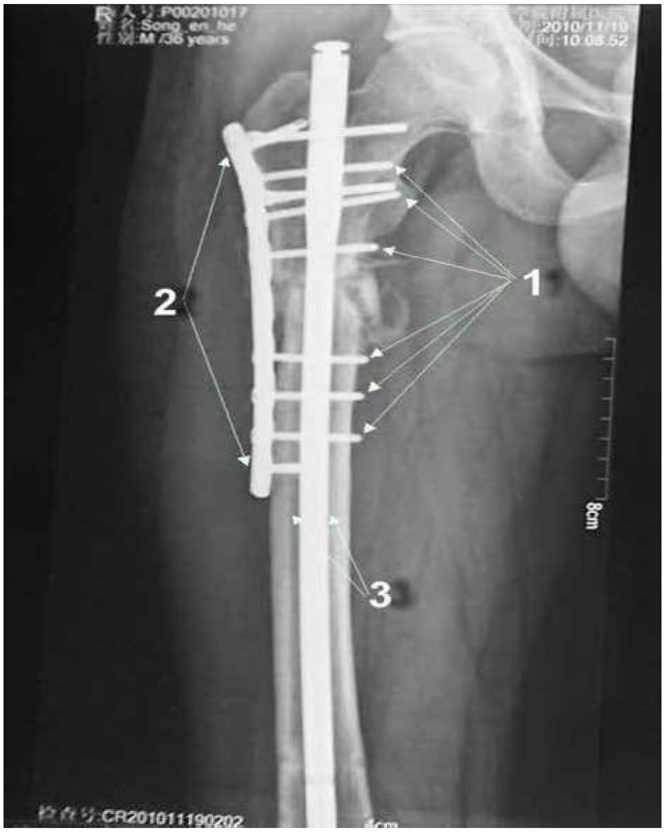

Figure 2: Intramedullary nails were retained, and the side plates were strengthened. Around 2–3 double cortical bone screws inserted on each side of the broken end, coronation block and forming sagittal stabilization (Fig. 2-1); with 1–2 locking nails on both sides, lengthen the locking nails according to the easing of the pulp cavity, and 'squeeze' the intramedullary nails to the opposite side by mechanical force, sagittal block and forming coronal stability (Fig. 2-2); intramedullary nail is pushed to the opposite side (Fig. 2-3); autologous iliac bone grafting.

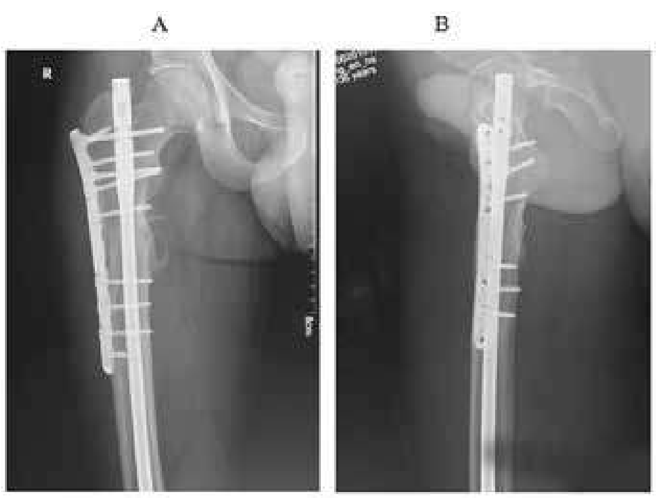

Figure 3: Fracture healing, positive (A) and lateral (B) at 5 months after side plate reinforcement and autologous iliac bone grafting.

Figure 4: The fracture healed firmly 2.5 years after surgery and X-ray film of positive position after removal of internal fixation.

tapping and inserting cortex bone screws with the appropriate length. The Kirschner wire should be sharp and drilling should be intermittent with water cooling to avoid fixation failure caused by bone burn necrosis.

Post-operative treatment

The negative pressure drainage tube was removed 1–2 days post-operatively. Twelve hours post-operatively, low-molecular-weight heparin calcium was used to prevent deep vein thrombosis. After removal of the drainage tube, patients were encouraged to start limb isometric muscle contraction exercises and adjacent flexion and extension exercises. Within 3 months, patients were gradually transitioned to full weight on the affected limb (10). One, 3, 6, and 12 months post-operatively, fracture healing and limb function recovery was assessed. The fracture healing criteria were as follows: no pain after limb load; no tenderness and no percussion pain at the fracture ends; and formation of continuous callus through fracture and corticalization based on X-ray examination.

RESULTS

The average operative time (exposure, clean-up, bone extraction, bone graft and plate fixation) for the six patients was 110–160 minutes (mean, 131 minutes), and the bleeding volume was 300–500 mL (average, 383 mL). Two patients reported pain at the bone extraction area; the pain was relieved within 1 month. There were no peri-operative complications and the activity of the adjacent joints did not decrease. The follow-up examinations were performed between 10 and 17 months (mean, 13.8 months). Imaging showed continuous callus for 4–6 months (mean, 4.83 months). No other interventions were taken during the follow-up period. No complications, such as infection, loosening of internal fixation or rupture, were observed (Table 1). Typical cases are shown in Figs 1–4.

DISCUSSION

Causes of femoral non-union after intramedullary nailing

After fracture, both biology and biomechanics should be considered to promote healing. In terms of biology, closed reduction of fracture should be attempted first. If closed reduction is difficult, limited open reduction is preferred to reduce destruction of the blood supply. In the current study, all six patients underwent open reduction and internal fixation (not limited open reduction), which greatly damaged the fracture blood supply and was one of the main causes of non-union. In terms of biomechanics, the fracture site should be stabilized as much as possible. Otherwise, non-union is likely to occur. With an intramedullary nail, the diameter of the nail hole is larger than the diameter of the nail, which can lead to a degree of rotation instability after the interlocking intramedullary nail fixed the long bone fracture.

Johnson *et al* (11) confirmed by mechanical testing that there is 10–15 degrees of rotation after intramedullary nail fixation of femoral shaft fracture, especially for comminuted fractures. For long bone distal and proximal third fractures, despite intramedullary nail fixation, because of a large medullary cavity, the frontal plane is unstable and prone to an abnormal force line (8). For most of the patients in this study, fractures occurred in the proximal or distal segment. In two patients, intramedullary nails were too small, which may have also caused instability. In addition to damage to the blood supply and fracture end instability, fracture incomplete contact is an important reason for non-union (5). Two of the patients did not undergo routine procedure to close the gap between fracture ends. Post-operatively, early weight bearing can result in an internal fixation fatigue fracture, suggesting that strain is another important reason for fracture non-union (12).

Treatment of femoral non-union after intramedullary nailing

For femoral non-union after intramedullary nailing, reaming and replacement with a larger intramedullary nail has become the standard treatment (3), achieving a 78%–96% success rate (13). Pihlajamaki *et al* (4) claimed that this method is the best treatment option; however, in 2000, Weresh *et al* (5) applied this procedure to 19 patients with femoral non-union. Distal intramedullary nailing and fracture union occurred in only 10 patients (53%) and a significant number of successful patients required additional treatment. Park *et al* (14) used a similar method on seven patients with non-stenotic femoral non-union after intramedullary nailing, five of whom failed. For humeral non-union after intramedullary nailing, the application of thicker intramedullary nails and even autologous iliac bone graft failed in many cases. The causes of the high failure rate have been summarized as follows: significant comminution of the fracture site; large segmental defect at the fracture site; non-union of a humeral shaft fracture; and small intramedullary nail and large medullary cavity at the fracture ends. All of these factors can lead

Table 1: Six data of non-healing cases after intramedullary nail fixation in femoral shaft fractures

No.	Sex	Age	Part	No healing type	Far-end power	No healing time (month)	Operation time (min)	Blood Loss (mL)	Image healing time (month)	Follow-up time (month)
1.	Male	35	Nearly 1/3	Atrophic	Yes	9	140	400	5	13
2.	Male	61	Far 1/3	Atrophic	No	14	120	400	4	10
3.	Male	34	Nearly 1/3	Atrophic	No	10	110	300	4	16
4.	Female	30	Nearly 1/3	Atrophic	No	14	160	500	5	13
5.	Female	38	Far 1/3	Hypertrophic	No	8	150	300	5	14
6.	Female	23	In 1/3	Atrophic	No	9	110	400	6	17

to unstable rotation of the fracture ends. The existence of an intramedullary nail maintains the normal axis and force line but does not improve rotation stability. Thus, maintaining fracture end rotation stability is essential to bone union (16). More and more literature has shown that reaming and replacement with a thicker needle is suitable for hyperplastic non-union but not for atrophic non-union (17).

In some femoral non-union patients after intramedullary nailing, Bellabarba *et al* (18) removed the original intramedullary nails and fixed with a steel plate instead, and selectively used an autologous iliac bone graft at the fracture ends. Despite a high fracture union rate of 91%, there were still cases which needed re-operation due to a broken plate. Furthermore, this method had the disadvantages of being complicated, requiring a longer operative time, high blood loss and sizable wounds.

In recent years, retaining the original intramedullary nails with additional plate fixation, and if necessary autologous iliac bone grafting, greatly improved the success rate of non-union after intramedullary nailing and the success rate was nearly 100% (6, 9, 10, 14, 19); however, success depended on the stability between fracture ends. To achieve sufficient stability, additional plate nails should be fixed through double cortical fixation, which can be difficult due to the presence of intramedullary nails, especially when non-union occurred in femoral stenosis. Choi and Kim (20) reported a problem with loosening of fixation nails. Some authors have replaced the ordinary plate with a locking plate (7, 17, 21) to better solve the problem. The single-cortical locking feature of locking plate facilitates the implantation of the fixing nails. Together with special angular stability, this change provided a better grip than a non-locking plate in the region where the intramedullary nail is present.

For fracture non-union after intramedullary nailing, Gao *et al* (22) combined the intramedullary nail replacement with Poller screws to improve fracture end stability. Krettek *et al* (8) used an intramedullary nail with Poller screws to correct abnormal force lines and to improve the initial stability of the nail-bone complex. We took full advantage of the original intramedullary nails with an additional locking plate fixation, and the derived Poller screws technique for the treatment of femoral non-union after intramedullary nailing and all six patients recovered. We have described our treatment principles and technical details.

Treatment principles and technical details of the additional locking plate-derived Poller screws technique

With retention of an original intramedullary nail, deformity correction is easy. To increase the stability of fixation, the length of the locking plate should be increased as much as possible with at least eight holes to stay away from fracture ends. As most of the adult femoral shaft diameters are > 30 mm, we only need to insert cortical bone screws into the wide side of the intramedullary nail. Because the work area is usually > 10 mm, inserting double cortical 4.5-mm nails will not be too difficult (Fig. 1). Cortical bone screws should be inserted close to the intramedullary nail, and the frontal plane blocking the stabilized sagittal plane as cortical bone screws play a role in Poller screws. Based on the size of the remaining medullary cavity around the intramedullary nail determined by X-ray, the locking nail length was increased (usually 2–4 mm). Mechanical strength was used to force the intramedullary nail back to one side (Fig. 2). The locking nail blocked the frontal plane, which stabilized the sagittal plane as the locking nail played the role of the Poller screw. This procedure greatly increased the stability of the bone and implant complex. Combined with an autologous iliac bone graft, the treatment ultimately ensured a high fracture union rate.

CONCLUSION

We can confidently conclude that for femoral non-union after intramedullary nailing, retaining the intramedullary nail and using the locking plate-derived Poller screw fixation technique combined with autologous iliac bone grafting is a simple and efficacious treatment option.

AUTHORS' NOTE

Yi-feng Zhao contribute to data analysis and manuscript preparation; Qing-hua Chang and Feng-hua Zhu contribute to definition of intellectual content; and Hai-bin Wang and Dai-liang Jia edited, reviewed and wrote the manuscript. Bin Wu and Chun-yang Meng collected the data. The authors declare no conflicts of interest with this study.

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