Int J Clin Exp Med 2016;9(7):14772-14780
www.ijcem.com /ISSN:1940-5901/IJCEM0025836

Case Report

Long Gamma3 compressing interlocking nails with a supplementary cross-cannulated screw for ipsilateral femoral neck and shaft fractures

Yi Zhao[1*], Jinlu Yu[2*], Chengxue Wang[1], Dong Zhu[1], Tiecheng Yu[1]

[1]Department of Orthopedics, First Hospital of Jilin University, Changchun 130021, China; [2]Department of Neurosurgery, First Hospital of Jilin University, Changchun 130021, China. [*]Equal contributors.

Received February 11, 2016; Accepted June 8, 2016; Epub July 15, 2016; Published July 30, 2016

Abstract: Ipsilateral femoral neck and shaft fractures are rare. These combined injuries are much more challenging to treat than either a femoral neck or shaft fracture alone and often require modification of the routine neck or shaft fracture treatment methods. In this study, we used long Gamma3 compressing interlocking nails ((long Gamma3 nail, Stryker, America, http://www.stryker.com/en-us/glp/index.htm). With a supplementary cross-cannulated screw (diameter 7.3 mm, Osteomed, America, www.osteomed.com) to stabilize the combined fractures, which is a novel technique. The supplementary cannulated screw was inserted from the anterior edge of the greater trochanter and was then orientated perpendicular to the femoral neck fracture line to increase the compression between the fracture edges. From October 2012 to January 2016, 11 patients with ipsilateral femoral shaft and neck fractures were treated using this technique at our hospital. One patient was lost to follow-up. A total of 10 patients were followed up at 6-week intervals for at least one year (range, 12-24 months; average, 18 months). All femoral neck fractures healed in an average of 13.2 weeks, ranging from 12 to 18 weeks). The average time to union for the femoral shaft fractures was 22.2 weeks, ranging from 18 to 24 months. There were no cases of nonunion or avascular necrosis of the femoral head. Our technique provides a new option for treating these combined fractures. Long Gamma3 compressing interlocking nails with a supplementary cross-cannulated screw, in the mid-term, yielded acceptable clinical and functional results. The procedures of the technique are simple and decrease the operating time. Further investigation should be performed to compare the methods with all currently available surgical options in large, multicenter trials.

Keywords: Long Gamma3 compressing interlocking nails, supplementary cross-cannulated screw, ipsilateral femoral neck and shaft fractures

Introduction

Ipsilateral femoral neck and shaft fractures are rareand occur in approximately 1-9% of all femoral shaft fractures [1, 2]. The combined injuries are typically a result of high-energy trauma in a young adult, particularly in road traffic injuries [2, 3]. Either isolated orcombined, femoral neck fractures in young adults are usually intracapsular and have an unstable transcervical (vertical) fracture line (Pauwels III) [1, 3, 4]. The combined injuries aremuch more challenging to treat than either a femoral neck or shaft fracture and often require modification of the routine neck or shaft fracture treatment methods [5]. A vast number of techniques have been performed to manage this combined injury [1, 2, 6, 7]. Until now, no surgical method has been demonstrated to be superior to others. Although numerous options have been explored to prevent a femoral neck nonunion, the complications of osteonecrosis of the femoral head and nonunion of the femoral neck are more difficult to manage [1, 2, 8, 9]. In the present study, gamma nails were used to treat the combined injuries (11 cases) and a supplementary cross-cannulated screw was posed across the femoral neck fracture line to increase the stabilization of the femoral neck fracture. Nofemoral head osteonecrosis or neck nonunion was found among the patients treated with this surgical technique. To our knowledge, the use of gamma nails with a supplementary cross-cannulated screw to treat these combined injuries

Table 1. Patient profiles

Patient number	Age	Gender	Side	Femoral neck fracture types (OTA)	Pauwels angle	Femoral shaft fracture types (OTA)	Open/closed fracture	Associated injuries
1	50	M	R	B2.1	73°	C1	Closed	Tibia shaft fracture (ipsilateral)
2	18	M	L	B2.3	78°	C2	Closed	Aortic dissecting aneurysm
3	32	M	L	B3.2	80°	C3	Closed	Calcaneus fracture (ipsilateral)
4	23	M	R	B3.2	85°	C2	Closed	None
5	40	F	R	B2.1	57°	C3	Closed	Ulnar shaft fracture (ipsilateral)
6	36	M	L	B3.2	64°	C1	Closed	Calcaneus fracture (ipsilateral)
7	41	M	L	B2.2	70°	C1	Closed	None
8	39	M	R	B2.3	69°	C2	Closed	Patella fracture (ipsilateral)
9	37	M	R	B3.2	79°	C1	Closed	None
10	39	F	R	B3.2	68°	C3	Closed	None

M, male; F, female; L, left; R, right; OTA, orthopedic trauma association classification.

Table 2. Treatment and outcome

Patient number	Delay to surgery (days)	Orientation of cannulated screw	Time to healing (weeks)		Follow-up time (months)	Tip-apex distance (mm)	Blood loss during operation (ml)	Operating time (minutes)	HHS (100)	Complications
			N	S						
1	11	C	12	18	24	10	100	190	93	Heterotopic ossification
2	8	C	12	24	18	15	200	150	90	None
3	9	H	12	18	12	15	150	120	88	None
4	5	H	18	24	18	18	80	140	86	Heterotopic ossification
5	8	C	18	18	12	19	90	130	92	None
6	5	C	12	24	24	9	200	150	93	None
7	10	H	12	24	24	18	150	180	95	Heterotopic ossification
8	4	H	12	24	24	11	180	130	96	None
9	5	C	12	24	12	22	150	150	90	None
10	5	H	12	24	12	21	200	180	91	None

C, the cannulated screw through the calcar; H, the cannulated screw toward the lower part of the femoral head; N, femoral neck fracture; S, femoral shaft fracture.

has not been reported previously. We believe this new method will offer a new option for the treatment of these combined injuries.

Materials and methods

From October 2012 to January 2016, 11 patients with ipsilateral femoral shaft and neck fractures were treated with gamma interlocking nails with a supplementary cross-cannulated screw at our hospital (**Tables 1**, **2**). One patient was lost during follow-up, and10 patients were included in this study (**Tables 1**, **2**). The injuries resulted from road traffic accidents (automobile collision as a passenger or a driver). The patients were followed up until both fractures were healed (an average of 8 months; range 6-12 months) (**Table 1**).

All patients were treated by the senior orthopedic trauma surgeons (Yi Zhao, Chengxue Wang, and Tiecheng Yu). The operation was performed after the adequate resuscitation and stabilization of the injured patient, particularly in patients with other associated injuries. The surgical procedure used gamma nails and was similar to that used for most intertrochanteric fractures. Under general anesthesia, surgery was performed with the patient lying supine on a fracture table in traction on foot plates. Closed fracture reduction was performed before surgery under the guidance of C-arm fluoroscopy with antero-posterior and lateral/axial views and, subsequently, was secured in traction. The affected leg was pulled, adducted and rotated to reduce the fracture. Achieving proper rotation of the femur with the patella in a horizontal position was crucial. The operative technique followed the manufacturer's instructions (long Gamma3 nail, Stryker, America, http://www.stryker.com/en-us/glp/index.htm).

First, the long gamma nail was inserted to fix the shaft fracture after reduction of the shaft

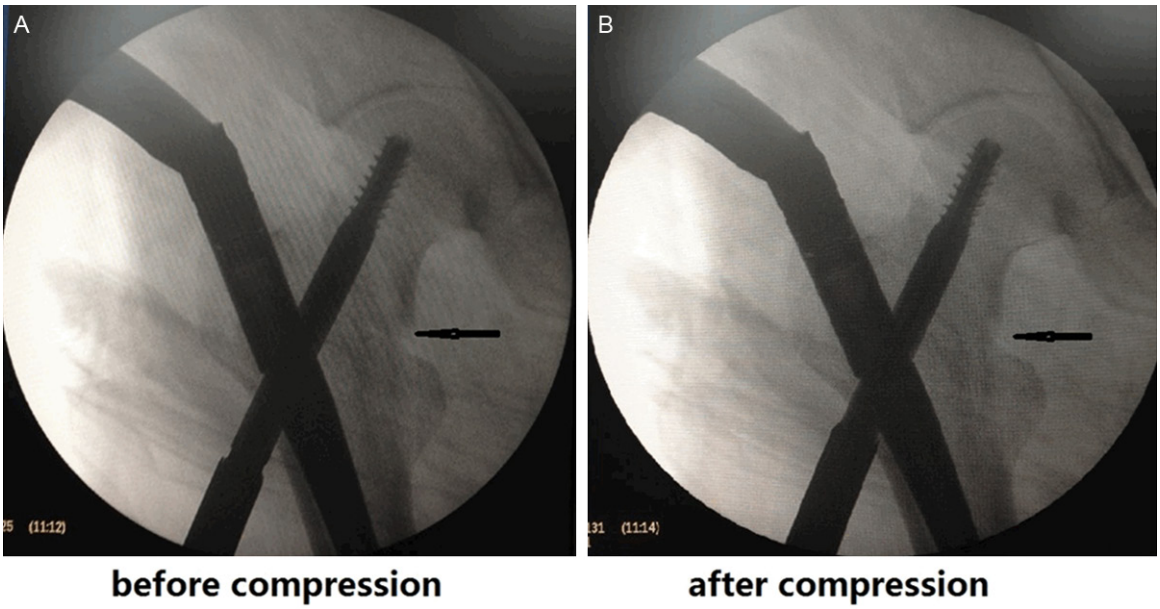


Figure 1. The displaced femoral neck fracture was reduced using the compression of the interlocking lag screw. The left arrowhead shows the displaced femoral neck fracture (A), and the right arrowhead shows the reduced femoral neck fracture after compression of the interlocking lag screw (B).

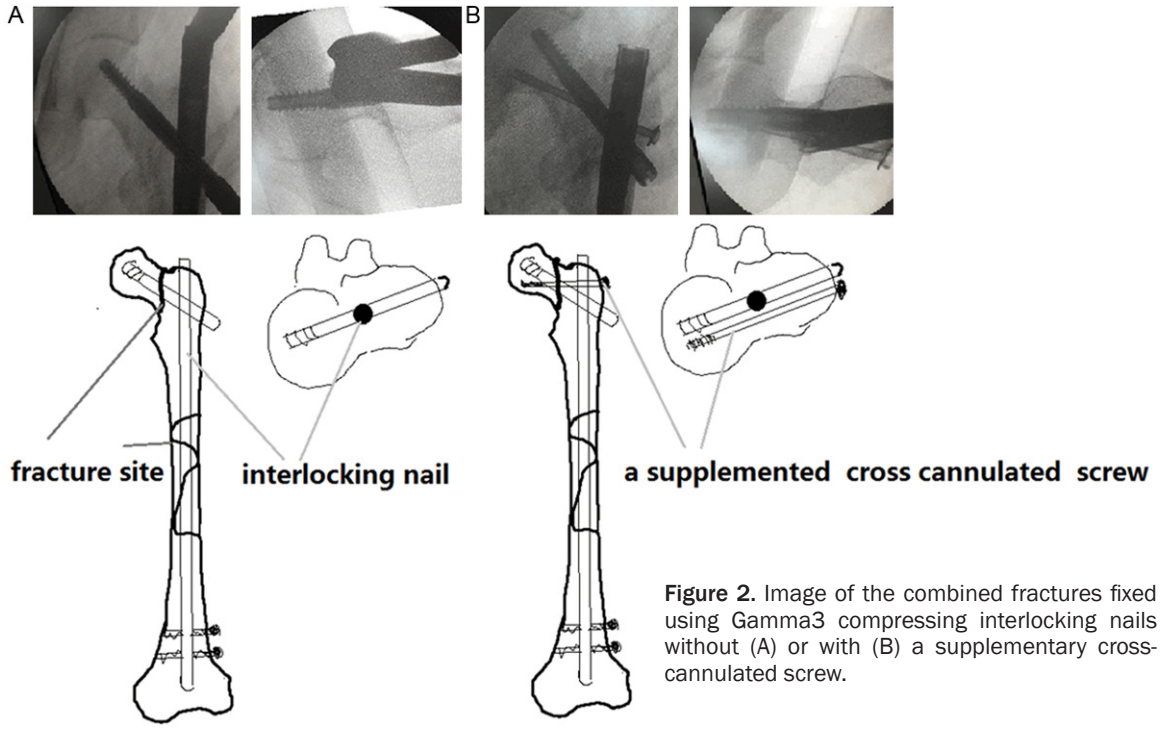


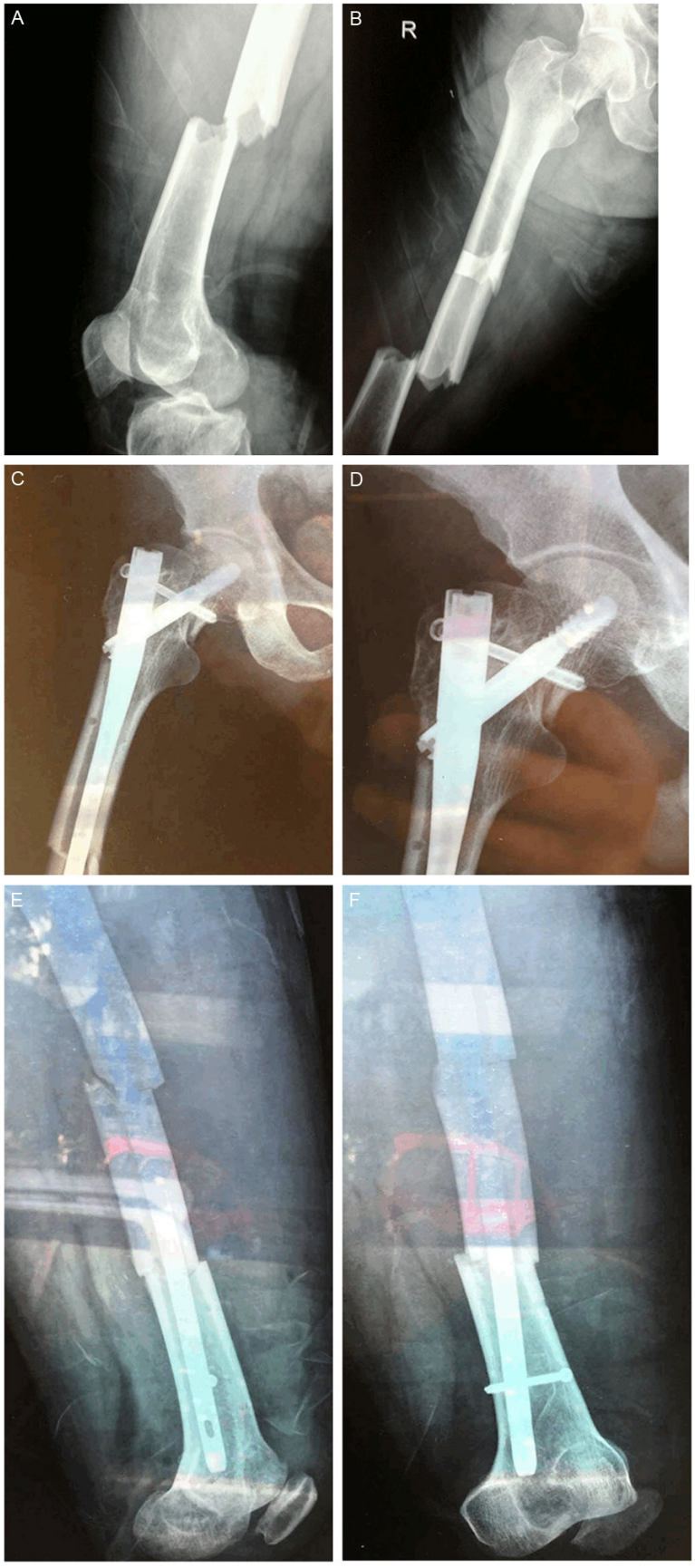
Figure 2. Image of the combined fractures fixed using Gamma3 compressing interlocking nails without (A) or with (B) a supplementary cross-cannulated screw.

fracture in a closed fashion. Careful X-ray monitoring during reaming and nail insertion was performed to prevent displacement of the neck fracture. Following insertion of the nail, the accurate reduction of the femoral neck fracture was evaluated again prior to proximal screw insertion. A single proximal 8.0-11 mm interlocking lag screw at a 130 degree insertion angle was inserted to fix the neck fracture with satisfactory compression between the fracture edges. Usually, there was slight displacement in the femoral neck fracture after insertion of

Figure 3. A 32-year-old man sustained right ipsilateral femoral neck and shaft fractures caused by a two-car collision (A). The combined fractures were treated with a long Gamma3 compressing interlocking nail with a supplementary cross-cannulated screw (B). The orientation of the supplementary cannulated screw toward the lower part of the femoral head was nearly perpendicular to the femoral neck fracture line (B). The combined fractures were healed 24 weeks after operation (C).

the nail to reduce the shaft fracture. However, it was easy to reduce the displaced femoral neck fracture with compression of the interlocking lag screw (**Figure 1**). Then, a supplemented cannulated screw (diameter 7.3 mm, Osteomed, America, www.osteomed.com) was added in front of the nail (**Figures 2**-**5**). In a vertical plane, the nail was inserted as deeply as possible to allow the lower proximal screw to be located closely to the distal femur, and the interlocking lag screw was posed to the intermedial cortex (or a little upper cortex) of the femoral neck (**Figure 2**). In a horizontal plane, the interlocking lag screws were located along the central axis of the femoral neck (**Figures 2**-**5**). The supplementary cannulated screw was inserted from the anterior edge of the greater trochanter and was then orientated downward through the calcar or toward the lower part of the femoral head in the frontal plane, which was always positioned to be perpendicular to the femoral neck fracture line to increase the compression between the fracture edges. This approach can prevent the impaction of the femoral head cancellous bone and, potentially, screw cutout. The orientation of the cannulated screw was such that it appeared toward the middle aspect of the femoral head in the transverse plane (**Figures 2**-**5**).

Early active or passive mobilization in bed was encouraged after the operation. Passive knee range of motion and isometric quadriceps-strengthening exercises were started from the second post-operative day. However, weight bearing was restricted for the first 8 weeks. Partial weight bearing was then allowed based on radiographic signs of callus formation 8 weeks after the operation. Weight bearing progressed as the femoral callus increased. Normally, full weight bearing was allowed 12 weeks after fracture healing was exhibited



upon radiographic examination.

All patients underwent an indicated clinical follow-up examination. Radiographs at injury, post-surgery and during follow-up were taken to evaluate the degree of fracture healing. The follow-up radiographs were repeated every 6 weeks until the healing of both fractures was detected. Fracture clinical healing criteria included no tenderness and no pain with weight bearing. Radiographic criteria were defined as bridged callus across 3 of 4 cortices of the fracture site. No-nunion was defined as the fracture site remaining unhealed one year after the operation. Complications and their management were also recorded. The functional results were assessed using the Harris Hip Score (HHS) at the time of union or before secondary surgery. The grade of function was defined as excellent (90-100), good (80-89), fair (70-79) or poor (<70). Tip-apex distance (TAD) was measured as described in the literature. The paired Student *t*-test or Fisher's exact test were performed to explore the relationship between patient factors and clinical results, and $P < 0.05$ was regarded as statistically significant.

Results

A total of 10 patients were followed up at 6-week intervals for at least one year (range, 12-24 months; average, 18 months) (**Tables 1**, **2**). One patient died during hospitalization due to severe associated injuries. The average operating time was 152 minutes (range, 120-190 mi-

Figure 4. A 50-year-old man sustained right ipsilateral femoral neck and shaft fractures caused by a two-car collision (A, B). The combined fractures were treated with a long Gamma3 compressing interlocking nail with a supplementary cross-cannulated screw (C-F). The orientation of the supplementary cannulated screw toward the lower part of the femoral head was nearly perpendicular to the femoral neck fracture line (C, D). The combined fractures were healed 24 weeks after operation (G, H).

nutes), which did not include the treatment of the associated fracture, and the average blood loss was 150 ml (range, 80-200 ml). All femoral neck fractures healed in an average of 13.2 weeks (range 12-18 weeks) (**Tables 1**, **2**). There were no cases of nonunion or avascular necrosis of the femoral head. The average time to union for the femoral shaft fractures was 22.2 weeks, ranging from 18 to 24 months. Patient factors, such as fracture pattern (neck and shaft classification) and any delay in surgery, were analyzed to identifytheir relationship to neck and shaft union. No significant relationships were noted. There was no significant correlation between the orientation of the cannulated screw or the TAD and the average time to union for the femoral neck fracture. The mean HHS was 91.4 (range, 88-96). The range of motion for the hip joint was normal in all patients. Two patients had slight limping because of osteoarthritis of the subastragalar joint due to ipsilateral calcaneus fractures. Two patients reported occasional pain that did not affect their everyday activities. All patients returned to their pre injury activity level and occupation.

Discussion

Here, we report the mid-term results of treatment of a series of patients with ipsilateral femoral neck and shaft fractures, which were fixed using long Gamma3 compressing interlocking nails with a supplementary cross-cannulated screw. In this study, no cases of nonunion or avascular necrosis in the femoral neck fractures were detected, likely because of effective stabilization and reduction. Our results indicate that this type of orthopedic technique could sufficiently stabilize and reduce the ipsilateral femoral neck and shaft fractures, as the minimal gap of the fracture site and adequate stability are the crucial factors for fracture healing.

It is difficult to stabilize and reduce ipsilateral femoral neck and shaft fractures with a simple orthopedic technique [1]. Treatment options for ipsilateral femoral neck and shaft fractures include reconstruction nails [3, 5, 10, 11], antegrade nails and separate screws adjacent to the nail [2, 4, 12], femoral neck screws and retrograde femoral nails [6, 13, 14], sliding hip screws with or without an additional derotation screw and retrograde femoral nail [15], or femoral neck screws and plate fixation of the shaft [15, 16].

The plate fixation of the femoral shaft fracture requires open reduction, which destroys the periosteal blood supply [16]. Therefore, it is inappropriate to use these methods to fix the shaft fracture [2]. In contrast to plate fixation, intramedullary nails are preferred devices, which include both antegrade and retrograde modes. If antegrade mode nails are selected to treat the combined fractures, it can be difficult

Figure 5. A 32-year-old man sustained right ipsilateral femoral neck and shaft fractures caused by a two-car collision (A, B). The combined fractures were treated with a long Gamma3 compressing interlocking nail with a supplementary cross-cannulated screw (C). The orientation of the supplementary cannulated screw toward the lower part of the femoral head was nearly perpendicular to the femoral neck fracture line (C). The combined fractures were healed 24 weeks after operation (D).

to place three cannulated screws to stabilize the femoral neck fracture because the antegrade nail occupies the space of the three cannulated screws [7, 8]. It was reported that antegrade nailing combined with lag screws to treat the combined fractures did not yield uniformly favorable results [17, 18]. The retrograde mode is relatively simple [14]. The shaft fracture can be fixed either first or second with a retrograde femoral nail, depending on whether the femoral head is displaced. Then, the combined fractures are treated in two separate operating fields with two varied implants (one retrograde nail and multiple cannulated screws). Therefore, the technique requires more time than antegrade nails [14, 19, 20].

Additionally, reconstruction intramedullary nails are used to fix the ipsilateral femoral neck and shaft fracture in an antegrade mode [21, 22]. The intramedullary nail is inserted first using a closed technique. However, it was reported that the technique easily leads to femoral neck nonunions because the two screws inserted through the reconstruction nail into the femoral head and neck were designed not to function as compression lag screws but, rather, to decrease the moment arm when stabilizing proximal femoral shaft fractures [21]. After the femoral head and neck are securely anchored by the two screws, no compression can be added between

the fracture edges. Furthermore, these screws have a poor sliding capability, which can lead to a progressively increased distance between the femoral neck fracture edges along with resorption of the fracture edge bone [21, 23]. Thus, in some case, femoral neck nonunions can not be avoided if the combined fractures are fixed with reconstruction nails.

In contrast to the screws of a reconstruction intramedullary nail, the interlocking lag screw of a Gamma3 compressing interlocking nail is designed to function as a compression lag screw, the function of which is shown in **Figure 1**. Because of the compression ability of the lag screw of Gamma3 nails, we used the long Gamma3 compressing interlocking nails to fix the ipsilateral femoral neck and shaft fractures. The associated femoral neck fractures in young adults have a propensity for occurring in an intracapsular location and are in an inherently unstable vertical orientation (Pauwels III). In our study, the Pauwels angles of the associated femoral neck fractures were all more than 50°, classified as Pauwels III. It was reported that Pauwels III fractures treated with gamma interlocking leg nails alone had a femoral neck nonunion rate of 8% [24, 25] because it is difficult to stabilize the high shear angles of the Pauwels III fracture with the lag screw of a gamma nail alone. Therefore, we used a supplementary cross-cannulated screw to increase the stabilization of the associated femoral neck fracture. The cross screw technique has been used to treat Pauwels III fracture for many years [26]. The orientation of the supplementary cannulated screw was perpendicular to the femoral neck fracture line such that it could increase the compression between the femoral neck fracture edges. Therefore, together with the interlocking screw, the supplementary cannulated screw can effectively stabilize the high shear angles of the associated femoral neck fractures. This is why there were no cases of nonunion or avascular necrosis in the femoral neck fractures in our study.

The limitations of this study include the number of patients examined, its retrospective methodology, and that no comparisons were made between different fixation techniques. However, our technique is a novel technique, which might provide a new option for treating the combined fractures. Long Gamma3 compressing interlocking nails with a supplementary cross-cannulated screw, in the mid-term, yielded acceptable clinical and functional results. The procedures of the technique are simple and decrease the operating time. Further investigation should be performed to compare this method with all currently available surgical options in large, multicenter trials.

Acknowledgements

This study was supported in part by grant 11432016 (Dong Zhu), grant 11272134 (Dong Zhu), grant 81172183 (Tiecheng Yu) and grant 31470932 (Tiecheng Yu) from the National Natural Science Foundation of China.

Disclosure of conflict of interest

None.

Address correspondence to: Tiecheng Yu, Department of Orthopedics, First Hospital of Jilin University, Changchun 130021, China. E-mail: tiechengyu@163.com

References

[1] Boulton CL, Pollak AN. Special topic: Ipsilateral femoral neck and shaft fractures–does evidence give us the answer. Injury 2015; 46: 478-83.

[2] Hak DJ, Mauffrey C, Hake M, Hammerberg EM, Stahel PF. Ipsilateral femoral neck and shaft fractures: current diagnostic and treatment strategies. Orthopedics 2015; 38: 247-51.

[3] Bali K, Gahlot N, Aggarwal S, Goni V. Cephalomedullary fixation for femoral neck/intertrochanteric and ipsilateral shaft fractures: surgical tips and pitfalls. Chin J Traumatol 2013; 16: 40-5.

[4] Wu QF, Yan SG. [Treatment of femoral neck fractures after the fixation of ipsilateral femoral shaft by antegrade intramedullary nail]. Zhongguo Gu Shang 2011; 24: 939-42.

[5] Tsarouhas A, Hantes ME, Karachalios T, Bargiotas K, Malizos KN. Reconstruction nailing for ipsilateral femoral neck and shaft fractures. Strategies Trauma Limb Reconstr 2011; 6: 69-75.

[6] Dousa P, Bartonicek J, Lunacek L, Pavelka T, Kusikova E. Ipsilateral fractures of the femoral neck, shaft and distal end: long-term outcome of five cases. Int Orthop 2011; 35: 1083-8.

[7] Gary JL, Taksali S, Reinert CM, Starr AJ. Ipsilateral femoral shaft and neck fractures: are cephalomedullary nails appropriate. J Surg Orthop Adv 2011; 20: 122-5.

[8] Wang WY, Liu L, Wang GL, Fang Y, Yang TF. Ipsilateral basicervical femoral neck and shaft

fractures treated with long proximal femoral nail antirotation or various plate combinations: comparative study. J Orthop Sci 2010; 15: 323-30.
[9] Chen HG, Wu YX, Xu XY, Wang LY, Gao ST. [Surgery treatment of ipsilateral femoral neck and shaft fractures: a report of 7 cases]. Zhongguo Gu Shang 2009; 22: 61.
[10] Wu CC, Tai CL. Reconstruction interlocking nails for ipsilateral femoral neck and shaft fractures: biomechanical analysis of effect of supplementary cannulated screw on intracapsular femoral neck fracture. Clin Biomech (Bristol, Avon) 2009; 24: 642-7.
[11] Vidyadhara S, Rao SK. Cephalomedullary nails in the management of ipsilateral neck and shaft fractures of the femur--one or two femoral neck screws. Injury 2009; 40: 296-303.
[12] Bedi A, Karunakar MA, Caron T, Sanders RW, Haidukewych GJ. Accuracy of reduction of ipsilateral femoral neck and shaft fractures--an analysis of various internal fixation strategies. J Orthop Trauma 2009; 23: 249-53.
[13] Schmal H, Strohm PC, Mehlhorn AT, Hauschild O, Sudkamp NP. [Management of ipsilateral femoral neck and shaft fractures]. Unfallchirurg 2008; 111: 886-91.
[14] Oh CW, Oh JK, Park BC, Jeon IH, Kyung HS, Kim SY, Park IH, Sohn OJ, Min WK. Retrograde nailing with subsequent screw fixation for ipsilateral femoral shaft and neck fractures. Arch Orthop Trauma Surg 2006; 126: 448-53.
[15] Tsai CH, Hsu HC, Fong YC, Lin CJ, Chen YH, Hsu CJ. Treatment for ipsilateral fractures of femoral neck and shaft. Injury 2009; 40: 778-82.
[16] Abalo A, Dossim A, Ouro Bangna AF, Tomta K, Assiobo A, Walla A. Dynamic hip screw and compression plate fixation of ipsilateral femoral neck and shaft fractures. J Orthop Surg (Hong Kong) 2008; 16: 35-8.
[17] Wiss DA, Sima W, Brien WW. Ipsilateral fractures of the femoral neck and shaft. J Orthop Trauma 1992; 6: 159-66.
[18] Chaturvedi S, Sahu SC. Ipsilateral concomitant fractures of the femoral neck and shaft. Injury 1993; 24: 243-6.
[19] Khallaf F, Al-Mosalamy M, Al-Akkad M, Hantira H. Surgical treatment for ipsilateral fractures of femoral neck and shaft. Med Princ Pract 2005; 14: 318-24.
[20] Wu CC. Ununited ipsilateral femoral neck and shaft fractures: treatment of 16 patients. Arch Orthop Trauma Surg 2004; 124: 173-8.
[21] Watson JT, Moed BR. Ipsilateral femoral neck and shaft fractures: complications and their treatment. Clin Orthop Relat Res 2002; 78-86.
[22] Randelli P, Landi S, Fanton F, Hoover GK, Morandi M. Treatment of ipsilateral femoral neck and shaft fractures with the Russell-Taylor reconstructive nail. Orthopedics 1999; 22: 673-6.
[23] Bhandari M. Ipsilateral femoral neck and shaft fractures. J Orthop Trauma 2003; 17: 138-40.
[24] Parker MJ. Results of internal fixation of Pauwels type-3 vertical femoral neck fractures. J Bone Joint Surg Am 2009; 91: 490-1; author reply 491.
[25] Liporace F, Gaines R, Collinge C, Haidukewych GJ. Results of internal fixation of Pauwels type-3 vertical femoral neck fractures. J Bone Joint Surg Am 2008; 90: 1654-9.
[26] Garden RS. Stability and union in subcapital fractures of the femur. J Bone Joint Surg Br 1964; 46: 630-47.