Reconstruction Intramedullary Nailing for Ipsilateral Femoral Neck and Shaft Fractures: Main Factors Determining Prognosis

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Background: Ipsilateral femoral neck and shaft fractures are rare, and currently available treatment methods each have their own benefits and limitations. Although reconstruction intramedullary nails have been considered to be effective alternative, clinical outcomes vary significantly in reports.

Methods: Thirty-seven consecutive adult patients with 37 combined fractures were treated with reconstruction intramedullary nails. All combined fractures were caused by high-energy injuries. Operations were performed as soon as possible after the patient's general condition was stabilized. Thirty combined fractures were treated within 24 hours, and the remaining seven were delayed for 3-13 days. Closed nailing was performed in all 37 subjects. Protected weight bearing was permitted as soon as possible postoperatively.

Results: Thirty-two patients were followed- up for an average of 23 months (range, 12-45 months). Neck fractures healed in 90.6% of patients, and shaft fractures healed in 78.1% of patients ($p = 0.11$). The average union time was 16 weeks (range, 6-30 weeks) for the neck fractures and 35 weeks (range, 25-45 weeks) for the shaft fractures ($p < 0.001$). The average union time for the shaft were 34.2 weeks for the mildly-injured shaft group (Winquist I, II), and 42 weeks for the severely-injured shaft group (Winquist III, IV, segmental, $p = 0.024$). No neck or shaft malunion, femoral head osteonecrosis or wound infection occurred.

Conclusions: The outcome of ipsilateral femoral neck and shaft fracture depends primarily on the result of the treatment of the femoral shaft fracture. Severe shaft injuries had poor results. The main factor may be that the shaft fracture in a combined fracture sustains very high energy, and local soft tissues are severely compromised. More meticulous management of the shaft fracture, neck reduction and post-op protective weight bearing, may improve the outcome and reduce complications.

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Key words: reconstruction intramedullary nail, ipsilateral femoral neck and shaft fractures, prognosis

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Ipsilateral femoral neck and shaft fractures are typically caused by high energy injuries.[1-3] The reported incidence of femoral shaft fractures is low in the medical literature, at 3-10%.[3,4] The popularity of high-speed vehicles has significantly raised the incidence of combined fractures. However, reported sample sizes have generally been small.[4,5] No conclusive treatment methods have been found.[1,4,6]

Cephalomedullary nails are commonly used surgical devices for treating combined fractures.[4-6] These devices include reconstruction intramedullary nails, which have been used for several years. Although reconstruction intramedullary nails are considered to be effective for treating combined fractures, their clinical outcomes have varied in reports. The success rates for first treatment range from 69 to 100%, and the prognosis for neck and shaft fractures is also inconclusive.[1,4-11]

Reconstruction intramedullary nails are ideal devices for concomitantly treating combined fractures in a single incision wound.[4-6] A closed technique can minimize bleeding and wound complications. Familiar surgical techniques can significantly improve operating time and technical faults. This study retrospectively describes our experience in using reconstruction intramedullary nails to treat combined fractures. The results from the use of these devices for combined fractures may further be clarified.

METHODS

From January 1999 to December 2005, 37 consecutive adult patients with 37 ipsilateral femoral neck and shaft fractures were treated with Russell-Taylor reconstruction intramedullary nails (Smith & Nephew, Warsaw, IN, U.S.A.) at our institution. The subjects consisted of 21 men and 16 women with an average age of 42 years (range, 18-70 years). All fractures were caused by vehicle crashes.

Eight patients had associated head, chest or abdominal injuries, and 20 patients had associated other fractures or soft tissue injuries. Neck fractures were composed of 3 Garden type I (8.1%), 13 type II (35.1%), 20 type III, (54.1%), and one type IV (2.7%).[12] Shaft fractures consisted of six Winquist type I (16.2%), 19 type II (51.4%), four type III (10.8%), and four type IV (10.8%), with four segmental fractures (10.8%).[13] Eight shaft fractures were open (three Gustilo type I, three type II, and two type IIIa).[14] The shaft fractures were located in the middle-third in 25 (67.6%), and the distal-third in eight (21.6%) and were segmental in four (10.8%).

The open fractures received surgical debridement initially, and were internally fixed with reconstruction intramedullary nails as soon as possible according to the wound condition. Thirty patients were treated with reconstruction intramedullary nails within 24 hours. The other seven patients had associated life-threatening conditions, and had delayed treatment delayed for 3-13 days until their conditions ameliorated.

Surgical techniques

All patients were anesthetized with endotracheal intubation, and were placed on the fracture table in the supine position. Both lower limbs underwent traction on foot plates. Initial closed reduction was not attempted. An image intensifier was routinely applied in the operation. The involved limb was kept in an adducted position to facilitate the closed nailing procedure.

A guide wire was inserted through the *piriformis fossa* into the canal of the proximal fragment, and reaming was performed. An L-shaped manipulation rod was then inserted into the canal, and the fragment ends of the shaft fractures were reduced in a closed fashion. Reaming was repeated after the guide wire was passed into the canal of the distal fragment.

The proximal femoral canal was enlarged to 1 mm larger than the distal femoral canal, and a reconstruction intramedullary nail 1 mm smaller than the distal reaming was inserted along the guide wire into the distal femur. The lower limb was then abducted 15°. The neck-shaft angle was checked by the image intensifier. The reconstruction intramedullary nail was rotated to adjust for an adequate inlet to insert two proximal locked screws, which had to be positioned inferiorly in the anteroposterior view, and centrally in the lateral view. The neck sometimes required manipulation and temporary stabilization with a 3 mm Kirschner wire (Mizuho, Tokyo, Japan) to assist locked screw insertion. Two proximal and two distal locked screws were inserted to reinforce stability.

Patients were permitted to ambulate with protected weight bearing as soon as possible after the operation. Patients were followed- up in the outpatient department at 4-6-week intervals to evaluate the clinical and radiographical fracture healing process.

Fracture clinical union was defined here as no pain, no tenderness, and no requirement for ambulation aids. Radiographical union was defined as bridged trabeculae across the fracture site, or solid callus with cortical density connecting both fragments.[3,15] Nonunion was defined as a fracture site that remained unhealed one year after treatment, or a fracture site that needed a second surgery to achieve union.

The clinical outcome was measured by the Harris hip score at the time of union or before secondary surgery. A score < 70 was graded as poor; 70-79 was fair; 80-89 was good, and 90-100 was excellent. A patient with a Harris hip score ≧ 80 or an image finding of union was ranked in the satisfactory group. A patient with a Harris hip score ≦ 79 or an image finding of nonunion or malunion, or who needed a second surgery, was ranked in the unsatisfactory group.

The union rate of the femoral neck and shaft were compared using Fisher's exact test or paired Student's *t*-test. Discriminant analysis or Fisher's exact test were performed to explore the relationship between patient factors and clinical results. A $p < 0.05$ was regarded as statistically significant.

RESULTS

Thirty-two patients were followed up for a minimum of one year (range, 12-45 months; average, 23 months). Two patients died during hospitalization due to severe associated injuries, and three patients were lost follow-up despite our best efforts to contact them.

The average operating time was 270 (range, 125-550) minutes and the average blood loss was 340 ml (range, 150-1000 ml).

Two patients sustained isolated neck nonunion, and six patients had isolated shaft nonunions. Additionally, one patient sustained combined neck and shaft non-unions. Thus, the union rate of the neck fractures was 90.6% (29/32) and shaft fractures, 78.1% (25/32, $p = 0.11$, Table 1).

The average union time was 16 weeks (range, 6-30 weeks) for neck fractures and 36 weeks (range, 25-45 weeks) for shaft fractures ($p < 0.001$). Except for patients with non-union, there was no malunion of neck fractures (neck-shaft angle < 105 degrees or > 145 degrees; anteversion < 2 degrees or > 22 degrees) or shaft fractures (angulation > 10 degrees, rotational deformity > 10 degrees or shortening > 2 cm).[16,17]

The satisfactory group consisted of 23 patients (71.9%) with a Harris hip score > 80 or united fractures. The remaining 9 patients (28.1%) had a Harris hip score ≦ 79, or fracture nonunion, or needed a second surgery, and were ranked in the unsatisfactory group.

Patient factors such as age, gender, fracture pattern (open or closed; neck and shaft classification), and any delay in surgery were analyzed to identify their relationship with neck and shaft union and satisfaction. No significant relationships were noted

Table 1. Comparison of Clinical Outcomes with Reconstruction Intramedullary Nails to Treat Ipsilateral Femoral Neck and Shaft Fractures

Authors	Case number	Union rate (%)		Union time (months)		Varus neck (%)	Osteonecrosis (%)	Infection (%)	Follow-up (years)
		Neck	Shaft	Neck	Shaft				
Randelli (1999)	27	100	100	3.7	4.8	4	4	0	2.0
Hossam (2001)	9	100	100	4.2	6.9	11	0	11	2.1
Jain (2004)	23	96	83	4	5.5	4	4	0	2.5
Kao (2006)	13	85	69	3	8.5	0	0	0	1.8
This review (2008)	32	91	78	4.0	8.8	0	0	0	1.9

between these factors and neck or shaft union (Table 2). Additionally, there were no significant relationships between these factors and satisfaction (Table 3).

The Winquist type I and II groups were also classified into the mildly-injured shaft group; Winquist type III, IV and segmental fractures were in the severely-injured shaft type; Garden type I and II were classified as the non-displaced neck group, and Garden type III and IV were in the displaced neck group. The union of the shaft and neck, union time of the shaft and neck, and satisfaction, were analyzed according to these classifications. The average union time was 34.2 weeks (range, 25-45 weeks) for the mildly-injured shaft group, and 42 weeks (range, 38-45 weeks) for the severely-injured shaft group ($p = 0.024$, Table 4).

One isolated neck nonunion was complicated by cutout of the proximal locked screws at 5 months. It was converted to a dynamic hip screw (Synthes, Bettalach, Switzerland) with a subtrochanteric osteotomy, and healed uneventfully. The remaining isolated neck nonunion was also treated using a dynamic hip screw with a subtrochanteric osteotomy, and healed uneventfully. One isolated shaft nonunion was associated with breakage of one distal locked screw at 7 months. It was treated using angled blade plating (Synthes, Bettalach, Switzerland) with cancellous bone grafting and it healed uneventfully (Fig. 1). Four patients with isolated shaft nonunion were treated with exchange nailing (a first-generation Russell- Taylor locked nail) and their fractures healed uneventfully (Fig. 2). The remaining isolated shaft nonunion was not treated, and was observed during follow-up in the outpatient department.

Treatment of the patient with combined

Table 2. Relationship between Patient Factors and Fracture Union (*p* - value)

	Neck nonunion	Neck union	*p* - value	Shaft nonunion	Shaft union	*p* - value
Number	3	29		7	25	
Age (mean)	53.0 y/o	38.97 y/o	0.096	45.29 y/o	38.88 y/o	0.288
Gender (M/F)	1/2	18/11	0.552	5/2	14/11	0.671
Delay OP	2	5	0.113	1	6	≒1.000
Winquist type						
Type I	0	5	≒1.000	1	4	≒1.000
Type II	1	16	0.589	2	15	0.209
Type III	0	3	≒1.000	1	2	0.536
Type IV	1	2	0.263	2	1	0.113
Segmental	1	3	0.340	1	3	≒1.000
Shaft location						
Proximal	0	0	–	0	0	–
Middle	3	19	0.543	5	17	≒1.000
Distal	0	6	≒1.000	1	5	≒1.000
Segmental	0	4	≒1.000	1	3	≒1.000
Garden type						
Type I	0	3	≒1.000	0	3	≒1.000
Type II	0	8	0.555	2	6	≒1.000
Type III	3	17	0.274	5	15	0.683
Type IV	0	1	≒1.000	0	1	≒1.000
Closed fracture	2	22	≒1.000	6	18	0.646
Open fracture						
Type I	0	3	≒1.000	1	2	0.563
Type II	0	3	≒1.000	0	3	≒1.000
Type III	1	1	0.181	0	2	≒1.000

Table 3. Relationship between Patient Factors and Satisfaction (*p* - value)

	Unsatisfied	Satisfied	*p* - value
Number	9	23	
Age (mean)	46 y/o	38.04 y/o	0.148
Gender (M/F)	6/3	13/10	0.704
Delay OP	2	5	≒1.000
Winquist type			
Type I	1	4	≒1.000
Type II	3	14	0.243
Type III	1	2	≒1.000
Type IV	2	1	0.184
Segmental	2	2	0.557
Shaft location			
Proximal	0	0	–
Middle	7	15	0.681
Distal	1	5	0.648
Segmental	1	3	≒1.000
Garden type			
Type I	0	3	0.541
Type II	2	6	≒1.000
Type III	7	13	0.422
Type IV	0	1	≒1.000
Closed fracture	7	17	≒1.000
Open fracture			
Type I	1	2	≒1.000
Type II	0	3	0.541
Type III	1	1	0.490

nonunions was complex. This patient also sustained severe chest and abdominal injuries, and an emergency laparotomy was performed. Temporary external fixation was applied at that time, and treatment with a reconstruction intramedullary nail was delayed for 7 days. The neck fracture was initially reduced in an acceptable position, but proximal locked screw cutout occurred at 3 months. Furthermore, the distal locked screws were initially missed to insert for the comminuted shaft fracture, shortening the lower extremity by 3 cm. The neck nonunion was treated with bipolar hemiarthroplasty (Wright, Arlington, TN, U.S.A.), and the shaft nonunion was treated with dynamic compression plating (Synthes, Bettalach, Switzerland) and cancellous bone grafting. The shaft healed uneventfully at 4 months (Fig. 3).

No subject had osteonecrosis of the femoral head or wound infection at the latest follow-up.

DISCUSSION

Factors favoring fracture healing include minimal gap, adequate stability and sufficient nutrition supply.[18] Combined fractures are typically caused by high energy injuries.[1-3] Moreover, most energy is dissipated in the femoral shaft.[3,5] Consequently, comminuted shaft fractures with severe soft tissue injury in combined fractures are common.[4-6] In this series, 32.4% of shaft fractures (Winquist type III, VI and segmental fractures) were severe, which may have severely impeded the fracture healing process.

Compromised vascularity interferes with the fracture healing process.[18] Open reduction with plate fixation further destroys the periosteal blood supply, making it inappropriate for use.[19,20] Intramedullary nails in either antegrade or retrograde modes are preferred devices.[21,22] However, each mode has specific advantages and disadvantages. Using antegrade-mode nails to treat combined fractures involves a complex surgical procedure. Surgeons generally require repeated practice to achieve familiarity. In contrast, the retrograde mode is relatively simple. However, two separated operating fields with two varied implants (one intramedullary nail with multiple cannulated screws) may significantly lengthen the operating time.[22] Antegrade intramedullary nailing can significantly shorten the operating time following technical familiarity.

Reconstruction intramedullary nails are inserted in an antegrade mode. The intramedullary nail is inserted first by a closed technique. The advantages of closed intramedullary nails in treating comminuted femoral shaft fractures are well defined. A high union rate and a low complication rate have been reported. Blumback's series achieved a 98% union rate with closed static locked nails in treating comminuted femoral shaft fractures.[23] In Wu's series, the union rate of isolated femoral shaft fracture managed with closed nailing was 100%.[24] However, our series achieved a 78.1% union rate of shaft fractures in combined fractures, compared to 69% to 100% reported in the literature. This may be because the shaft fracture in combined fractures sustains much high energy and local soft tissues are more severely

Table 4. Relationship between Clinical Results and Clinical Classifications (*p* - value)

	Mildly-injured shaft	Severely-injured shaft	*p*-value	Non-displaced neck	Displaced neck	*p*-value
Number	22	10		11	21	
Shaft union	19	6	0.165	9	16	≒1.000
Shaft nonunion	3	4	0.165	2	5	≒1.000
Neck union	21	8	0.224	11	18	0.534
Neck nonunion	1	2	0.224	0	3	0.534
Shaft union time	34.2 weeks	42 weeks	0.024	38.5 weeks	34.7	0.238
Neck union time	16.7 weeks	14.3 weeks	0.388	13.3 weeks	17.7	0.087
Satisfied	18	5	0.096	9	14	0.441
Unsatisfied	4	5	0.096	2	7	0.441

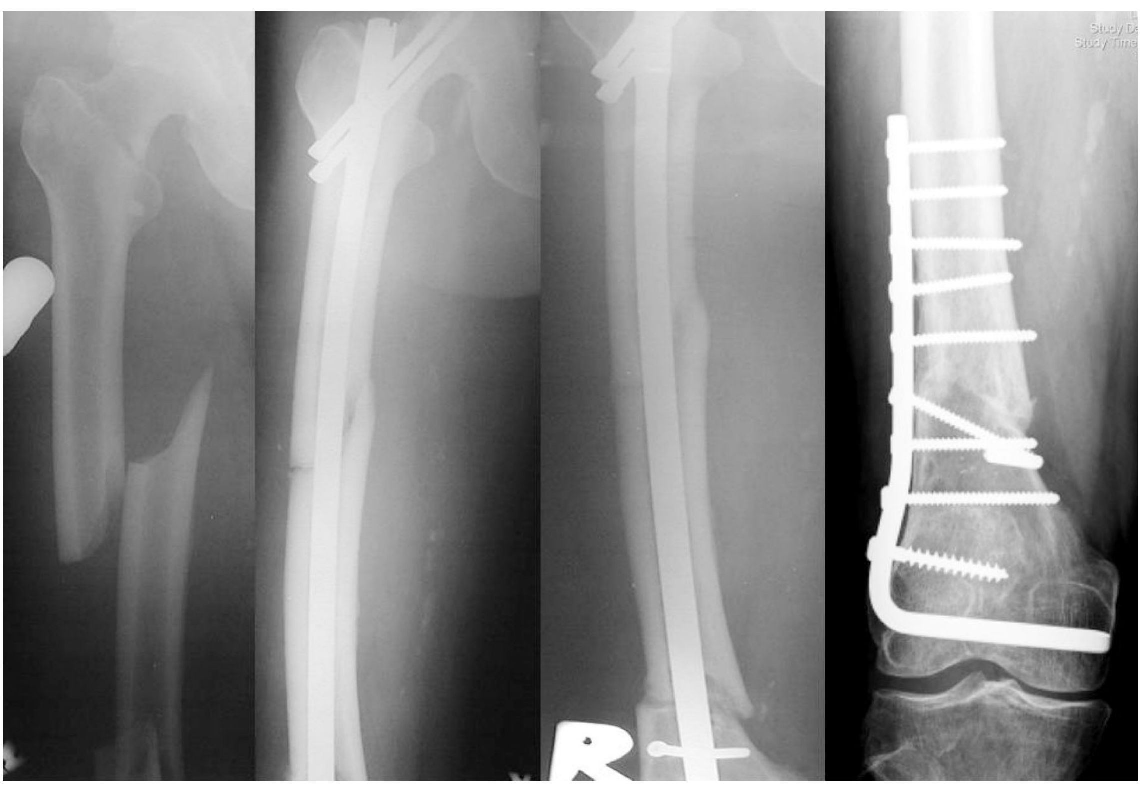

Fig. 1 A 70-year-old man sustained right ipsilateral femoral neck and shaft fractures caused by a motorcycle accident. The shaft fracture was segmental. Combined fractures were treated using a reconstruction intramedullary nail, but nonunion in the distal fragment occurred. The nonunion was treated using an angled blade plate, and it healed uneventfully.

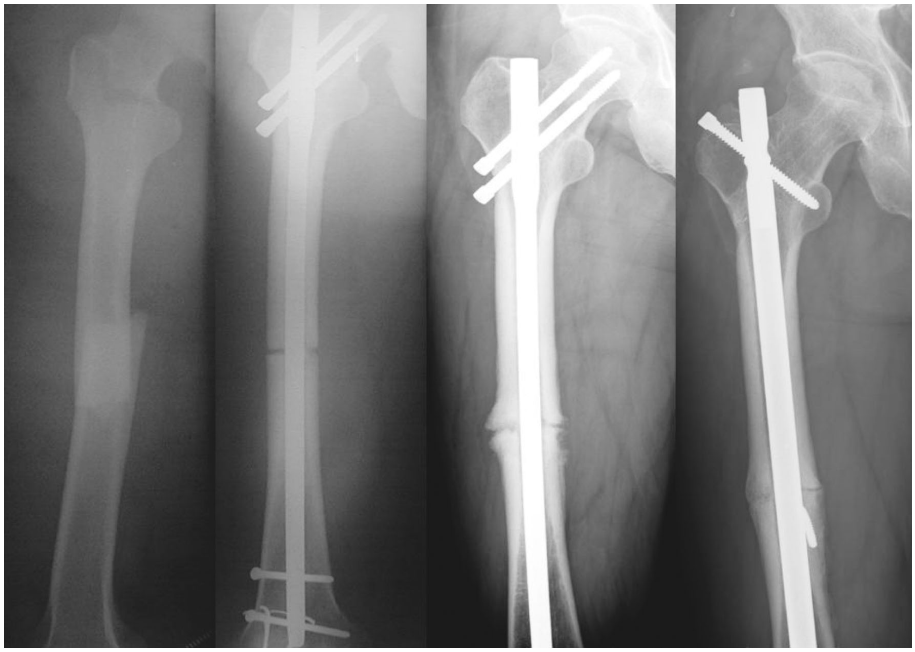

Fig. 2 A 51-year-old man sustained right ipsilateral femoral neck and shaft fractures caused by a car accident. The combined fractures were treated with a reconstruction intramedullary nail but shaft nonunion occurred. The nonunion was treated by exchange nailing using a first-generation locked nail, and it healed uneventfully.

Fig. 3 A 62-year-old woman sustained right ipsilateral femoral neck and shaft fractures caused by a car accident. The combined fractures were treated with a reconstruction intramedullary nail, but both neck and shaft nonunions occurred. Neck nonunion was treated with bipolar hemiarthroplasty and shaft nonunion was treated with dynamic compression plating.

compromised.[3] Conversely, implant failure may occur if the patient discontinues the use of a crutch.[25,26] In this study, four of seven shaft nonunions were associated with broken distal locking screws, and the fixation stability was lost. One of the Winquist type IV shaft nonunions had missing distal locking screws at the index surgery. A skillful surgeon and protective weight bearing after surgery may be essential to reduce the complication rate.

In the medical literature, neck fractures in combined fractures are considered relatively mild, and the prognosis is much better than in isolated neck fractures.[3,5,27] Although neck fractures displaced in 56.8% of our cases, only 3 cases had non-unions (all displaced), giving a 9.4% nonunion rate, with no osteonecrosis of the femoral head. A 10-20% incidence of osteonecrosis and 2-22% incidence of nonunion has been reported in isolated neck fractures.[28] One study of isolated femoral neck fractures in our hospital also showed the same trend: no nonunion occurred among non-displaced neck fractures; the incidence of nonunion in displaced fractures was 13.8%; the incidence of osteonecrosis in non-displaced femoral neck fractures was 5.4%, and that in displaced femoral neck fracture was 34.4%.[29] The low incidence of neck nonunion and osteonecrosis in this combined fracture is mainly because most of energy has been dissipated in the shaft, allowing a satisfactory outcome for neck fractures.

In this combined fracture, the shaft absorbs most of the energy, resulting in more severe injury than in the femoral neck. This leads to lower rates of union and satisfaction, and a longer union time. In our series, the union and satisfactory rate were poor in the -severely-injured shaft group (union rate: 86.4%, 19/22, in mildly-injured group; 60%, 6/10, in severely-injured group; satisfactory rate: 81.8%, 18./22, in mildly-injured group; 50%, 5/10, in severely-injured group; Table 4), and the union time for the shaft were significantly different between mildly-injured and severely-injured shaft groups ($p = 0.024$). This may be due to the small number of patients in this series. The union time of the shaft and neck were also significantly different ($p < 0.001$) in the series. The union time of the shaft mainly determines the period of disability and union, and more severe shaft injuries have a longer union time. A patient with a long shaft union time likely has a long period of disability. In the literature, the shaft determines the main union time and union rate,[3] and also significantly affects complications.[5,8] We conclude that the outcome of this combined fracture depends mainly on the result of treatment of the femoral shaft fracture. A more severe shaft injury seems to lead to a worse result. Careful management of shaft fractures and post-op protective weight bearing are important.

Although no osteonecrosis of the femoral head occurred in this series, meticulous management of neck fractures is absolutely necessary. Although osteonecrosis of the femoral head is rare in combined fractures, further treatment becomes difficult and controversial. Most importantly, neck fractures initially require gentle anatomic reduction and good stabilization with two proximal locked screws.[2] This situation should be achievable following technical familiarity with reconstruction using intramedullary nails.

Technically, closed insertion of reconstruction intramedullary nails into the femoral shaft is not very different from conventional procedures for isolated shaft fractures.[4,6] However, to avoid the inserted nail preventing consequent neck reduction in a closed fashion, the proximal femoral canal should be 2 mm larger than the nail size. The non-tight nail-canal interface does not prevent neck reduction after the lower limb has been abducted by 15°. This technical modification has been found to be useful in our practice.

A normal neck-shaft angle is in the range 125-130°.[16,30,31] Acceptable ranges will decide the incidence of neck malunion. Incidences of 4-11% varus malunion of neck fractures have been reported.[7,8,10] In this study, the acceptable range was set at 105-145°. No subjects had angles beyond this range after nail stabilization.[16] Two of the 32 subjects had cutouts of proximal locked screws (6.3%) in the treatment course, possibly because only two locked screws were applied to stabilize the femoral head in one plane.[32] The three-dimensional stresses may endanger femoral head stability once the patient is allowed to ambulate. Protective weight bearing must be followed to reduce the complication rate.

Supplementary treatment to reinforce healing of shaft fractures may be helpful once sufficient stability is provided by reconstruction intramedullary nails in combined fractures. Currently available devices include electric stimulation, ultrasound and shock waves.[33-35] These devices may be used early if the fracture healing process appears to be delayed. The principles of use are similar to those for delayed union or nonunion management.

In conclusion, the results of treatment of shaft fractures mainly determine the outcome of combined fractures treated with reconstruction intramedullary nails. The soft tissue compromised during an accident potentially determines future outcomes. Complications can be reduced by carefully managing the shaft fracture, meticulous neck reduction and protective weight bearing after surgery.

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重建式骨髓內釘治療同側股骨頸和股骨幹骨折之主要預後決定因子

蔡旻虔 吳基銓 蕭智文 黃炤文 高軒楷 許喻敦

背 景： 同側股骨頸和股骨幹骨折大多爲高能量的傷害，治療此類骨折手術難度仍高且對於最佳治療方式仍無定論，本研究選擇使用重建式骨髓內釘來治療這種複雜性高的骨折。

方 法： 回溯 1999 至 2005 間，37 個採用重建式骨髓內釘治療同側股骨頸和股骨幹骨折的病患，30 個病患在受傷 24 小時內接受手術，其餘 7 位病患在狀況穩定後接受手術，延遲 3 至 13 天不等；所有病患皆是採用閉鎖式手術方式，手術後定期追蹤。

結 果： 32 個病患完整追蹤，平均追蹤 23 個月，股骨頸平均癒合時間爲 16 周，癒合率爲 90.6%；股骨幹平均癒合時間爲 35 周，癒合率爲 78.1%；無骨折癒合不正、股骨頭無菌性壞死或傷口感染的併發症發生。

結 論： 以重建式骨髓內釘治療同側股骨頸和股骨幹骨折，股骨幹的癒合狀況爲主要的癒後決定因子。若能加強股骨幹的癒合，應能提升此類骨折的預後結果。
(長庚醫誌 2009;32:563-73)

關鍵詞： 重建式骨髓內釘，同側股骨頸及股骨幹骨折，預後

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