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Open Reduction and Olecranon Fossa-Penetrating Anterograde Intramedullary Nailing (The Modified Nonomiya Method) for the Treatment of Distal Third Humeral Shaft Fractures

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Abstract

The management of distal third humeral shaft fractures is often controversial and challenging. We report a new surgical method for distal third humeral shaft fracture using open reduction and olecranon fossa-penetrating anterograde intramedullary nailing. We prospectively studied 9 consecutive patients who underwent intramedullary fixation, in our emergency center in the past 5 years. The following data was collected and analyzed: patient demographics, duration of follow-up, shoulder and elbow active range of motion, UCLA shoulder score, and Mayo elbow score. Nine patients (8 men, 1 woman) were enrolled in this study. The mean age was 42 (15-65) years. Fracture patterns included 2 cases of AO type A and 7 cases of type B. All fractures had a mean time to union of 9.8 (8.6-11.0) weeks. All patients were followed over 12 months. The mean follow-up duration was 16.8 (12-35) months. At the last follow-up, the mean shoulder forward flexion was 171.1 (150-180) degrees; the mean elbow flexion was 137.8 (130-145) degrees. The UCLA shoulder rating scale was a mean 33.4 (29-35) and the Mayo elbow score was 100 in all patients. No intra- and post-operative complications were observed. Although several limitations, open reduction and olecranon fossa-penetrating intramedullary nailing is a safe and effective surgical method and an alternative option for the treatment of distal third humeral shaft fractures.

Keywords: Anterolateral approach for the distal humerus; Anterograde intramedullary nailing; Distal third humeral shaft fracture; Olecranon fossa penetration; Open reduction and intramedullary nailing; Operative treatment

Introduction

The treatment of distal third humeral shaft fractures remains controversial. Both conservative and operative treatment options are still debated, and the optimal treatment method is still unclear. Sarmiento et al. reported using functional bracing as conservative treatment with favorable clinical outcomes [1]. In recent years, other authors have also reported good functional outcomes with this method [2,3]. However, issues remain with prolonged bracing, including nonunion and malunion. Operative treatment of the distal third humeral shaft fracture is challenging because of the area's anatomy. Single or double plating in operative treatment is often performed with good clinical and functional outcomes in many reports [4-9]. However, the plating procedure is highly invasive and increases the risk of complications, such as intraoperative nerve injury and surgical site infection. Operative treatment with an external fixator is minimally invasive and produces good clinical outcomes, but certain inherent complications exist, such as pin site infection and prolonged external device wearing [10].

Intramedullary nailing for humeral shaft fractures show good fracture stability and clinical results; however, surgeries have been performed on proximal- and middle-third humeral fractures [11,12]. In general, anterograde and retrograde intramedullary nailing can be performed only in fractures with at least a 5-cm diaphysis in the distal fragment to sufficiently block the nail [13,14]. Hence, intramedullary nails are rarely used with distal third humeral shaft fractures. To resolve these problems, Dr. Nonomiya has been reported the use of the olecranon fossa-penetrating anterograde intramedullary nailing method to treat these fractures in Japan [15]. To our knowledge, this was the only case report of its kind in studies from Japan and no case series have been reported currently. We believe that this method provides the most stability with minimal invasion, and has been used as a as first-line treatment for fracture of the distal third humeral shaft with some modification. Herein, we report open reduction and olecranon fossa-penetrating anterograde intramedullary nailing for distal third humeral shaft fracture and the resulting clinical outcomes in detail.

Patients and Methods

Between July 2011 and December 2015, 9 consecutive patients (8 men and 1 woman; mean age, 42.0±18.65 [range, 15~65] years) with distal third humeral shaft fractures were treated at our hospital, using the olecranon fossa-penetrating anterograde intramedullary nailing method. The mechanisms of injury included am accidental fall from a height in 2, arm wrestling in 2, throwing a baseball in 2, road traffic accident in 2, and local crush in 1. Seven were right-sided (dominant arm) injuries, whereas 2 were left-sided (non-dominant arm) (Table 1). All study participants provided informed consent, and the study design was approved by the appropriate ethics review board. The fractures were classified using the AO/OTA classification [16]. There were 3 fractures of type 12-A1.3, 2 fractures of type 12-B1.3, 1 fracture of type 12-B2.3, and 3 fractures of type 12-B3.3 (Table 1). Eight patients underwent primary surgery and 1 patient failed to undergo primary intramedullary nailing due to intra-operative fracture and resulted in post-operative varus deformity and non-union. Distal cortical length was defined as Lee et al reported previously, that the distance between the superior border of the olecranon fossa and distal end of the fracture line on initial radiographs [17]. Mean distal distal cortical length was 51.0±12.03mm (range 35~68mm). Local pre-operative complications were examined in 4 patients: including 1 case of Gustilo 2 open fracture, 1 case of Gustilo 3A open fracture, 1 case of Gustilo 3C open fracture, 2 case of incomplete radial nerve palsy, and 1 case of complete median and radial nerve palsies (Table 1).

Case No.	Age (years) / Sex	Injury Mechanism	Dominant Arm	OTA classification	Distal cortical length (mm)	Local complications	Nerve injury
1	65/F	Load traffic accident	N	12B2.3	54	Gustilo 3a open fr.	
2	15/M	Fall from height	Y	12B3.3	68		
3	63/M	Local crash	N	12B3.3	62	Gustilo 3c open fr.	Complete median and radial
4	37/M	Arm wrestling	Y	12A1.3	51		Incomplete radial
5	46/M	Load traffic accident	Y	12B3.3	64		
6	65/M	Fall from height	Y	12B1.3	46	Gustilo 2 open fr.	
7	27/M	Throwing baseball	Y	12A1.3	35	Delayed union	Incomplete radial
8	31/M	Throwing baseball	Y	12A1.3	36		
9	29/M	Arm wrestling	Y	12B1.3	43		

N: no; Y: yes; F: female; M: male

Table 1: Pre-operative patient data.

Intra- and post-operative evaluation items were day of operation, operation time, open reduction and wiring, implant choice, intra- and post-operative complications, fracture union status, additional procedures, follow-up duration in months, shoulder and elbow range of motion, UCLA shoulder rating scale, and Mayo elbow score [18,19]. Fracture union was defined as an external callus bridging three cortices on the fracture line on anteroposterior and lateral plain radiography. The distribution of continuous variables is described by mean and standard deviations using SPSS ver. 19.0(SPSS, Inc., Chicago, IL, USA).

Surgical technique

The patients were placed in the supine position with the operative arm free (Figure 1A). In each case, the anterolateral approach was used from the subacromial space for anterograde nailing as well as for distal third humeral shaft fracture reduction

(Figure 1B).

Figure 1: Patient positioning. **A:** Patient position is supine, and the operative arm is free. **B:** Proximal incision using an anterolateral approach to the sub-acromial space and distal incision using an anterolateral approach to the distal third humerus.

We performed open fracture reduction in 7 cases, and if needed and/or possible, fracture wirings were performed. First, we performed open fracture reduction and wiring fixation (Figure 2, 3A-C).

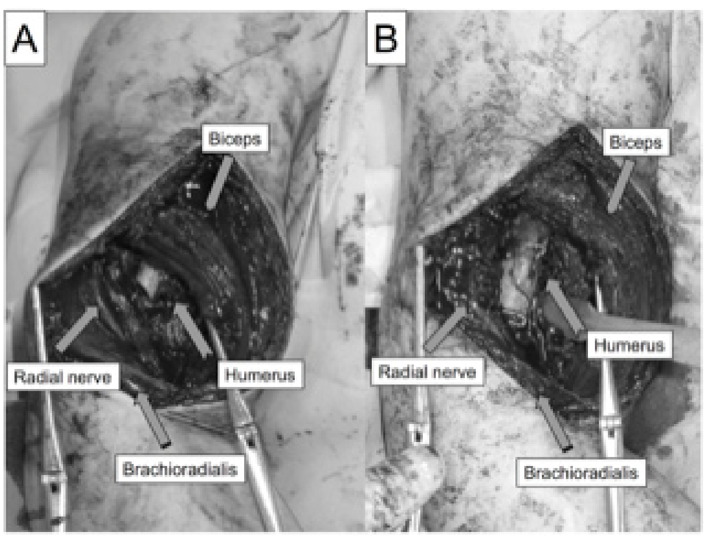

Figure 2: Intra-operative findings of fracture site in case 9. **A:** The fracture site is entered between the biceps and brachioradialis muscle. The biceps is retracted on the ulnar side. Thus, intra-operative injury of the radial nerve can be avoided. **B:** Following opening, reduction and wiring for fracture site was performed. There was no tension on the radial nerve. Open reduction and wiring fixation are usually performed before nailing.

A guide wire was then inserted from the subacromial space using an anterolateral approach (Figure 3D). We usually penetrated the olecranon fossa by a long guide wire and then reamed until the olecranon fossa was reached. However, if long guide wire penetration was not possible, we reamed directly until the olecranon fossa was penetrated using the sharp reamer. We use an 8.5 mm diameter SynReam (Figure 3E). This reamer tip was sharp and able to penetrate into the olecranon fossa. After the reaming procedure, an anterograde intramedullary nail was inserted into the olecranon fossa. The Synthes Expert Humeral nail was used in 8 patients and the MultiLoc Humeral nail was used in 1 patient. There are three distal locking holes at 14, 29, and 44 mm from the nail tip, respectively. After confirming that extension of the elbow joint was possible, we adjusted the depth of the nail tip and inserted at least 2 distal locking screws (Figure 3F).

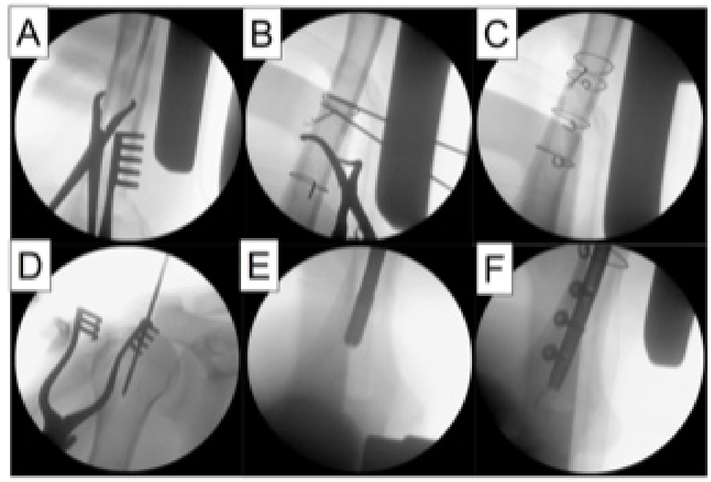

Figure 3: Intra-operative C-arm images in case 9. **A-C:** Open reduction and wiring. Reduction and wiring were performed. **D:** Anterograde nail insertion via the humeral head using an anterolateral approach to the subacromial space. **E:** Reaming procedure: After anatomical reduction, we performed intramedullary reaming by penetrating the olecranon fossa using an 8.5 mm diameter SynReam. **F;** Following distal fragment fixation, the tip of the nail penetrated the olecranon fossa and 3 distal locking screws were inserted at the non-fractured region.

After distal locking, the wire was tightened, and, if necessary, mechanical compression was applied. Proximal locking screws were inserted to complete the fixation (Figure 4).

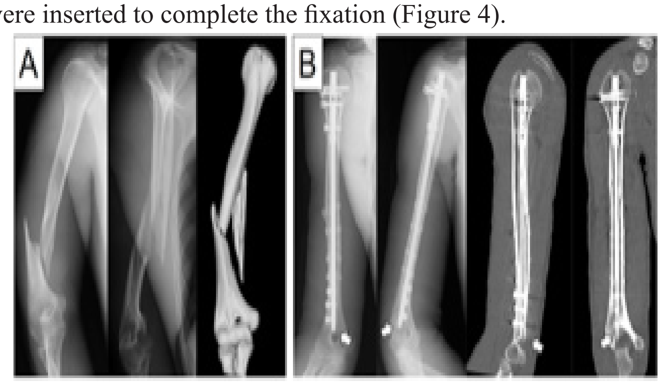

Figure 4: Case presentation of an OTA type 12-B1.3 fracture that occurred while arm wrestling in the dominant arm of a 27-year-old man (case 9). **A:** Pre-operative plain radiograph and 3D-CT image. **B:** Post-operative radiograph and multi-sliced CT scans. Distal tip of the humeral nail penetrating the olecranon fossa. **C:** Final follow-up findings. Full ROM

of the shoulder and elbow was observed. The patient complained of no symptoms in the shoulder and elbow. **D:** Final follow-up anteroposterior and lateral plain radiograph. Bony union was achieved, and implant removal was performed.

Post-Operative Care

After withdrawing the drain within 48 hours after surgery, we began exercising the active and passive range of the shoulder joint and the elbow joint without restriction. We did not limit the weight-bearing and rotation movements.

Results

The mean duration from injury to treatment was 3.4 (range, 0-9) days in 8 fresh fractures and 74 days in 1 delayed union case. The average duration of surgery was 116.1±32.38 (range, 80-180) minutes. Open fracture reduction was performed in 7 patients and fracture wiring was performed in 5 patients (Table 2).

Case No.	Day of OP	OP time	Open reduction	Nail	Cerclage Wiring
1	5	80	yes	EHN	no
2	3	100	no	EHN	no
3	9	90	yes	EHN	no
4	1	100	yes	EHN	yes
5	1	100	no	EHN	no
6	0	110	yes	EHN	yes
7	74	150	yes	EHN	yes
8	5	135	yes	EHN	yes
9	4	180	yes	MHN	yes

Table 2: Intra-operative patient data.

Intra- and post-operative complications were not observed in any patients. All preoperative nerve injuries were recovered 6 months after injury. All fractures healed and the mean union time was 9.8±0.92 (range, 8.6-11.0) weeks from fixation (Table 3).

Case No.	Time to union (weeks)	Follow-up (months)	Shoulder active ROM (abd/flex) (deg)	Elbow active ROM (ext/ flex) (deg)	UCLA shoulder score	Mayo elbow performance score	Intra-/post-operative complications	Secondary procedure
1	8.6	25	180/180	0/140	33	100	N	Nail removal
2	10.3	15	180/180	0/140	35	100	N	Nail removal
3	11	35	160/160	0/130	33	100	N	Nail removal
4	8.7	12	180/180	0/135	35	100	N	Nail removal
5	8.9	12	130/160	0/135	29	100	N	Nail removal
6	10.3	12	180/180	0/135	33	100	N	Nail removal
7	10.9	12	160/160	0/140	35	100	N	N
8	9.9	13	180/180	0/140	35	100	N	Nail removal
9	9.4	12	180/180	0/145	35	100	N	Nail removal

Table 3: Post-operative outcome data of patients.

All patients were followed up for 16.8±9.01 (range, 12-35) months. At the final follow-up, the mean shoulder active abduction and flexion were 171±11.67 (range, 150-180) degrees and 168.9±16.91 (range, 150-180) degrees. The mean active extension and flexion were 0 (range, 0-0) degrees and 137.8±4.41 (range, 130-145 degrees), respectively (Figure 4C). The mean UCLA shoulder score was 33.4±1.94 (range, 29-35); 8 patients showed excellent results and 1 patient showed good results. The Mayo elbow performance score was 100 points in all 9 patients, with excellent results (Table 3). Regarding additional procedures, we performed implant removal in 8 patients per patient request (Figure 4D).

Discussion

To our knowledge, this is the first comprehensive report of treatment for a distal third humeral shaft fracture with anterograde intramedullary nails. The clinical outcome of our method using oglecranon fossa-penetrating anterograde intramedullary nailing yielded good results without any complications. The optimal treatment for humeral shaft fracture is still controversial. Conservative or surgical treatments are still selected as appropriate and are able to result in good treatment outcomes. Conservative treatment is based on use of the functional brace reported by Sarmiento et al., which has resulted in favorable treatment outcomes in recent years [1-3]. Conversely, surgical treatment predominantly uses either a plate or intramedullary nail with many comparative studies available; however, whether conservative or surgical treatment is better has not been clarified [20-27]. In biomechanical studies for humeral shaft fractures, intramedullary nailing showed better stability than plating at the proximal region, but, at the mid-shaft region, stability was reported to be equal between both methods [11,28]. There are also many comparative studies of conservative treatment and surgical treatment. These studies have indicated that conservative treatment tends to result in more cases of nonunion and malunion, whereas surgical treatment tends to have more complications, such as iatrogenic nerve injury, iatrogenic fracture, and surgical site infection [29-31].

The treatment of distal third humeral shaft fractures is challenging because of the area's anatomy. In the surrounding soft tissues, the frequency of radial nerve injury is high with both initial injury and intra-operatively. In the bone anatomy, an adequate medullary canal disappears at the metaphyseal region. Meanwhile, in the distal humeral bone, the olecranon and coronoid fossae are present, which then become thin and flat. Therefore, unlike other long bones, it is difficult to use an intramedullary nail at this site. In general, intramedullary nailing can be performed only in fractures in which nerves are not involved and with at least a 5 cm diaphysis in the distal fragment to lock the nail [13]. However, in most distal third humeral shaft fractures, the unfractured medullary canal is less than 5 cm in size. In our cases, the unfractured distal medullary canal averaged 2.6 cm (range, 0.8-4.0) cm in size. Intramedullary nailing can be considered the ideal option since it is minimally invasive and offers the advantages of biomechanical load-sharing [11]. However, several authors have mentioned the risk of rotator cuff damage during anterograde insertion. In retrograde intramedullary nailing for the humeral shaft fractures, the intra-operative fracture rate of the distal fragment was reported to be 5-15% [32]. In cases in which the distal 1/3 is at risk, the intra-operative fracture rate will be higher than in proximal and middle 1/3 shaft fractures. Furthermore, there is a possibility that the entry point of the intramedullary nail or the distal locking screw will be applied to the fracture line. In addition, both standard anterograde and retrograde nailing may not provide stable fixation at the level of the distal third of the medullary canal, thereby resulting in potential non-union and malunion [12,33]. Therefore, plate fixation by a posterior or lateral approach tends to be selected in these fracture types. However, there is a possibility that a fixation force weakens the distal end in a single plate using a normal straight plate. Good outcomes have been reported with an anatomical locked single plate, but the frequency of complications after operation, mainly postoperative deformation, remains higher than ideal [4]. Hence, double plating is often selected. Although favorable outcomes have been reported with the use of double plating [6-8], the invasion of both soft tissues and bone is high, and intraoperative radial nerve injury, surgical site infection, or non-union may occur. As a minimally invasive method, MIPO from the anterior approach is used [5,9]. Although biological bone healing can be expected in MIPO, there is still a possibility that the stability of the distal fragment will decrease because it is a single plate. Another reported minimally invasive method is external fixation [10]. However, there is the possibility of pin-site infection and prolonged external fixation less than 3 months until bone union. In our method, the anterolateral approach is used. Thus, there is no invasion or risk to the radial nerve. In addition, since it is an intramedullary type fixation, it is easy to obtain a normal mechanical axis. Biomechanically, it seems to be more advantageous against rotation and load sharing force than plating. In addition, since the medullary canal is expanded by perforating the olecranon fossa, more than two distal locking screws of the distal bone fragment can be sufficiently inserted. Furthermore, by applying the tip of the nail to the olecranon fossa, a tip anchoring effect is also obtained. Thus, the stability of the distal bone fragment increased. Although the process of expanding the medullary canal is somewhat cumbersome in this method, the original method reported by Nodomiya is directly guiding the guide wire to the medullary canal by drilling a hole from the olecranon fossa. In some cases, it may be better to use the original method [15]. Our method is believed to allow anatomical reduction enabling extremely solid internal fixation from the bone. Our study has the following limitations. First, it is a small case series with no control groups. Second, the fracture patterns were only of the AO, A, and B types. In AO type C fractures, this method may not be feasible. Furthermore, in order to safely puncture the olecranon fossa, it is better to have a sharp guide wire and a sharper reamer. The shape of the intramedullary nail has no taper at the distal end, and so the distal locking screw holes are located more distally, while a multidirectional hole will be better. Finally, as this method is an anterograde procedure, problems might occur regarding post-operative shoulder function. In our case, by performing early active and passive shoulder range of motion exercises, shoulder dysfunction could have been minimal.

Conclusion

Distal third humeral shaft fractures can be effectively treated with open reduction and olecranon fossa-penetrating anterograde intramedullary nailing. We believe that our method is a good alternative with good clinical results for the treatment of distal third humeral shaft fractures.

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