Outcome of antegrade intramedullary fixation for juvenile fifth metacarpal neck fracture with titanium elastic nail

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Abstract. The purpose of the current study was to assess the outcome of antegrade intramedullary fixation with titanium elastic nail (TEN) in displaced fifth metacarpal neck fractures. The present study included 69 consecutive juvenile patients with displaced fifth metacarpal fractures. The head-shaft angle of the fifth metacarpal and range of motion (ROM) of the metacarpophalangeal (MCP) joint were evaluated. A disabilities of the arm, shoulder and hand (DASH) questionnaire was used to assess upper arm function. The head-shaft angle of the affected side was significantly improved postoperatively ($P<0.05$). No marked difference was observed between the affected and unaffected side in head-shaft angle and ROM. The average DASH score was 1.7 (range, 0-6.0). All patients obtained anatomical reduction postoperatively and the average healing time was 5.7±1.09 weeks (range, 5-10 weeks) with no non-union cases. Therefore antegrade intramedullary fixation with TEN is recommended as an easy, reliable and minimally invasive surgical technique for treating displaced fifth metacarpal neck fractures.

Introduction

The term 'fifth metacarpal neck fracture' is known as 'the boxer's fracture'. It is the most common fracture of the hand and is responsible for 9.7-50% of all cases (1-3). It is commonly observed in the dominant hand of male patients (4). The majority of these fractures are nondisplaced or minimally displaced without rotational deformity, and may be treated by conservative treatment with a good functional outcome (5,6). However, operative intervention is recommended for severely displaced fracture or volar angulation with severe rotational deformity.

Previously, numerous surgical techniques have been proposed to treat unstable neck fractures of fifth metacarpal fracture to perform closed/open reduction and achieve stability. These techniques include retrograde pinning (RP) by means of intramedullary K-wires, transverse pinning (TP) using K-wires, external fixation and standard or low-profile plates (7-9). However, complications including marked angulation accompanied by potential reduction in the range of motion (ROM) and reduced grip strength (10,11) may occur. Previous studies have demonstrated that antegrade intramedullary nailing (AIMN) is a reliable and minimally invasive method to treat metacarpal fractures (12-14). Although AIMN was reported to be a safe and reliable option to treat 66 children and juveniles with metacarpal fractures (15), more cases and studies are required to provide clinical guidance for treating the disease in juvenile patients.

Titanium elastic nail (TEN) has received increasing attention in previous years and is considered minimally invasive with excellent functional and cosmetic outcomes in treating fractures (15,16). Therefore the present study investigated the efficacy of treating displaced fifth metacarpal neck fractures in 69 juvenile patients using antegrade intramedullary fixation with TEN. The results of the current study may provide useful information for guiding clinical treatment of neck fractures.

Materials and methods

Patients. The present prospective study was approved by the Ethics committee of Shanghai Children's Medical Center affiliated to Shanghai Jiao Tong University School of Medicine (Shanghai, China) and written informed consent was obtained from the parents of participants prior to the study. It included 69 juvenile patients who received surgery intervention due to fifth metacarpal neck fractures in the Department of Pediatric orthopaedics, Shanghai Children's Medical Center affiliated to Medicine School of Shanghai Jiaotong University (Shanghai, China) between February 2012 and

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January 2014. The inclusion criteria were as follows: i) volar angulation of the fifth metacarpal head >30˚ (8) or ii) rotational deformity (>15˚) (13). Participants were excluded if they had segmental comminuted fractures or intraarticular involvement. The mean age of the patients was 14.9±1.5 years (range, 12-17 years). They included 60 males and 9 females, all of who experienced unilateral limb injury. The right hand was involved in 63 cases and the left hand in 6 cases. The head-shaft angle of fifth metacarpal fracture angle was measured in accordance with a previous study by Picture Archiving and Communication Systems (PACS) (17). Its normal value is ~15˚, however, in the current study, the mean head-shaft angle of fifth metacarpal fracture was 48.8±3.0˚.

Surgical technique. All surgery was performed under general anesthesia. Anesthesia was induced with midazolam (0.1 mg/kg; Fresenius Kabi AG, Ban Homburg, Germany), propofol (3 mg/kg; Fresenius Kabi AG), fentanyl (2 mg/kg; Fresenius Kabi AG) and rocuronium (0.6 mg/kg Esmeron; MSD, Shanghai, China) and maintained with sevoflurane (3%; Baxter, Deerfield, IL, USA). The surgery was performed by experienced surgeons under fluoroscopy. Following routine skin sterilization and draping, a medial incision (0.5-0.8 cm in length) was made over the dorsal ulnar side of the fifth metacarpal bone. The subcutaneous tissue was separated bluntly to expose bone cortex. A preflex TEN (2 mm in diameter, Synthes GMbH, Umkirch, Germany) was selected based on the pre-operative width of the medullary canal. Entry point of the nail was located on the dorsal ulnar side of the fifth metacarpal bone, which was not covered by nerves and tendons, under constant C-arm radiographic guidance (Siemens AG, Munich, Germany). The entry point was then drilled and the TEN was inserted into medullary canal under constant C-arm radiographic guidance (Fig. 1A) and the awl (Synthes GmbH, Umkirch, Germany) was used to perforate the cortex. The tip of TEN was introduced under direct view, went over the fracture line and was fixed on the edge of the metacarpal articular surface (Fig. 1B). The nail was then rotated through 180˚ to acquire good reduction of the fracture (Fig. 1C). Re-examination was conducted to confirm good fracture reduction and proper position of the TEN using C-arm fluoroscopy, followed by cutting off the TEN tail (Fig. 1D and E). The remaining nail tail was buried intradermally and the incision was closed. Closed reduction was not conducted in the present study.

Postoperative treatment. All patients received routine antibiotics (cefazolin, 0.5 mg/kg) postoperatively. The affected hand and forearm were immobilized in a short arm plaster cast for 2 weeks. X-ray examination of the hand was performed for review at two days and two weeks after surgery. The plaster was then removed, and the patients performed functional exercise of metacarpophalangeal (MCP) joints gradually as previously described (18). As not all hospitals had rehabilitation departments, patients were not specifically required to complete functional exercises in the hospital. A hand X-ray was taken to evaluate fracture healing 5 weeks postoperatively. If firm fracture union was not observed, the X-ray was taken again 8 weeks postoperatively. When firm fracture union was observed radiographically, the TEN at the medial insertion site of the fracture was directly removed under general anesthesia in our hospital 3 months postoperatively.

Table I. General characteristics of the enrolled patients.

Variable	Mean (Range)
Age, year	14.9±1.5 (12-17)
Sex, male/female	60/9
Operating time, min	15.5±6.5 (5-32)
Number of fluoroscopy	7.8±2.4 (5-13)
Healing time, weeks	5.7±1.09 (5-10)
Follow-up time	16.9±6.3 (7-30)
DASH	1.7 (0-3.0)

Data are presented as mean ± standard deviation. DASH, disabilities of the arm, shoulder and hand.

Patients were asked to return for re-evaluation using X-ray examination during follow-up. The patients were clinically followed up from 7 to 37 months following surgery (average 16.9±6.3 months). From the clinical point of view, operating time, time of C-arm usage and healing time were recorded for each patient. Additionally, the head-shaft angle of the fifth metacarpal and the ROM of the MCP joint for the affected and unaffected sides were evaluated. Disabilities of the arm, shoulder and hand (DASH) scale (0-100 points) (19) was performed to assess upper arm function. The DASH questionnaire consists of 30 items and facilitates comprehensive evaluation of upper-extremity functional activity (20). Although it is not recommended for children, it is suitable for these participants in the present study, as they had mean age of 14.9±1.5 years. Each patient finished the questionnaire.

Statistical analysis. Statistical analysis was performed using SPSS 16.0 software (SPSS, Chicago, IL, USA). The measurement data were expressed as mean ± standard deviation and analyzed using a paired *t* test. P<0.05 was considered to indicate a statistically significant difference.

Results

Clinical outcomes. The general characteristics of the enrolled patients are presented in Table I. The present study included 60 males and 9 females with an age range of 12-17 years (mean, 14.9±1.5 years). All patients experienced unilateral limb injury, including 63 cases with right hand injury and 6 cases with left hand injury. The operating time ranged from 5-32 min (mean time, 15.5±6.5 min). The frequency of the C-arm usage intraoperatively was 7.8±2.4 times per surgery (range, 5-13 times), and the duration time was 0.5 sec per time. Patient healing time ranged from 5-10 weeks (mean time, 5.7±1.09 weeks). The results of head-shaft angle and ROM of the MCP joint are presented in Table II. The mean ROM of the MCP joint of the affected side was 87.9±4.3˚ postoperatively, and no significant difference was observed compared with that of the unaffected side (89.1±4.6˚, P=0.35). The mean DASH score was 1.7 (range, 0 to 6.0).

Table II. Head-shaft angle of the fifth metacarpal and the ROM of the MCP joints.

Side	ROM of MCP joint, ˚	Head-shaft angle of the fifth metacarpal		P-value
		Pre-op, ˚	Postop, ˚	
Affected	87.9±4.3	48.8±3.0	15.8±1.8	<0.001[a]
Unaffected	89.1±4.6	-	15.0±1.6	-
P-value		0.35	0.06	

[a]P<0.001. Data are presented as mean ± standard deviation. ROM, range of motion; MCP, metacarpophalangeal; pre-op, pre-operatively; postop, postoperatively.

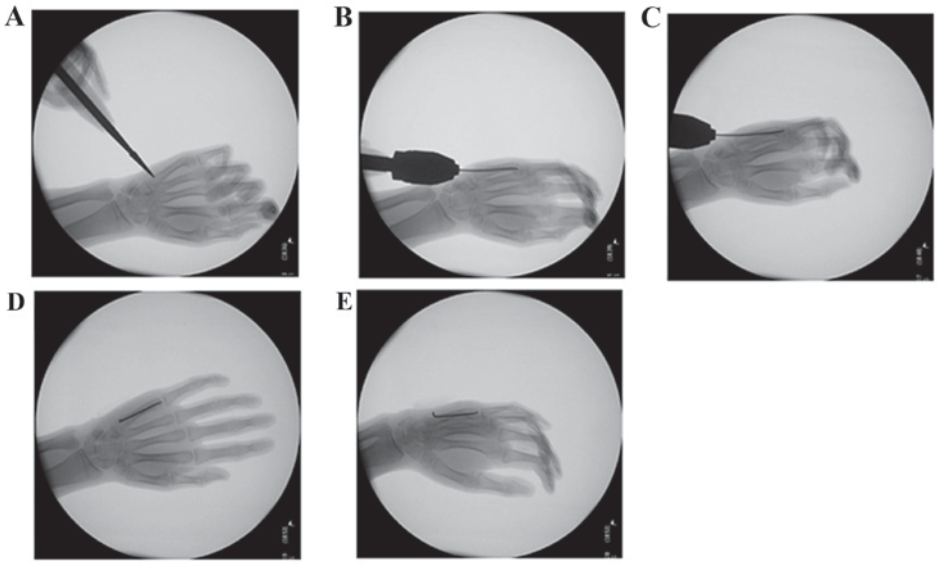

Figure 1. Intra-operative images of one representative patient. (A) Enter point is localized, (B) the tip of TEN is introduced to the medullary canal and (C) the nail is rotated through 180˚ to acquire good reduction of the fracture. (D and E) The nail tails were removed.

Radiographic outcomes. The head-shaft angle of the affected side was 48.8±3.0˚ pre-operatively and 15.8±1.8˚ postoperatively, indicating a significant improvement (P<0.001) following surgery. However, there were no significant differences in the head-shaft angle between the affected and unaffected sides (15.8±1.8˚ vs. 15.0±1.6˚, respectively; P=0.06). All patients obtained anatomical reduction and presented with complete fracture healing.

Subjective outcomes. Antegrade intramedullary fixation with TEN was successful in each patient with displaced fifth metacarpal neck fracture (Fig. 2). There were no cases of complications, including paralysis of dorsal branch of ulnar nerve, injury of dorsal extensor tendon, avascular necrosis of metacarpal head, nonunion, and abnormal healing. One case (16 year old male) experienced delayed union (>8 weeks, Fig. 3) but acquired good healing after 3 months, at which point the nail was removed. The nail was removed within 3 months of surgery in all patients as fracture union was confirmed radiographically. Excellent functional results were presented during the final follow-up at 37 months post-surgery. A total of four cases developed nail tail irritation but it was tolerated and did not require special management. The symptoms disappeared when the internal fixation was removed.

Discussion

In the present study, the clinical outcome of antegrade intramedullary fixation with TEN in displaced fifth metacarpal neck fractures was evaluated. The results determined that antegrade intramedullary fixation with TEN is a simple technique to perform. In addition, it is also a straightforward, reliable, minimally invasive surgical technique, and seems to achieve excellent functional results.

Initial treatment for the fifth metacarpal neck fracture is nonsurgical and involves certain types of immobilization. Different types of studies demonstrate that treatment of this injury consists of a closed reduction of the fracture and immobilization with cast application (21,22). This treatment is suitable for nondisplaced or minimally displaced fracture without rotational deformity (23). However, long-term cast immobilization limits the activities of the patients and may lead to a stiff joint and pressure necrosis of the skin, thus prolonging rehabilitation. In addition, the nondisplaced

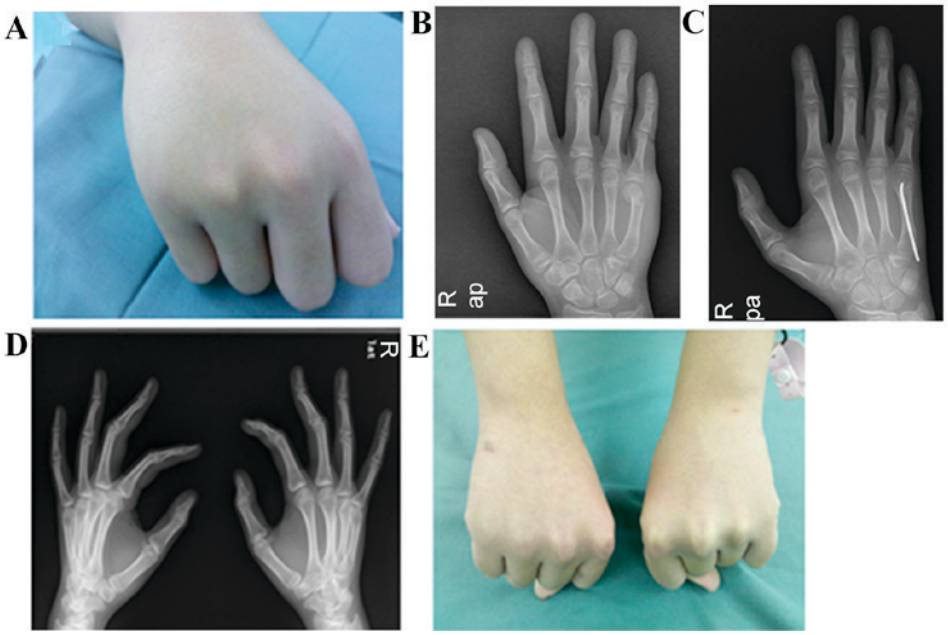

Figure 2. Images of one patient with fifth metacarpal neck fracture of right hand. (A) Pre-operation image presenting dorso-ulnar swelling, (B) X-ray image demonstrating the fifth metacarpal neck fracture, (C) X-ray image at 6 weeks post-operation and (D) X-ray image at final follow-up. (E) Cosmetic and functional image. Post-operatively, ulnar scar is visible.

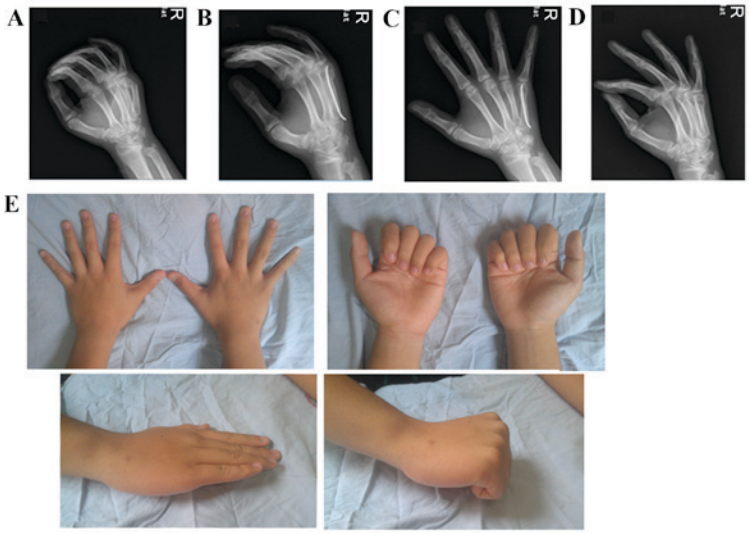

Figure 3. Images of the case experiencing delayed union. X-ray images (A) Pre-operation, (B) 8 weeks post-operation demonstrating a delayed union, (C) at 3 months post-operation and (D) at final follow-up. (E) Cosmetic and functional images.

fracture may shift or cause mal-union due to cast loss. Therefore, surgical treatment with internal fixation is recommended for severely displaced and unstable fractures to avoid impairment of hand function. Surgery is recommended for injuries with a dorsal angulation ≥30˚, a shortening ≥5 mm and rotatory deformity >15˚ (8). Percutaneous or cross intramedullary Kirschner wire (K-wire) fixation is a common procedure used in open reduction for operative treatment (24,25). However, patients may experience complications including osteomyelitis, tendon rupture, nerve lesion, pin tract infection, pin loosening and migration (26-28), highlighting the limitations of this procedure.

TEN is widely accepted as the most reliable and valid method for treating paediatric long bone fractures (29-33). TEN is able to maintain biomechanical stability owing to the divergent 'C' configuration, which generates six points of fixation and permits the construct to act as an internal splint (34). Furthermore, TEN offers stable and elastic fixation and permits restricted motion at the fracture site, leading to healing by external callus (35). Additionally, it avoids any growth disturbance by conserving the epiphyseal growth plate and reducing bone impairment or weakening due to the construct elasticity, which offers a load sharing and biocompatible internal splint (29). TEN also allows rapid mobilization

with few complications and avoids prolonged immobilization (36). Finally, it involves a minimal risk of bone infection. Antegrade intramedullary fixation with TEN was used in the present study to treat displaced fifth metacarpal neck fractures in 69 juvenile patients. This technique achieved good functional results.

In line with aforementioned previous studies (27,37), the operating time in the present study was relatively short. The ROM of the MCP joint recovered well postoperatively and the average DASH score was 1.7, demonstrating that the function of the affected side underwent good recovery (DASH scores are on a scale from 0-100, with higher scores indicating greater disability). A 2 mm preflex TEN was selected as the material of internal fixation to treat the fifth metacarpal neck fractures. It was not big enough to suppress endosteum of the affected side. Furthermore, no cases required open reduction postoperatively, indicating that the inserted TEN did not injure the periosteum. This suggests that TEN insertions do not impede healing of the fifth metacarpal neck fracture.

There were no cases of serious complications reported in the present study, such as paralysis of dorsal branch of ulnar nerve and injury of dorsal extensor tendon. To avoid these complications, it is worthwhile mentioning a number of important points. Firstly, correct selection of the incision site is of paramount importance for operative success; secondly, superficial sensory nerves should be protected when subcutaneous tissue is separated; thirdly, attention should be focused on managing the nail tails to avoid irritation of the surrounding tissue, thus truncation and short length of nails would be good choices. Finally, it should be stressed that antegrade intramedullary fixation with TEN is suitable only for fractures presenting with an intact metacarpal head. If a comminuted fracture of the metacarpal head is involved, intramedullary nail is insufficient to maintain post-reduction stability and may penetrate into the MCP joint, causing internal fixation failure. In the current study, only one case experienced delayed recovery (>8 weeks), which may be due to a variety of factors, such as the severity of injury or the nutritional status of patients.

The present study should be cautiously interpreted due to certain limitations. It included a small sample size and a short-term follow-up, therefore larger-scale studies are required to confirm the analysis results. Long-term follow-up is in process to evaluate the clinical outcome of antegrade intramedullary fixation using TEN.

Antegrade intramedullary fixation with TEN is a straightforward, reliable and minimally invasive surgical technique. The results may provide good clinical learning experiences for treating juveniles with fifth metacarpal neck fracture.

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