Handgun injuries with metacarpal and proximal phalangeal fractures: early definitive treatment

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Abstract Most gunshot injuries to the hand involve a combination of tissue types. The goal of this study is to report the results of early definitive treatment in extra-articular metacarpal and proximal phalangeal fractures due to low velocity gunshot wounds and to analyse their outcomes. A retrospective analysis of 51 metacarpal and 41 proximal phalangeal fractures of 76 patients due to low velocity gunshot wounds treated between January 2001 and December 2004 was carried out. We applied acute fixation in the first 24 hours. The patients were evaluated with total active motion scores, radiographic control, complication rate and the need for revision surgery. The infection frequency was 10.5% and the need for a revision surgery was 7%. The plate fixation group had significantly higher total active motion scores than the external fixation group. The K wire group had the highest revision rate. The bone grafting group was associated with good total active motion scores and low complication rates. The majority of the low velocity gunshot injuries are surgically clean wounds which allow not only early fracture fixation, but also early bone grafting and soft tissue reconstruction. Plate and screw fixation is associated

with significantly better functional outcomes than the minimal fixation group.

Résumé Les blessures par armes à feu au niveau de la main entraînent des lésions tissulaires complexes. Le but de cette étude est de rapporter les résultats du traitement des fractures des phalanges proximales et des métacarpiens en fonction de la force du tir. Une analyse rétrospective de 51 fractures métacarpiennes et de 41 fractures des phalanges proximales sur 76 patients ont été traitées entre janvier 2001 et décembre 2004. Nous avons réalisé une fixation de première intention en urgence dans les 24 premières heures. Ces patients ont été évalués par la mobilité, l'aspect radiographique et le taux de complication. Le taux d'infection a été de 10,5% et les nécessités de reprises chirurgicales de 7%. Le groupe des patients traités par plaque a une mobilité plus importante que ceux traités par fixateurs externes. Le groupe des patients brochés a entraîné un taux important de réinterventions. Le groupe des patients greffés a bénéficié d'une bonne récupération de la mobilité et d'un taux de complication relativement bas. La majorité des blessures par armes à feu avec une vitesse de pénétration relativement lente permet à la plaie d'être relativement propre et permet également une fixation de la fracture et une greffe précoce ainsi qu'une reconstruction des tissus mous. Une ostéosynthèse par plaque et vis peut être associée avec un résultat fonctionnel bien meilleur que ceux bénéficiant d'une fixation plus aléatoire.

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Introduction

Low velocity gunshot wounds are, by definition caused by bullets travelling less than 2000 ft/s [1]. However, maintenance of length, alignment and restoring the hand

function are common problems in these severe hand injuries. Certainly, these weapons cause less bone and tissue loss and a lower risk of contamination than high velocity gunshots [6, 7]. These advantages allow the surgeon to carry out early and effective bone fixation. Nevertheless, early bone grafting is recommended by various authors. In these cases, bone grafting and/or external fixation are favourable treatments to cope with shortening [11]. The type of fixation and timing of surgical procedures remain controversial in these injuries.

The goal of this study is to report the results of early definitive treatment in extra-articular metacarpal (MC) and proximal phalangeal (PP) fractures due to low velocity gunshot wounds and to analyse their outcomes.

Materials and methods

A retrospective analysis of 51 metacarpal and 41 proximal phalangeal fractures of 76 patients due to low velocity gunshot wounds treated between January 2001 and December 2004 in our department were included in this study (Fig. 1, Table 1). In total, 92 fractures in 76 patients are reported.

Tetanus prophylaxis was given, wound cultures were obtained, and meticulous irrigation and debridement of necrotic materials were performed initially in the emergency department with local blocks. A loop (magnification: six times) was used for a meticulous debridement and neurovascular assessment. The wound was then dressed aseptically. Penicillin and cephazolin were initially started and changed according to the culture results. The antibiotic

Table 1 Location of surgery

Location	Number of cases
SMC	30
DMC	6
TMC	2
SPP	32
DPP	3
MC+PP	3
Total	76

SMC: Single metacarpal, DMC: Double metacarpal, TMC: Triple metacarpal,
SPP: Single phalangeal, DPP: Double phalangeal

therapy was continued until the 5th day of surgery when there was no evidence of infection.

Our primary goal was to apply acute fixation and soft tissue coverage in 24 hours. Skin grafts, local flaps, cross-finger flaps were used for 27 hands, and cross-finger fascial flaps (Fig. 2) were used for three hands with severe soft tissue loss (Table 2). Three digital nerves were primarily repaired; four digital revascularisations and two extensor tendon repairs were performed (Fig. 3).

The patients were examined weekly for 5 weeks and then examined every month for a year. The active range of motion of the metacarpophalangeal, proximal interphalangeal and distal interphalangeal joints were recorded at each visit. Total active motion (TAM) was also calculated and graded using the method of Pun et al [9].; considering $>210^\circ$ =good, 180° – 210° =fair, $<180^\circ$ =poor. Repeat radiographs were taken every 2 weeks until union and then every three months after radiographic union. Bridging callus and

Fig. 1 Soft tissue necrosis developed by the reason of gun shot injury and the radiological appearance of proximal phalanx fracture caused by gun shot injury

Fig. 2 Intra-operative clinical and radiological appearance of rubber band technique

cortical continuity were the radiographical union criteria (Fig. 4). Bone shortening, angulation in the AP and lateral planes were the items measured. Comparison view of the other hand was the guide for shortening.

All of the statistical evaluations were performed by SPSS version 11.5. Descriptive statistics were shown as the arithmetic mean $\pm$ standard deviation. The distributions of the continuous variables were parametric -tested by Shapiro-Wilk test and histogram plots. The differences among the fixation type (plate screw, plate screw with grafting, external fixation, minimal fixation) and fractured bone (metacarpal and proximal phalanx) were analysed by multivariate analysis of variance. If the interaction terms were significant; Tukey test was used to identify the significance of the differences between each treatment method. Statistical significance was set at $p < 0.05$.

Results

Sixty-eight (89%) patients were treated successfully without requiring a second surgical procedure. Eight patients underwent secondary surgery; two for non-union, three for angulation and three for rotational deformities.

Complications

The infection rate was 10.5 % with one deep soft tissue infection and seven superficial wound infections (one in the

plate fixation group, three in the K-wire group, four in the external fixation group and one in the group with plate fixation combined with bone grafting). All of them responded to parenteral antibiotic therapy regimen without further complications. There were no cases of osteomyelitis.

Three PP fractures fixed with K wires had rotational deformity; one with 15°, one with 25° and one with 30°. There were angular deformities of more than 15° in two fractures from the K-wire group and one from external fixation group. There was non-union in one case from the external fixation group and one from the bone grafted group. All of the eight fractures underwent an additional operation with plate and screws.

None of the digits with digital revascularisation (n:4) had circulation problems after the operation. All had paresthesia in the side of the digit after the operation, all but three of them recovered spontaneously.

Range of motion

The average TAM scores for the entire MC fractures were 219° and for entire PP fractures were 213° (Fig. 5). The results for this group were as follows: good for 31 MC and 19 PP, fair for 20 MC and 18 PP; and poor in four PP and for none of MC (Table 3).

Radiographic evaluation

Callus bridge formation was achieved in all fractures after 12 weeks except one defective PP fracture without an additional operation. Antero-posterior and lateral X-rays showed an average angulation of 5° (range: 0°–23°). Seven patients had an average angulation of more than 10°. There was no shortening of more than 5 mm. Seven of 18 MC fractures -that required either external fixation or bone grafting- had shortening between 2–5 mm. Also nine of 16 PP fractures that required external fixation or bone grafting had shortening between 2–5 mm.

Table 2 Major concern regarding soft tissue type injury

Type	Number of cases
Local flaps	9
Skin grafts	12
Cross-finger flaps	6
Cross-finger fascial flaps	3
Total	30

Fig. 3 The clinical appearances of cross-finger fascial flap and skin graft after operation

Discussion

Low-velocity gunshot wounds frequently cause only moderate damage to the soft tissue envelope, which allows early closure and fracture fixation [2, 7]. These fractures are often associated with loss of stability and comminution of more than 50% and tend to redisplace and shorten when treated conservatively [7]. Chappell et al. advocate early fracture

stabilisation and a low threshold for internal fixation for gunshot wounds to the hand, as conservative regimens cause a higher complication rate and higher economic impact [2]. Kiehn, Mitra and Gutowski have reported low infection rates with early definitive treatment for fractures without bone defects [8]. The infection rate in our cases is 10.5% and all of them responded to parenteral antibiotic therapy regimen without further complications.

Fig. 4 The radiologic appearance after postoperative six months

Fig. 5 The functional appearance after six months

Bone grafting is usually necessary for the fractures with bone defects, especially for the gunshots from an extremely close range. Freeland et al [4], used bone grafts in clean wounds of the hand within 10 days of injury and reported a low rate of infection and uniform incorporation of bone. However, early bone grafting has evolved from being a secondary procedure to a delayed primary procedure and finally to a primary bone grafting procedure [10]. Early bone grafting can be applied in the presence of clean wounds, adequate blood supply and healthy soft tissue [1, 4]. We applied bone grafting as a primary procedure with plate screw fixation in defective fractures. The results of this group did not have significant differences from the “pure” plate screw group. Thus, these results were satisfactory except for one case that underwent a second operation because of non-union.

The wounds with massive soft tissue loss require local or distant flaps [1]. Local flaps were sufficient for our patients as the soft tissue loss was not so extensive. In our opinion, early application of these flaps is worthwhile as they raise the patients comfort, preventing the wound from necrosis and allow one stage surgery with early fracture fixation.

Technically, all gunshots to the hand cause nerve injury, but small cutaneous nerves are involved most often [12]. Despite fractures and joint damage, tendons and larger

nerves often escape serious injury in low-velocity gunshot wounds. Nerve injuries due to low-velocity gunshot wounds are often concussive neuropraxias and they generally recover spontaneously [1, 3, 5].

The source of stabilisation is the main issue for discussion. Sixty-eight patients (89%) were successfully treated without the need of a secondary procedure in this study. Fixation with both K wires and external fixators are often preferred to prevent deep infection by minimal implant use in an open fracture. However, in our study a total of five patients in the K wire fixation group developed rotational deformities (n:3) and angulations (n:2). Thus, the revision rate was highest (25%) in this group. Rigid fixation will obviously reduce the delay period before the rehabilitation [5]. Therefore, the average functional TAM score of the minimal fixation group was lower than that of the immediate bone grafted plate screw group, because of the avoidance of early mobilisation. We had assumed external fixation to be a good choice in fractures that had poor soft tissue envelope. However, TAM scores of the external fixation group were significantly lower than the plate fixation group. Infection level was the highest in this group, though most were pin-tract infection which responded well to antibiotics. The immediate bone grafted plate screw group did not present a significant difference from any of the other groups. One (6%) case from this group required revision surgery.

Table 3 The total active motion scores according to treatment type

	PP		MC		Total	
	N	Mean±SD	n	Mean±SD	n	Mean±SD
Plate	7	227.1±23.79	8	235.3±22.44	15	231.5±22.63
K wire	10	218.8±27.01	10	227.1±18.60	20	223.0±22.97
External fixation	14	204.4±21.80	27	210.9±16.55	41	208.7±18.50
Plate+graft	10	209.2±22.08	6	222.3±20.76	16	214.1±21.90
Total	41	213.0±24.21	51	219.2±20.26	92	216.4±22.20

It is well known that the treatment of proximal phalangeal fractures is more complicated and the impairment of motion is greater than in metacarpal fractures [6, 7]. This can be attributed to the adjacent metacarpal bones bound by the inter-metacarpal ligaments, providing stability and making early movement safer. Nevertheless, there was not a statistically significant difference between the fractures of these bones in our study group.

The majority of the low velocity gunshot injuries are surgically clean wounds, which allow not only early fracture fixation, but also early bone grafting and soft tissue reconstruction. Plate and screw fixation is associated with better functional outcomes than the external fixation group and minimal fixation group. Shortening can be avoided by early bone grafting, with either plate and screw fixation or external fixation. Local flaps are usually sufficient for low-velocity gunshot wounds with soft tissue injury. Successful outcomes with early one-stage surgery for low-velocity gunshot wounds should be expected.

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