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A Novel Handmade External Fixator for Phalangeal and Metacarpal Fractures

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Abstract

Background: The value of external fixation in complex hand injuries is well established. Expenses and technical difficulties of commercial mini external fixator sets have led to the innovation of handmade external fixators. These fixators are used as versatile facilities to treat certain hand fractures. Usually, these structures are made by k-wires crossed filled with cement plastic tube. However, these fixators have multiple deficiencies that should be addressed.

Objectives: In this study, we described in detail the surgical technique of a handmade concrete like mini external fixator and report its clinical use and results.

Methods: Our handmade external fixator was applied for 52 patients with 56 fractures. Only 5% of the fractures were closed, non-comminuted extra-articular, and the other 51 fractures were more complex injuries. The mean follow up time was 9.3 months. At the end of the follow up, radiologic and functional assessment (DASH: Disability of arm, shoulder and hand and TAM: Total active motion) was evaluated.

Results: All 56 fractures were united completely. None of the cases experienced pin loosening or reduction loss. Of the fractures, 8.9% malunited due to fracture complexity. The mean dash score was 3.76. TAM was excellent in 45% of the fractures; it was good in 7% and fair in 4%.

Conclusions: This type of handmade external fixator is simple, lightweight, and cheap. Furthermore, all implements are readily available in most operating fields. The probability of loosening has been greatly diminished because of the concrete like structure. Easy and fast assembly and good clinical and functional results are the other advantages of this technique. Due to the less complication and benefits, this technique could be used for many phalangeal and metacarpal fractures with confidence.

Keywords: Mini External Fixator, Handmade, Phalangeal Fracture, Metacarpal Fracture

1. Background

Treatment of comminuted or open fractures of the hand is challenging, especially if accompanied by tendon or neurovascular injuries, for which internal fixation maybe inappropriate (1). Several studies supported the use of external fixators in these complex injuries, showing good results (2-4).

One of the main advantages of mini external fixators is that the patient can move adjacent joints while the instrument is on the hand.

Many types of commercial and handmade external fixators have been described. Several formal mini external fixators are available in the market, but various improvised techniques have been described as cheap simple and effective alternatives (5-14). These fixators are low profile, cost-effective and readily available in emergency situations. These handmade fixators are often fabricated from k-wires crossed a plastic tube filled by bone cement, but it has some technical drawbacks, which we will discuss later.

The idea of bent Kirshner wires in cement was first described by Barabas et al. (15). This concrete like structure covers many drawbacks of the mini external fixators.

2. Objectives

In this study, we improved the surgical technique, providing a detailed explanation, as well as assessment of clinical application.

The possibility of a low cost and effective external fixator is especially important in developing countries or emergency situations where expensive sets may not be available.

3. Methods

Fifty-two patients with 56 fractures were treated by our handmade external fixator from 2012 to 2015.

This project was approved by the Institutional Review Board. All patients signed a written informed consent prior to their participation in the study.

A wide variety of mechanisms of injuries was described; nonetheless, the majority of these injuries were caused by motor vehicle accidents (63%). Figure 1 displays the geographic pattern of hand fractures.

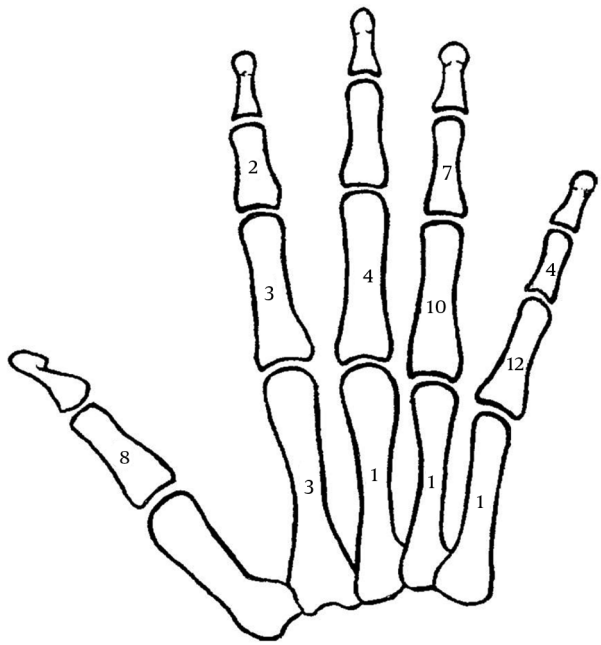

Figure 1. Location and Frequency of Fractures

The demographic data of the patients are summarized in Table 1. Only three (5%) of the cases were simple, non-comminuted, non-articular closed fractures.

Table 1. Demographic Data

	Mean or No. (%)
Age	34.5 (17 - 66)
Gender	
Male	45
Female	7
Total	52
Risk factors	
Fracture type	Open: 16 (28.6)
Articular involvement	Intra-articular: 29 (52)
Comminuted fracture	52 of 56 cases (93)

3.1. Inclusion Criteria

Inclusion criteria were as follows: Open fractures of the hand and metacarpals, comminuted fractures, intra-articular fractures, and simple fractures but with severe soft tissue injury like swelling or contusion.

3.2. Exclusion Criteria

Exclusion criteria were as follows: Nondisplaced or stable fractures, simple fractures suitable for closed reduction and splinting, distal phalangeal fractures, fractures with specially recommended treatments (e.g., volar base fracture of second phalanx suitable for open reduction internal fixation or hemi-hamate arthroplasty), and lack of consent to participate in the study.

All surgeries were performed by one hand surgeon.

We followed all the patients of the study until the union and removal of the external fixator.

One hand surgeon, who had not participated in any of the surgeries, evaluated all the patients.

Functional recovery was assessed by the disabilities of the arm, shoulder and hand score and total active movement (TAM) according to Duncan et al. (16), which adds active flexion of metacarpophalangeal, proximal interphalangeal and distal interphalangeal joint, and then subtracts the sum of extension lag of these three joints (Table 2).

Table 2. Total Active Movement (TAM) according to Duncan et al.

Finger	Thumb	Result
220 to 260	119 to 140	Excellent
180 to 219	98 to 118	Good
130 to 179	70 to 97	Fair
< 130	< 70	Poor

3.3. Operative Technique

The application of this fixator should be based on the accepted principles of hand fracture management.

After local or general anesthesia, prep and drape was done while the limb was flat on hand on the operating table. Following the debridement of any open wounds, the surgeon manipulated the fracture under fluoroscopic control to assess the possibility of reduction by closed manipulative techniques; nevertheless, there was no contraindication for open reduction and use of these external fixators.

Then while maintaining a relative reduction, the surgeon inserted a minimum of two 0.045-inch (1.14 mm) pins in each side of the fracture. The pins were inserted obliquely in the 10 O'clock position, as described by Drenth

et al. (17), so they neither interfered with the free extensor gliding, nor caused neurovascular damage.

Then by a 0.5-inch space off the skin, proximal and distal pins were bent towards each other by needle- nose plier. This aggregation of pins helped the surgeon to wrap them tightly together by orthopedic cement (Figure 2).

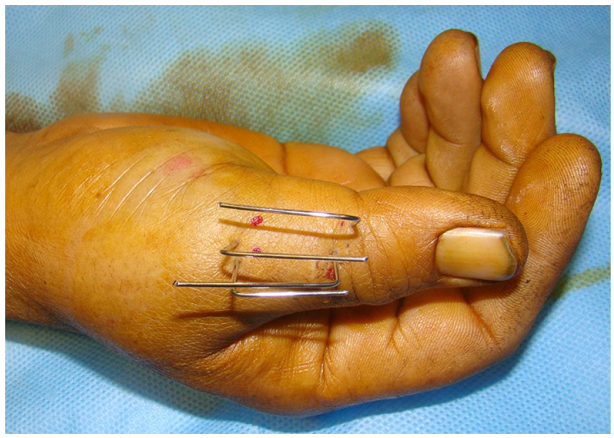

Figure 2. Pin Insersion and Bending

A little amount of cement and liquid was mixed, and the pins were affixed together by cement like a concrete structure at the time of no adherence to gloves. While cement hardened, the surgeon had enough time to obtain the final reduction under fluoroscopic control, although traction and visual control were sufficient most of the time (Figure 3).

This fixator could be used as a joint spanning instrument when fracture pattern is necessary.

Closed reduction and multiple subchondral pins (like rafting screws in knee plateau fractures) was our preferred technique of external fixation in phalangeal base fractures. Therefore, two other pins were inserted in phalangeal shaft, functioning as columns of a building. Finally, bending of pins and cementing was carried out as mentioned above (Figure 4A-E).

To finish, pin sites were covered by petroleum gauze and soft dressing.

3.4. Post-Op: (Assessment)

One day after surgery, the patient was trained for pin care and movement protocols. For construct rigidity, the patient was encouraged to start active joint movements shortly after operation. In the event of nerve or other soft tissue repairs, the specific protocols were carried out.

First visit was set at one week after discharge and continued by two- week intervals for soft tissue assessment, pin stability check and control X-rays until radiographic union and fixator removal. The patient underwent hand training instructions in each follow up visit and referred to hand therapist in case of stiffness.

Follow up visits were continued until complete bone healing and achieving a plateau in functional improvement.

4. Results

The mean interval to definitive treatment was 38 (SD, 13) hours. The mean fixator stay time was 4.2 (SD, 1.2) weeks.

No reduction loss or nonunion, neither loosening at pin-bone nor pin-cement Junction, were observed.

Two cases of superficial pin site infection were treated by oral antibiotics and local attention.

There were five (8.9%) malunions (non-malrotated, 1 mal-apposed, 1 shortened and 3 articular steps). All malunited fractures were comminuted, and no appropriate reduction was obtained at the time of the surgery. One fracture with increased angulation was corrected by local anesthesia and bending of fixator k-wires at the first postoperative visit.

Patients were followed up for a mean of 9.3 (SD, 3.4) months. At the end of the follow- up period, functional scoring was done by DASH and TAM. The mean DASH score was 3.76 (SD, 6.29). Table 3 demonstrates the functional results according to TAM.

Figure 5 illustrates that open fractures affect TAM and DASH by worsening end functional results.

Table 3. Functional Results According to TAM

TAM	Frequency (%)
Excellent	45 (78.6)
Good	7 (12.5)
Fair	4 (7.1)
Poor	0
Total	56 (100)

5. Discussion

Treatment of open or comminuted phalangeal and metacarpal fractures is challenging, especially if accompanied by intra-articular extension that could not be managed by simple pinning or internal fixation. In such cases, external fixation may be the answer. External fixators reduce complex fractures by ligamentotaxis, bridge wounds and maintain the reduction until fracture union.

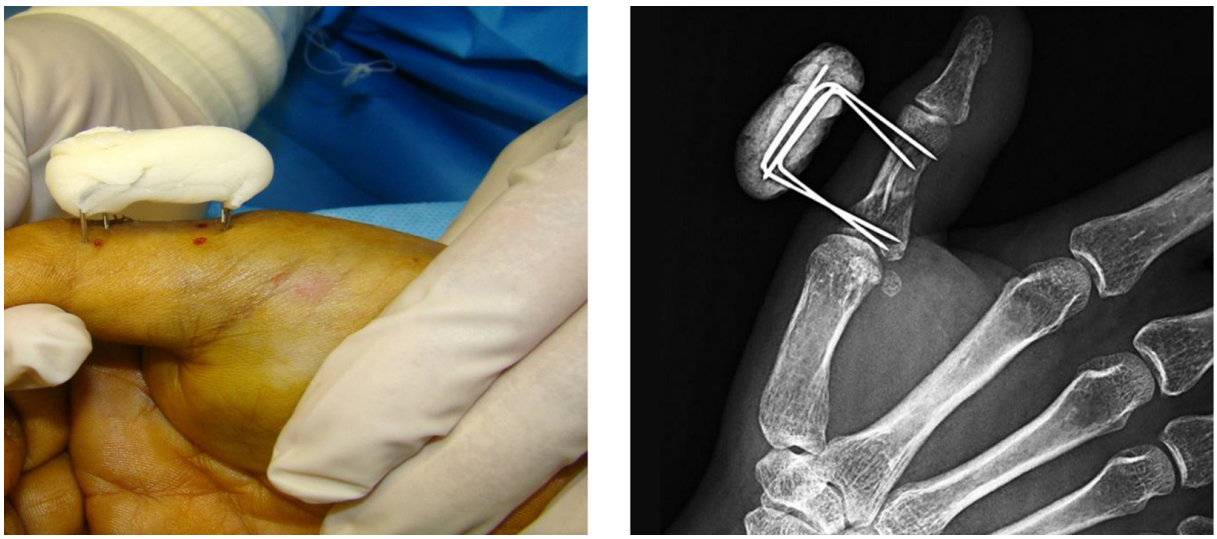

Figure 3. Wrapping of k-Wires by Cement

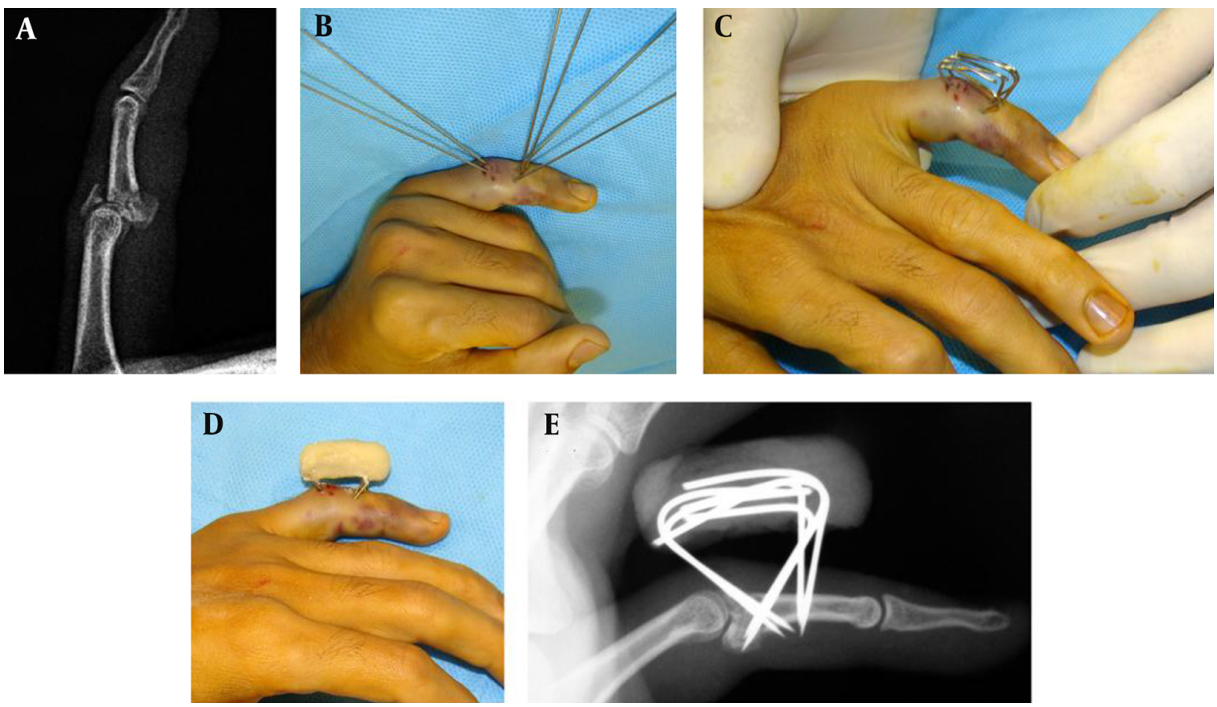

Figure 4. Our Preferred Technique for Comminuted Phalangeal Base Fractures

Many commercial and handmade external fixators have been proposed for hand surgery.

Commercial fixators are costly and often not available in emergent situations. Moreover, their application is technique demanding and cause obstacles to plain x-rays due to radio opacity.

To overcome these insufficiencies, the surgeons improvised handmade external fixators. The technique of external fixation, by Kirshner-wires incorporated to resin was first described by Crockett (5) in 1974, and was followed

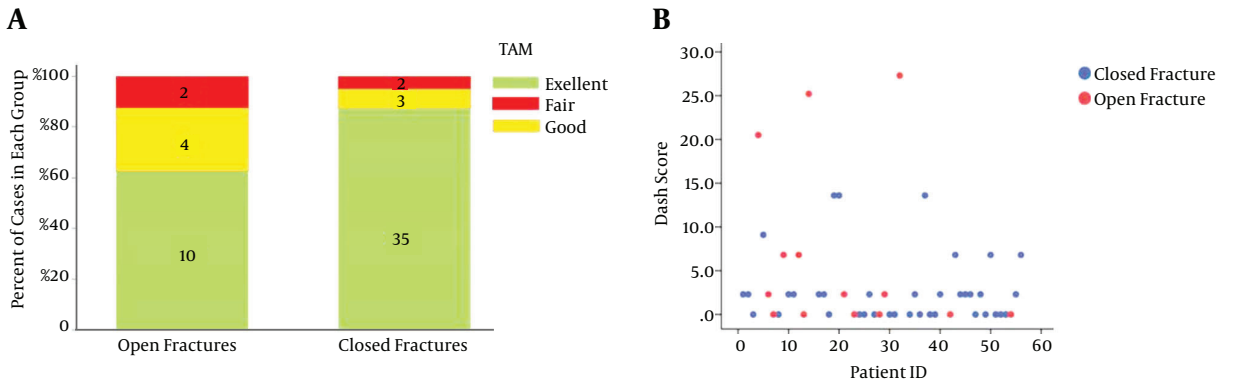

Figure 5. A, Total Active Movement in Closed Fractures vs. Open Fractures; B, Dash Score in Open vs. Closed Fractures

by Dickson (10) in 1975. McCauley and Hasting (6) used an intravenous cannula as a crossbar to hold the k-wires. However, the length of cannula was inadequate and often slipped over pins, adhering to the skin and losing stability.

Generally these fixators, which were constructed by multiple Kirshner-wires, crossed a plastic tube and then through fracture fragments (11, 14, 18-20). Sometimes, for better Incorporation of the pins, the plastic tube is filled by bone cement (7-9, 21).

Pin + plastic tube + cement construct has some technical defects as listed below:

- Passage through a plastic tube then into the body has the risk of foreign body Incorporation.
- After pinning if reduction is unacceptable, Kirshner wires should be extracted and reinserted, meaning that the technique necessitates two skilled persons, one for maintaining final reduction and the other for pinning.
- When large plastic tubes like cement gun (7, 21), or a plastic Kirshner wire storage tube (8) or anesthetic tube (9) are filled by cement, they become heavy and cumbersome.
- Because of short contact area, there is a possibility for pin loosening or slippage (6, 8, 11, 14).

Constructs that have been made only by pin and cement (13, 22) have been reported, but the probability of loosening increases due to the minimum contact area.

The technique of wrapping bent Kirshner wires by Methyl methacrylate for fracture fixation has the following advantages:

- Construction is simple and fast and requires only basic orthopedic expertise.
- All materials are readily available in most operating rooms.
- No need for plastic tubes like cement Gun that increases the expense.
- With a Ferro-cement structure and vast contact area between the pin and cement, reduction loss or pin-cement loosening is significantly reduced. In our study, none of the cases knocked up such complications. Thus, early active range of motion was allowed.
- The surgeon may first insert w Kirshner wires, and final reduction may be obtained later. Therefore, pin extraction and reinsertion may not be required.
- The surgeon can bend Kirshner wires to any appropriate direction to avoid adjacent finger or soft tissue insult.
- The pins can be placed in different angles, diameter and distances, which allows for a near infinite possibility of pin placement options.
- Final reduction can be obtained after pin placement. While the cement is hardening, the surgeon manipulates the fracture under fluoroscopic control. Therefore, the operation can be done alone.
- In the first 1 - 2 weeks, fine tuning and manipulation of the fracture is possible by bending Kirshner wires.
- Fixator removal is performed quite simply with a wire cutter and plier in an office setting.

Considering the ease and good results, this technique is widely used even in simple noncomminuted fractures. Moreover, this is our preferred method to treat comminuted phalangeal base fractures.

One of the weak points of this study was its case heterogeneity. Fractures with minor complexity to open comminuted intra-articular were studied together.

In the future, case control studies should be conducted to compare the outcomes of various external fixators. Until then, this technique represents one option with good outcomes and minor complications.

Footnote

Authors' Contribution: Study concept, data collection, analysis and interpretation, drafting of the manuscript

and critical revision were performed by Davod Jafari, and Ali Ajvadi.

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