

# Treatment of intra-articular phalangeal fracture of the hand by Suzuki frame external fixator.

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## Abstract

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### Purpose

This study aims to evaluate the functional, clinical and radiological outcome of treatment of fractures of proximal inter-phalangeal joints of hand by Suzuki frame external fixator technique.

### Patients and Methods

A prospective study was held in Benha university hospital including 20 patients with intraarticular PIPJ fractures treated with Suzuki frame external fixator technique. All the patients were followed up for a minimum period of 12 weeks and the maximum period of follow up was 36 weeks. Post operatively, Plain radiographs were used for assessing fracture reduction, congruity and healing. The visual analogue score (VAS) and the Michigan Hand Outcome Questionnaire (MHQ) were used for functional evaluation. PIPJ range of motion (ROM) and hand grip strength were also assessed.

### Results

The mean age of the studied patients was  $33.85 \pm 8.65$  years and there was a male predominance (75%). The left hand was affected in 12 patients (60%). The non-dominant hand was involved in 13 patients (65). The mechanisms of injury were crushing by hard object (45%), followed by falling on the ground (35%), and Sport injury (20%). The mean time from injury was  $2.05 \pm 1.88$  days. The mean time of surgery was  $17.55 \pm 3.1$  minutes. The mean time of the bony union was  $11.8 \pm 2.9$  weeks. The mean time of the frame removal was  $4.7 \pm 0.57$  weeks. At the final follow-up, all patients had no residual pain. The average PIPJ-ROM was  $86.25 \pm 9.6^\circ$ , and the average grip-strength was  $89.9 \pm 8.19\%$  as compared to the healthy side. The mean normalized MHQ score was  $86.1 \pm 11.26$  points, with 7, 10, and 3 patients had excellent, good, and fair results retrospectively. Complications included pin tract infection (three cases), stiffness (one case), aseptic loosening and osteolysis at head of proximal phalanx (one case), and flexion contractures (one case).

### Conclusion

The pins and rubber traction frame technique is simple, reliable, available, reproducible, time-saving and cost-effective for managing complex PIPJ fractures while allowing early joint mobilization, which proven effective in achieving high satisfactory functional results.

### Keywords

Proximal Interphalangeal Joint, Fracture, Dislocation, Dynamic Fixation, Frame.

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## Introduction

Fractures and dislocations involving the proximal interphalangeal joint (PIP) are common injuries.<sup>(1)</sup> The PIP joint plays a crucial role in the function of the hand.<sup>(2,3)</sup> In comparison with other hand joints, the PIPJ has the greatest arc of motion and is responsible for up to 85% of the total encompassment during grasp.<sup>(4)</sup> The PIP joint is a simple hinge joint, its stability is provided by the articular congruency and soft tissue supports. Soft tissue stability is provided by collateral ligaments, volar plate, joint capsule, dorsal expansion, and extensor tendon as well as the flexor tendons.<sup>(5)</sup> The spectrum of injury varies from minor strains to complex intraarticular fractures. Often, the severity of injury is underestimated by the patient, especially "jammed finger" injuries that do not lead to gross deformity or angulation.<sup>(6)</sup> Inadequate treatment and late diagnosis may lead to prolonged disability, pain and stiffness.<sup>(7)</sup> Various treatment options have been described including extension block splinting or pinning, open reduction and internal fixation (ORIF), hemi-hamate arthroplasty, volar plate arthroplasty, traction and force couple splinting.<sup>(8)</sup> Maintenance of satisfactory alignment of the fracture and acceptable congruent joint surface, while allowing early joint motion would seem to be an ideal treatment option.<sup>(9)</sup> The use of a dynamic traction device allows both early mobilization and reduction of fracture fragments (even if subtotal) by the process called capsuloligamentotaxis<sup>(10)</sup> early

mobilization of a damaged joint is likely to promote osteochondral remodeling and reduce the formation of intra- and periarticular adhesions, reducing the incidence of stiffness and late joint contracture. In addition "traction" capsuloligamentotaxis also prevents collapse of fracture fragments and contractures of the collateral ligaments and volar plate, thus further reducing the risk of joint stiffness.<sup>(11)</sup>

## Patients and Methods

A prospective study was held in Benha university hospital including 20 patients with intraarticular PIPJ fractures treated with Suzuki frame external fixator technique. A written consent was obtained and the patients were informed about the surgical procedure. All the patients were followed up for a minimum period of 12 weeks and the maximum period of follow up was 36 weeks. Post operatively, these patients were assessed clinically by The visual analogue score (VAS) and the Michigan Hand Outcome Questionnaire (MHQ) were used for functional evaluation. PIPJ range of motion (ROM) and hand grip strength were also assessed. Fracture union was confirmed radiologically. There were 15 men and 5 women with a mean age of  $33.85 \pm 8.65$  years. Patient's demographics and fracture characteristics are shown in (Table1). Inclusion criteria include recent fracture dislocation and comminuted fractures of proximal inter-

phalangeal joints. All patients included in this study were co-operative and skeletally mature. Exclusion criteria include chronic Injury, significant preexisting arthritis, segmental digital injuries compromising the phalangeal head and simultaneous need for reconstructive soft-tissue coverage.

### Preoperative Assessment

A complete assessment including history and physical examination was performed in all patients. Patient history included identifying the mechanism of injury. Local examination included Careful inspection of the skin and soft tissue as wounds or lacerations, localized swelling and ecchymosis over PIP joint and Neurovascular examination. Motor function was also checked in the finger flexors and extensors. Plain X- ray (PA, oblique, and lateral) of the affected digit or hand should be obtained (fig.1). Lateral views were key for the diagnosis of a subtle subluxation of the PIP joint (V sign). Computed tomography (CT) scans may be used for evaluation of fracture comminution.

**Table.1.** Patients demographics and fracture characteristics of 20 cases in this study

<b>Age (year)</b>	33.85±8.65
<b>Gender</b>	
Male	15 (75%)
Female	5 (25%)
<b>Occupation</b>	
Manual worker	10 (50%)
Farmer	3 (15%)
Housewife	5 (25%)
Student	2 (10%)
<b>Mechanism of injury</b>	
crushing by a hard object	9 (45%)
falling on the ground	7 (35%)
Sport injury	4 (20%)
<b>Fracture type</b>	
Volar lip	7 (35%)
Dorsal lip	4 (20%)
Pilon	9 (45%)
<b>Affected finger</b>	
Little	6 (30%)
Ring	9 (45%)
Middle	3 (15%)
Index	2 (10%)
<b>Affected side</b>	
Dominant	7 (35%)
Non-dominant	13 (65%)
<b>Co-morbidity</b>	
Diabetes Mellitus	2 (10%)
Hypertension	3 (15%)
Smoking	5 (25%)

### Operative technique

The technique used for the application of the Suzuki frame was exactly as described by Suzuki et al<sup>(12)</sup> in their original paper.

All patients received preoperative antibiotic prophylaxis within 30 minutes before the beginning of the procedure. All patients were operated upon under digital block anesthesia with the use of an image intensifier after confirming adequate digital vascularity. The first 1.2 mm K-wire was inserted percutaneously and placed through the center of rotation of the head of proximal phalanx in the sagittal plane and parallel to the joint in the coronal

plane without violating the joint capsule (fig.2). The second 1 mm K-wire was drilled perpendicular to the center of rotation of middle phalangeal head (fig.3). On both sides of the finger, the proximal wire is bent 90° near the skin in the direction of the fingertip. Each end of the wire must be long enough to reach distal to the fingertip, and is bent as a hook. Each end of the second K-wire was also bent around the first wire external to the skin. In some cases to correct any dislocation and maintain axis of traction, a third K-wire named the “reduction pin” was inserted near the base of middle phalanx in addition to the original traction system. The 2 ends of this short pin are bent upwards so that this pin lies underneath the limbs of the axial traction pin, producing a palmar-directed force on the displaced fragment. Rubber bands were applied between the hooks of these wires on both sides of the finger and the reduction is checked radiographically (fig.4). The strength of the elastic traction can be adjusted by the thickness and a number of the elastic bands used. Intraoperatively, after the rubber bands are placed, the patient is asked to flex and extend the digit under fluoroscopic guidance. The PIP joint is examined for congruency throughout the arc of motion.

### Postoperative protocol

In all cases, the hand was elevated to minimize the edema and thus diminishing the postoperative pain.

A four-seven days course of a broad spectrum oral antibiotic along with an analgesic and anti-edematous medications were prescribed. Early ROM was encouraged to be started as tolerated by the patients.

Postoperative x-rays were done for all patients before discharge. All patients were discharged in the same day of the surgery. Pin sites should be kept clean with daily swabs of alcohol.

### Follow up program

All patients were followed up at Benha university hospital outpatient clinic at weekly intervals till removal of the frame, and then every 2 weeks till union, and at a monthly-basis thereafter till the last visit. Serial x-ray radiographs (A-P, oblique and lateral views) were obtained at each visit to ensure PIPJ reduction, congruency, and fracture healing. The frame was left for 4–6 weeks after surgery. Functionally, patients were assessed as regard to: (1) pain using visual analogue scale (VAS). (2) ROM of PIPJ using goniometer. (3) Grip-strength was measured and compared to the contralateral healthy side by dynamometer. (4) Final functional results according to the Michigan Hand Outcome Questionnaire (MHQ).<sup>(13)</sup> In this study, MHQ results were graded as: excellent (91–100 points), good (66–90), fair (51–65 points), or poor (< 50 points) (fig.5).

### Results

The mean operative time of the procedure was 17.55±3.1 minutes. The mean follow-up period was 20 ± 5.5 weeks. The mean time of the frame removal was 4.7±0.57 weeks. The mean time from injury was 2.05±1.88 days. The results are summarized in (Table 2). Radiologically, all fractures achieved solid union with a mean time to solid fusion of 11.8 ± 2.9 weeks without any residual instability.

Regarding the functional results, the mean normalized MHQ score was 86.1 ± 11.26 points, the mean ROM of PIPJ was 86.25 ± 9.6°, the mean DIP joint ROM was 72.5 ± 8.19° and

the average grip-strength compared to the healthy side was  $89.9 \pm 10.5\%$ . According to MHQ, there were 7 patients (35%) who ended up with excellent results, 10 patients (50%) with good results, and 3 patients (15%) with fair results. All patients returned to previous work and recreational activities without disability after a mean of  $5.9 \pm 1.9$  weeks. Significant differences were noted regarding Surgery lag ( $P = 0.044$ ), Time to ROM start postoperatively ( $P = 0.013$ ) and pain score ( $P = 0.017$ ) (Table.3), however, other patient- and fracture-characteristics had no significant effect ( $P > 0.05$ ) on the functional end results. In addition, in this study, there were five smokers. Three of them had unsatisfactory surgical outcome. Studying the relation between smoking and the surgical outcome showed to be statistically significant ( $P$  value =0.009) (table.4). Six patients (30%) manifested with complications during their follow up period. Pin tract infection was noticed in three patients which was superficial in two of them managed with oral antibiotics and local antiseptic care while it occurred four weeks postoperatively in the third case and managed by removal of the fixator, local debridement and oral antibiotics. Stiffness was encountered in one patient. Flexion contracture about 20 degrees was encountered in one patient. A septic loosening and Osteolysis was encountered in one patient at the head of proximal phalanx at the fourth week, which was managed with frame removal.

## Discussion

The treatment goals for intra-articular PIP joint fractures are to restore anatomic alignment of the joint and to allow early active movement to avoid stiffness.<sup>(14,15)</sup> Various treatment options have been described including extension block splinting ,or pinning, open reduction and internal fixation (ORIF), hemi-hamate arthroplasty , volar plate arthroplasty , traction and force couple splinting.<sup>(8)</sup> Stern et al<sup>(14)</sup> performed a comparative analysis of three different forms of treatment: splintage, internal fixation and external dynamic fixation. With an average follow-up of 1 year, the best results were achieved with traction using an external dynamic fixator. In the internal fixation group, 75% of the patients achieved a satisfactory outcome with a comparable range of motion, but 25% of the patients in this group required PIPJ arthrodesis due to complications, including infection and loss of reduction. Extension blocking splintage produced the least successful results, with some degree of pain in all cases and the highest incidence of degenerative arthritis and restricted joint motion. It is important to note that, irrespective of the type of treatment, the final range of motion at the distal interphalangeal joint was reduced. However, this was least affected in the external fixation group. As regard to Salter et al,<sup>(16)</sup> the problem is two-fold: firstly, the PIPJ fracture fragments are too small to be reconstituted anatomically with open procedures. Secondly, the fibroblastic reaction around the PIPJ leads to long-term stiffness unless joint motion is maintained throughout the healing period. Freiberg et al<sup>(17)</sup> stated that In general, when dealing with finger fractures and dislocations, one must always remember that for every case of delayed or non healing fracture, there are at least 100 permanently stiff fingers. All dynamic external fixators share fundamental properties. First, they provide distraction across the PIP joint, which takes load off the articular cartilage, thereby allowing it to heal without a displacement force. Second, traction across the joint and soft tissues can reduce fracture

fragments via the principle of ligamentotaxis. Third, many but not all dynamic external fixators link traction with a volar-directed force on the middle phalanx, which ensures that the PIP joint is held in its reduced position. Fourth, early active and passive ROM allowed by these fixators prevents contractures or adhesions of the collateral ligaments, volar plate, and extensor and flexor tendons. Continuous passive motion in and of itself has proven to affect cartilage healing by supplying nutrients to and removing waste products from the joint. Finally, with dynamic external fixators one can avoid the trauma of extensive open surgery, which may exacerbate stiffness and not accomplish the goal of stable reduction of the fracture fragments. This is true especially when significant comminution is present.<sup>(3)</sup> Schenck<sup>(18)</sup> used a dynamic circular frame, which allowed passive finger flexion and extension at regular intervals. This device was large and cumbersome and was worn for at least 7 weeks. Inanami<sup>(19)</sup> used smaller fixators using springs and pulleys which were often difficult to construct. In This study we used the Suzuki frame dynamic fixator in treatment of complex, comminuted and unstable PIPJ fractures in 20 patients with some modifications in form of bending of the distal



Fig.(1): plain xray hand: PA, oblique and lateral views showing intra-articular fracture of the middle phalanx base of the little finger.

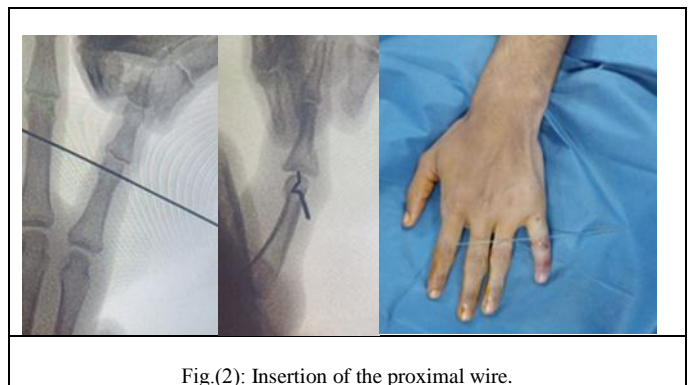


Fig.(2): Insertion of the proximal wire.

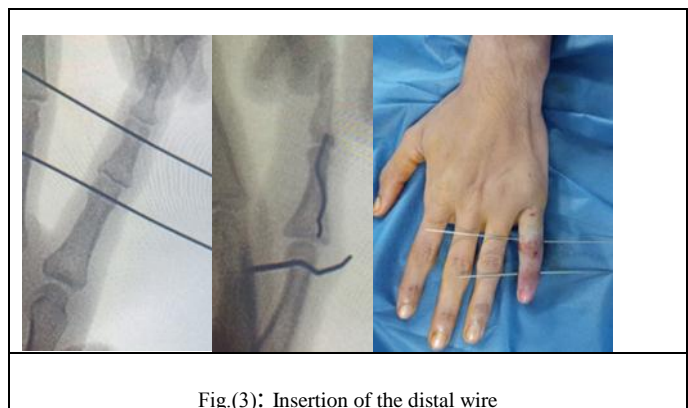


Fig.(3): Insertion of the distal wire

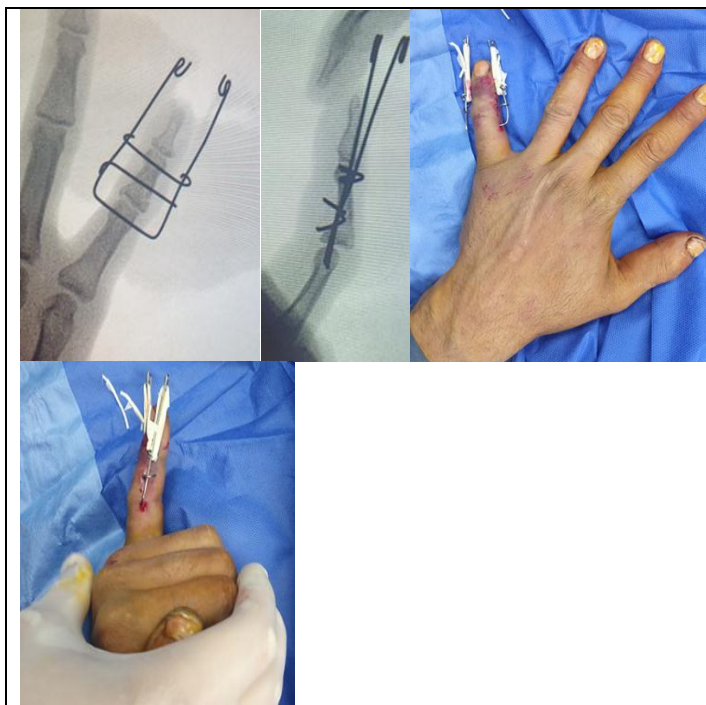


Fig.(4): After rubber bands applied between the hooks of wires.



Fig.(5):Xray hand(P.A and lateral) and clinical photos follow up (10weeks post-operative) Showing stable united fracture of middle phalanx base after removal of the frame.

k-wire around the proximal k-wire giving the advantage of stability and parallelism of the proximal wire to the long axis of middle phalanx. This makes the traction in line with the long axis of middle phalanx bone which results in more easily, maintained and acceptable fracture reduction. Results were denoted to be satisfactory in 17 (85%) patients and unsatisfactory in 3 patients (15%). There was a statistically significant relation between surgery lag and net results. However, Kanthan et al<sup>(20)</sup> found that there was no significant correlation between surgery lag and the AROM of the PIPJ. Moreover, Inability to start early postoperative range of motion negatively impacted the final end result, which was essentially attributed to either massive edema or intractable pain, and there was a statistically significant relation between postoperative early range of motion (ROM) and the net results. Patients' compliance greatly influenced the final end results to the degree that Abou Elatta et al<sup>(21)</sup> who used dynamic traction devices excluded incompliant patients from their study. Smoking as well could have attributed to those poor results being a common factor in all patients who have ended in unsatisfactory results. such correlation was found to be statistically significant. Regarding the demographic distribution of the patients; The mean age in our study was 33.85, ranged from 18-50 years. The male to female ratio in our study was 3:1. While in Finsen et al,<sup>(22)</sup> median age was 54 (18-77) years and the male to female ratio in our study was 2:1. In this study there was statistically insignificant relation between age, gender and net results as predicted. Male predominance could be explained by the fact that most of them were manual worker with high susceptibility to hand trauma. The device was left in situ for an average of 4.7 weeks while in Finsen et al, the traction was removed after a median of 38 days .The mean follow up period was 20 weeks(ranged 12-36 weeks), which was short period as compared to median follow up in Finsen et al,<sup>(22)</sup> which was 49 months. Regarding functional results; mean normalized MHQ score was 86.1(ranged from 63-100 %), mean PIPJ active range of motion (AROM) was 86.25 degrees, mean DIP AROM was 72.5 degrees and the average grip strength compared to the healthy side was 89.9%. These results were comparable to

Finsen et al<sup>(22)</sup> where The median Quick DASH score was 2 (0-48), while median PIP AROM, median DIP AROM and median grip strength were 72, 53 and 97% respectively. All patients returned to their previous jobs, but all had experienced difficulty in carrying out activities of daily living while the fixator was applied, Patients returned to work after a mean of 5.9 weeks. In 2007 Keramidas et al,<sup>(11)</sup> published their results over 11 patients treated by the Suzuki frame external fixator technique with mean follow up of 18 months. The average AROM of the PIPJ was 84 degrees (from 50-105 degrees). There were two cases of infection that were treated successfully with oral antibiotics, without removal of the frame. The frame failed in one patient who had sustained a comminuted fracture. This patient developed a fixed flexion deformity and pain. Treated by arthrodesis of the PIP joint one year postoperatively. Five of our patients developed radiographic evidence of osteoarthritis but with no pain. In 2010 Finsen et al,<sup>(22)</sup> reviewed 18 patients with fractures of the base of the middle phalanx treated with the Suzuki frame external fixator technique. In most cases a thick "vessel loop" instead of rubber bands was used to achieve traction. There were two superficial infections and one deep. One proximal interphalangeal (PIP) joint had been treated by arthrodesis and another amputated before review. In 2021 Turgut<sup>(23)</sup> made a retrospective study over eight patients (five males and three females) with fracture dislocations of the PIP joint treated by the Suzuki frame external fixator technique with mean follow up of 14.88 months. The mean age of the patients was 28.50 ± 3.42 (range: 24-34) years. The mean time between trauma and surgery was 3.88 ± 2.29 (range: 1-7) days. The mean range of motion of the PIP joint of patients was 4.88° to 86.25° (range: 0-10° and 80-90°), the mean range of motion of the DIP joint of the patients was 4.38° to 86.25° (range: 0-15° and 70-100°). Complications developed moderate pain in two patients (25%), limitation of movement in the DIP and PIP joints in two (25%) patients, and pin-track infection in one (12.5%) of them. In 2004 Deshmukh et al,<sup>(24)</sup> reviewed 13 patients with a complex fracture-dislocation of the proximal interphalangeal joint of a finger and one patient with a complex fracture-dislocation of the interphalangeal joint of thumb treated with a

**Table.2:** Surgical results in the studied patients.

<i>Surgical outcomes</i>		
<b>PIPJ AROM (degree)</b>	Mean ±SD Range	86.25 ± 9.6 60 – 100
<b>DIPJ AROM (degree)</b>	Mean ±SD Range	72.5 ± 8.19 50 – 80
<b>Grip strength (%)</b>	Mean ±SD Range	89.9 ± 10.5 60 – 100
<b>Time off work (weeks)</b>	Mean ±SD Range	5.9 ± 1,9 4 – 12
<b>Complications</b>	N (%)	6 (30%)
<b>Pin tract infection</b>	N (%)	3 (15%)
<b>Stiffness</b>	N (%)	1 (5%)
<b>Flexion contracture</b>	N (%)	1 (5%)
<b>Aspetic loosening and osteolysis</b>	N (%)	1(5%)

**Table.3:** Surgery lag, Time to ROM start postoperatively, pain score and surgical outcome.

		satisfactory (n = 17)	unsatisfactory (n = 3)	P-value
<b>Surgery lag (days)</b>	Mean ±SD	1.59 ± 1.37	4.67 ± 2.52	0.044*
	Range	(0 -5)	(2 - 7)	
<b>Time to ROM start (days)</b>	Mean ±SD	1.17± 0.39	3.33± 3.21	0.013*
	Range	(0 - 2)	(2 - 7)	
<b>Pain score</b>	Median (range)	1 (0 - 3)	4 (2 -5)	0.017*
	Mean ±SD	0.94±1.02	3.66±1.53	

**Table.4:** Correlation between patients' smoking and surgical outcome.

	Satisfactory Number of frequency (%)	Unsatisfactory Number of frequency (%)	P Value
<b>Smokers</b>	2 (12%)	3(100%)	0.009* Calculated by Fisher Exact
<b>Nonsmokers</b>	15 (88%)	0 (0%)	

joint of a finger and one patient with a complex fracture-dislocation of the interphalangeal joint of thumb treated with a modified PRTS of Suzuki et al<sup>(12)</sup> with average follow up of 34 months. The results were an average AROM of the PIPJ of 85°, an average grip strength of 92%, and a mean normalized MHQ of 84%. Two patients developed a minor pin-tract infection which did not require removal of the wire only treated with oral antibiotics. Two developed mild cold intolerance. Two fractures united in 10° of valgus and one in 10° of hyperextension. In 2008 Ruland et al,<sup>(8)</sup> published their results over 34 patients treated by modified PRTS with average follow up 16 months (range from 6-84 months). The final arc of motion at the PIP joint averaged 88°, and the average DIP joint arc of motion was 60°. Eight patients experienced superficial pin-tract infections that were easily controlled with oral antibiotics. There were no cases of septic arthritis or osteomyelitis requiring intravenous antibiotics or premature fixator removal. Loss of reduction did not occur. All patients returned to their prior level of activity and duties.

In 2016 Fouad et al,<sup>(9)</sup> published their results over 22 patients treated by modified PRTS of Suzuki et al,<sup>(12)</sup> with average

follow up 8 months (range from 6-9 months).Its modifications were the use of tension band wire instead of rubber bands and the bending of sliding traction pin around the axial traction pin. The average time from injury to surgery was 5 days (range from 2-21 days). The average AROM of the PIPJ was 93 degrees (from 50-120 degrees) and a mean normalized MHQ was 88 at an average follow up of 8 months. Five patients developed pin tract infection without wire loosening resolved with oral antibiotics. One patient developed osteomyelitis treated with fixator removal, surgical debridement and antibiotics. Aseptic loosening of the wires and osteolysis in the head of proximal phalanx occurred in one patient that treated with fixator removal. Twenty patients returned to previous work without disability and the other two patients changed their work because of pain with PIP flexion more than 50 degrees. In a biomechanical study using cadaveric hands, Kneser et al<sup>(25)</sup> showed that with the presence of a pins and rubber bands traction system, the force required for flexion of the PIPJ was significantly increased in different positions of flexion (30, 60 and 90 degrees). In addition, it was also shown that the position of the third wire placed at the middle phalanx base to provide a volar directed force also influences the force required for finger flexion. A more proximal position of the wire, while producing an increased volar directed force, increases the force needed for PIPJ flexion. These factors explain the difficulty that a patient may face post-operatively when attempting to mobilize the finger. If reduction is maintained without the third K wire at the middle phalanx base, omitting this wire may allow the patient to mobilize more easily.

Regarding the complications; stiffness was encountered in one patient. Flexion contracture was encountered in one patient. Flexion contracture was 25 degrees in this patient while this complication was encountered in two patients in Naguib et al<sup>(26)</sup> 20 degrees in one patient and 40 degrees in other patient. Hynes and Giddins<sup>(27)</sup> had a mean fixed flexion deformity of the PIPJ of the fingers of 12 degrees (range, 0–35), that did not affect the net results Reports have shown that patients can tolerate 15–20° flexion contractures without functional deficit and their incidence does not significantly differ across techniques.<sup>(28)</sup> Aspetic loosening and osteolysis occurred in one case That occurred at the fourth week in head of proximal phalanx around the proximal wire where osteolysis wasn't evident in the previous follow ups; however it was treated with removal of the frame. The patient ended up with satisfactory end result. This complication was reported in one case in Fouad et al<sup>(9)</sup>. Pin tract infection was superficial in two patients managed conservatively with antibiotic ended with satisfactory results and severe in one patient treated with frame removal and debridement ended with unsatisfactory results. This result was similar to Finsen et al<sup>(22)</sup>. Other authors have also reported a high incidence of pin track sepsis around the proximal wire which can lead to serious complications.<sup>(29)</sup>

Syed et al<sup>(29)</sup> suggested that high rates of pin site infection may occur for three reasons. Firstly, the use of straight K-wires will result in static longitudinal traction and any active or passive motion will result in rotation of the wire at the proximal bone/wire interface, rather than the wire coupling, leading to loosening and sepsis. This was demonstrated by Allison,<sup>(30)</sup> who used a dynamic fixator made of stainless-steel spring wire with windings hooked around 2 K-wires. None of their patients developed any pin site infections. The reason for this could be that, during finger motion, the spring moved independently and did not interfere with the proximal and the distal wire–bone interfaces. The second reason for high

infection rates in the previous series may be that the cancellous bone of the proximal phalangeal metaphysis is not strong enough to resist the torque generated at the bone–wire interface. This again leads to wire loosening and sepsis.<sup>(25)</sup> The third reason why other studies may have experienced high infection rates is that the fixator was unnecessarily retained for up to 6 weeks: this may increase the risk of pin site infection. With these points in mind, the design of our fixator was used and the duration of fixation was shortened. It is possible that loosening and infection may be reduced by adopting the modification of Deshmukh et al.<sup>(24)</sup> They recommended cutting the most proximal pin short and not bending it distally, leaving it as a transverse bar through the phalangeal head. An additional pin is bent into a long U-shape, which passes beyond the tip of the finger and to which the rubber bands are attached. This pin hinges around the proximal transverse pin making it unnecessary for the latter to rotate in the bone.

The limitations of this study were that it was a non-randomized prospective study which included a relatively small number of patients, without a control series of patients treated with a different method. There was an unequal demographic distribution of patients with a relatively short follow-up period. Long-term follow up will be required to identify whether patients develop post-traumatic arthritis within their joints.

## Conclusion

We believed that the Suzuki frame external fixator uses the principles of capsuloligamentotaxis and early mobilization to achieve articular realignment and healing and has given very acceptable results with a low rate of complications. It is light, cheap, effective and easy to apply with capability of readjustment with local anesthesia. Regular physiotherapy or occupational therapy supervision postoperatively is required to optimize the results and to identify and treat early problems such as joint contractures or infections.

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