Treatment of intra-articular phalangeal fractures of the hand by Suzuki frame external fixator

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Purpose
This study aims to evaluate the functional, clinical, and radiological outcome of treatment of fractures of proximal interphalangeal joints of the hand by the Suzuki frame external fixator technique.
Patients and methods
A prospective study was held in Benha University Hospital that included 20 patients with intra-articular proximal interphalangeal joint (PIPJ) fractures treated with the Suzuki frame external fixator technique. All of the patients were followed up for a minimum period of 12 weeks, and the maximum period of follow-up was 36 weeks. Postoperatively, plain radiographs were used for assessing fracture reduction, congruity, and healing. The visual analog score and the Michigan Hand Outcome Questionnaire were used for functional evaluation. PIPJ range of motion and hand grip strength were also assessed.
Results
The mean age of the studied patients was 33.85±8.65 years, and there was a male predominance (75%). The left hand was affected in 12 (60%) patients. The nondominant hand was involved in 13 (65%) patients. The mechanisms of injury were crushing by hard object (45%), followed by falling on the ground (35%), and sports injury (20%). The mean time from injury was 2.05±1.88 days. The mean time of surgery was 17.55±3.1 min. The mean time of the bony union was 11.8±2.9 weeks. The mean time of the frame removal was 4.7±0.57 weeks. At the final follow-up, all patients had no residual pain. The average PIPJ-range of motion was 86.25±9.6°, and the average grip strength was 89.9±8.19% as compared with the healthy side. The mean normalized Michigan Hand Outcome Questionnaire score was 86.1±11.26 points, with seven, 10, and three patients having excellent, good, and fair results, respectively. 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 is proven to be effective in achieving high satisfactory functional results.

Keywords:
dislocation, dynamic fixation, fracture, frame, proximal interphalangeal joint

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Introduction

Fractures and dislocations involving the proximal interphalangeal joint (PIP) are common injuries [1]. The PIP joint plays a crucial role in the function of the hand [2,3]. In comparison with other hand joints, the proximal interphalangeal joint (PIPJ) has the greatest arc of motion and is responsible for up to 85% of the total encompassment during grasp [4]. 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 [5]. The spectrum of injury varies from minor strains to complex intra-articular fractures. Often, the severity of injury is underestimated by the patient, especially 'jammed finger' injuries that do not lead to gross deformity or angulation [6]. Inadequate treatment and late diagnosis may lead to prolonged disability, pain, and stiffness [7]. Various treatment options have been described, including extension block splinting or pinning, open reduction and internal fixation, hemi-hamate arthroplasty, volar plate arthroplasty, traction, and force couple splinting [8]. 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 [9]. The use of a dynamic traction device allows both early mobilization and reduction of fracture fragments (even if subtotal) by the process called capsuloligamentotaxis [10]. Early mobilization of a damaged joint is likely to promote osteochondral remodeling and reduce the formation of intra-articular 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 [11].

Patients and methods

A prospective study was held in Benha University Hospital including 20 patients with intra-articular PIPJ fractures treated with the Suzuki frame external fixator technique. A written consent was obtained, and the patients were informed about the surgical procedure. All of the patients were followed up for a minimum period of 12 weeks, and the maximum period of follow-up was 36 weeks. Postoperatively, these patients were assessed clinically by the visual analog score and the Michigan Hand Outcome Questionnaire (MHQ) 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 five women, with a mean age of 33.85 ± 8.65 years. Patients' demographics and fracture characteristics are shown in Table 1. Inclusion criteria were recent fracture dislocation and comminuted fractures of PIP joints. All patients included in this study were co-operative and skeletally mature. Exclusion criteria included chronic injury, significant preexisting arthritis, segmental digital injuries compromising the phalangeal head, and simultaneous need for reconstructive soft-tissue coverage. The study was approved by the institutional ethics committee in the Orthopedic Department of Orthopedic Surgery, Benha University, Egypt.

Preoperative assessment

A complete assessment including history and physical examination was performed for 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 radiograph (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 scans may be used for evaluation of fracture comminution.

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

Age (year)	33.85 ± 8.65
Sex [*n* (%)]	
Male	15 (75)
Female	5 (25)
Occupation [*n* (%)]	
Manual worker	10 (50)
Farmer	3 (15)
Housewife	5 (25)
Student	2 (10)
Mechanism of injury [*n* (%)]	
Crushing by a hard object	9 (45)
Falling on the ground	7 (35)
Sport injury	4 (20)
Fracture type [*n* (%)]	
Volar lip	7 (35)
Dorsal lip	4 (20)
Pilon	9 (45)
Affected finger [*n* (%)]	
Little	6 (30)
Ring	9 (45)
Middle	3 (15)
Index	2 (10)
Affected side [*n* (%)]	
Dominant	7 (35)
Nondominant	13 (65)
Comorbidity [*n* (%)]	
Diabetes mellitus	2 (10)
Hypertension	3 (15)
Smoking	5 (25)

Operative technique

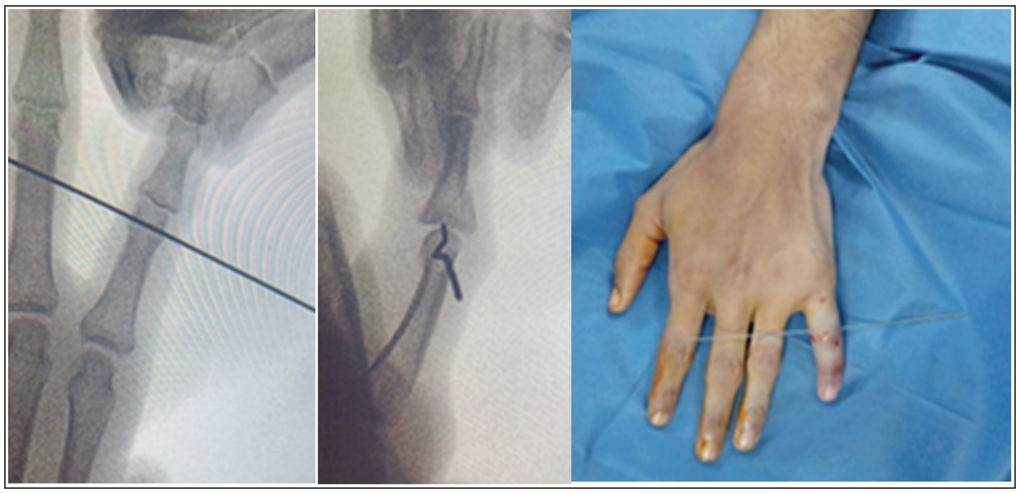
The technique used for the application of the Suzuki frame was exactly as described by Suzuki *et al.* [12] in their original paper.

All patients received preoperative antibiotic prophylaxis within 30 min 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 two ends of this short pin are bent upward so that this

Figure 1

Plain radiograph hand: PA, oblique and lateral views showing intra-articular fracture of the middle phalanx base of the little finger.

Figure 2



Insertion of the proximal wire.

pin lies underneath the limbs of the axial traction pin, producing a palmar-directed force on the displaced fragment (Fig. 4). Rubber bands were applied between the hooks of these wires on both sides of the finger, and the reduction is checked radiographically (Fig. 5). The strength of the elastic traction can be adjusted by the thickness and the number of 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.

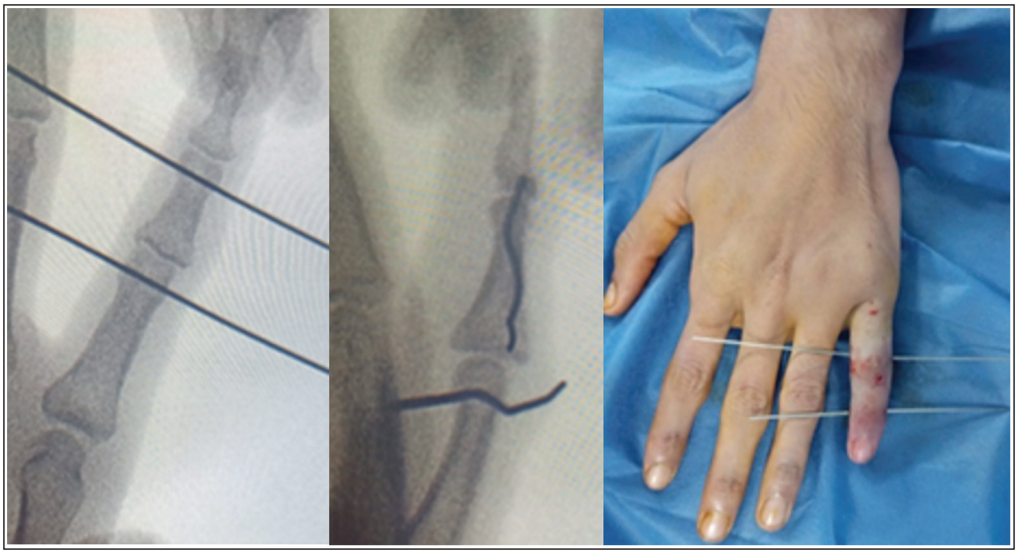
A 4–7-day course of a broad-spectrum oral antibiotic along with an analgesic and anti-edematous medications was prescribed. Early ROM was encouraged to be started as tolerated by the patients.

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

Follow-up program

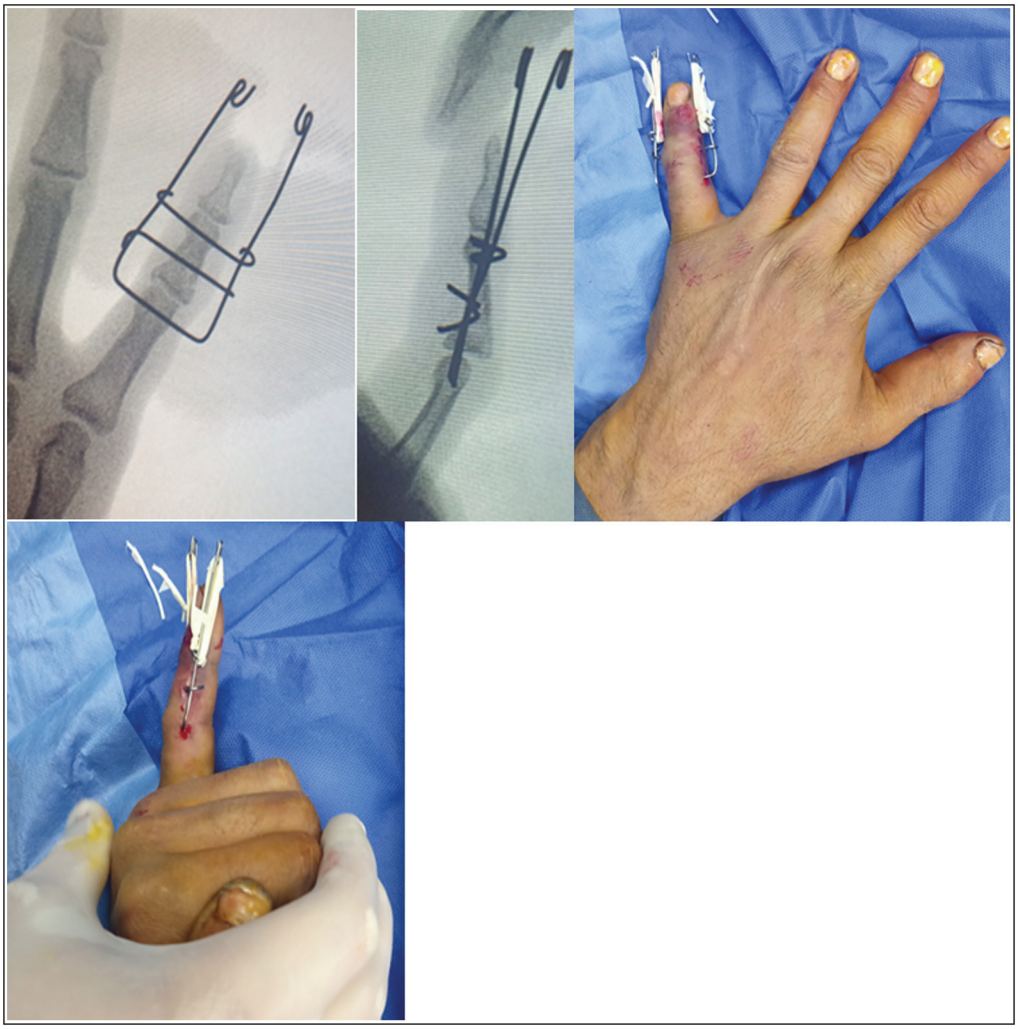
All patients were followed up at Benha University Hospital outpatient clinic at weekly intervals till removal of the frame, then every 2 weeks till union, and on a monthly basis thereafter till the last visit. Serial radiograph (AP, oblique, and lateral views) were obtained at each visit to ensure PIPJ reduction, congruency, and fracture healing. The frame was left for 4–6 weeks after surgery. Functionally, patients were assessed regarding the following: (a) pain using visual

Figure 3



Insertion of the distal wire.

Figure 4



After rubber bands applied between the hooks of wires.

Figure 5

Radiograph hand (PA and lateral) and clinical photograph at follow-up (10 weeks postoperatively) showing stable united fracture of middle phalanx base after removal of the frame.

analog score, (b) ROM of PIPJ using goniometer, (c) grip strength was measured and compared to the contralateral healthy side by a dynamometer, and (d) final functional results according to the MHQ [13]. In this study, MHQ results were graded as follows: excellent (91–100 points), good (66–90), fair (51–65 points), or poor (<50 points).

Results

The mean operative time of the procedure was 17.55 ± 3.1 min. 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 with the healthy side was 89.9 ± 10.5%. According to MHQ, there were seven (35%) patients who ended up with excellent results, 10 (50%) patients with good results, and three (15%) patients with fair results. All patients returned to previous work and recreational activities without disability after a mean of 5.9 ± 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. There was a statistically significant relation between smoking and the surgical outcome (P=0.009) (Table 4). Six (30%) patients manifested with complications during their follow-up period. Pin-tract infection was noticed in three patients which was superficial in two of them and was managed with oral antibiotics and local antiseptic care, whereas it occurred

Table 2 Surgical results in the studied patients

Surgical outcomes		
PIPJ AROM (deg.)	Mean±SD	86.25 ± 9.6
	Range	60–100
DIPJ AROM (deg.)	Mean±SD	72.5 ± 8.19
	Range	50–80
Grip strength (%)	Mean±SD	89.9 ± 10.5
	Range	60–100
Time off work (weeks)	Mean±SD	5.9 ± 1.9
	Range	4–12
Complications	*n* (%)	6 (30)
Pin-tract infection	*n* (%)	3 (15)
Stiffness	*n* (%)	1 (5)
Flexion contracture	*n* (%)	1 (5)
Aseptic loosening and osteolysis	*n* (%)	1 (5)

AROM, active range of motion.

Table 3: Surgery lag, time to range of motion start postoperatively, pain score and surgical outcome

	Satisfactory (*N*=17)	Unsatisfactory (*N*=3)	*P* value
Surgery lag (days)			
Mean±SD	1.59 ± 1.37	4.67 ± 2.52	0.044*
Range	0–5	2–7	
Time to ROM start (days)			
Mean±SD	1.17 ± 0.39	3.33 ± 3.21	0.013*
Range	0–2	2–7	
Pain score			
Median (range)	1 (0–3)	4 (2–5)	0.017*
Mean±SD	0.94 ± 1.02	3.66 ± 1.53	

ROM, range of motion.

*No significance.

Table 4 Correlation between patients' smoking and surgical outcome

	Satisfactory [*n* (%)]	Unsatisfactory [*n* (%)]	*P* value
Smokers	2 (12)	3 (100)	0.009*
Nonsmokers	15 (88)	0	Calculated by Fisher exact

4 weeks postoperatively in the third case and was managed by removal of the fixator, local debridement, and oral antibiotics. Stiffness was encountered in one patient. Flexion contracture of about 20° was encountered in one patient. A case of 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 [14,15]. Various treatment options have been described including extension block splinting or pinning, open reduction and internal fixation, hemi-hamate arthroplasty, volar plate arthroplasty, traction, and force couple splinting [8]. Stern *et al.* [14] 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 ROM, but 25% of the patients in this group required PIPJ arthrodesis owing 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 ROM at the distal interphalangeal joint was reduced. However, this was least affected in the external fixation group. According to Salter [16], the problem is two-fold: first, the PIPJ fracture fragments are too small to be reconstituted anatomically with open procedures, and second, the fibroblastic reaction around the PIPJ leads to long-term stiffness unless joint motion is maintained throughout the healing period. Freiberg [17] stated that in general, when dealing with finger fractures and dislocations, one must always remember that for every case of delayed or nonhealing 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 [3]. Schenk [18] 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 *et al*. [19] used smaller fixators using springs and pulleys which were often difficult to construct. In this study, we used the Suzuki frame dynamic fixator in the treatment of complex, comminuted, and unstable PIPJ fractures in 20 patients with some modifications in the form of bending of the distal 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 three (15%) patients. There was a statistically significant relation between surgery lag and net results. However, Kanthan *et al.* [20] found that there was no significant correlation between surgery lag and the active range of motion (AROM) of the PIPJ. Moreover, inability to start early postoperative ROM negatively affected 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 ROM and the net results. Patients' compliance greatly influenced the final end results to the degree that Abou Elatta *et al.* [21] who used dynamic traction devices excluded noncompliant 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 years and ranged from 18 to 50 years. The male-to-female ratio in our study was 3: 1. However, in the study by Finsen [22], median age was 54 (18–77) years and the male-to-female ratio was 2: 1. In this study, there was a statistically insignificant relation between age, sex, and net results as predicted. Male predominance could be explained by the fact that most of them were manual workers with high susceptibility

to hand trauma. The device was left in situ for an average of 4.7 weeks. However, in the study by Finsen, the traction was removed after a median of 38 days. The mean follow-up period was 20 weeks (range, 12–36 weeks), which was a short period as compared with the median follow-up in Finsen [22], which was 49 months. Regarding functional results, mean normalized MHQ score was 86.1 (range, 63–100%), mean PIPJ AROM was 86.25°, mean DIP AROM was 72.5°, and the average grip strength compared with the healthy side was 89.9%. These results were comparable to Finsen [22], where the median Quick DASH score was 2 (0–48), whereas 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*. [11] published their results on 11 patients treated by the Suzuki frame external fixator technique, with a mean follow-up of 18 months. The average AROM of the PIPJ was 84° (50–105°). 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, which was 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 [22] 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 PIP joint had been treated by arthrodesis and another amputated before review. In 2021, Turgut and Serdar [23] performed a retrospective study on eight patients (five males and three females) with fracture dislocations of the PIP joint treated by the Suzuki frame external fixator technique, with a 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 ROM of the PIP joint of patients was 4.88–86.25° (range, 0–10° and 80–90°), and the mean ROM of the DIP joint of the patients was 4.38–86.25° (range, 0–15° and 70–100°). Complications developed moderate pain in two (25%) patients, 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*. [24] reviewed 13 patients with a complex fracture-dislocation of the PIP 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.* [12] with an 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 and was treated with only 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*. [8] published their results on 34 patients treated by modified PRTS with an average follow-up 16 months (range, 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*. [9] published their results on 22 patients treated by the modified PRTS of Suzuki *et al*. [12], with an average follow-up of 8 months (range, 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, 2–21 days). The average AROM of the PIPJ was 93° (50–120°), 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 who was treated with fixator removal. A total of 20 patients returned to previous work without disability and the other two patients changed their work because of pain with PIP flexion more than 50°. In a biomechanical study using cadaveric hands, Thomas *et al.* [25] 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°). 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 postoperatively 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° in this patient, whereas this complication was encountered in two patients in Naguib *et al.* [26]: 20° in one patient and 40° in other patient. Hynes and Giddins [27] had a mean fixed flexion deformity of the PIPJ of the fingers of 12° (range, 0–35), which 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 [28]. Aseptic loosening and osteolysis occurred in one case, which occurred at the fourth week in head of proximal phalanx around the proximal wire where osteolysis was not 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.* [9]. Pin-tract infection was superficial in two patients, which was managed conservatively with antibiotic and ended with satisfactory results, and was severe in one patient, who was treated with frame removal and debridement and ended with unsatisfactory results. This result was similar to Finsen [22]. Other authors have also reported a high incidence of pin-tract sepsis around the proximal wire which can lead to serious complications [29].

Syed *et al.* [29] suggested that high rates of pin-site infection may occur for three reasons: first, 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 [30], who used a dynamic fixator made of stainless-steel spring wire with windings hooked around two 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 [25]. 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.* [24] 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 nonrandomized 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 would be required to identify whether patients develop posttraumatic 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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Nil.

Conflicts of interest

There are no conflicts of interest.

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