

Functional Outcomes of Suzuki Frame Fixation for Intra-articular Fracture of Proximal Interphalangeal Joint

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Abstract

Background: Intra-articular fractures of the proximal interphalangeal (PIP) joint are challenging due to joint incongruity, stiffness, and functional impairment. Prolonged immobilization often leads to poor outcomes. The Suzuki frame fixation, also known as the pins and rubber traction system (PRTS), is a dynamic external fixator that maintains reduction by ligamentotaxis while allowing early mobilization. **Methods:** A prospective observational study was conducted at IGM&RI, Puducherry, including 30 patients with unstable intra-articular PIP joint fractures between April 2022 and September 2022. Suzuki frame fixation was performed using percutaneous Kirschner wires and rubber bands. Early mobilization was encouraged from postoperative day one. Patients were evaluated using the Duruoz Hand Index (DHI), Visual Analog Scale (VAS) for pain, and range of motion (ROM) at 4, 8, and 12 weeks. Complications were recorded. **Results:** Of 30 patients (20 males, 10 females; mean age 32 years), 18 had PIP joint fractures, 8 DIP joint fractures, and 4 comminuted shaft fractures. Mean DHI scores improved from 60 at 4 weeks to 15 at 12 weeks. VAS decreased from 8 preoperatively to 1 at 12 weeks. Mean ROM improved from 30° at 4 weeks to 85° at 12 weeks. Minor complications included pin tract infections (4 patients) and mild stiffness (2 patients). **Conclusion:** Suzuki frame fixation is a simple, cost-effective, minimally invasive method that allows early mobilization and provides excellent functional outcomes for unstable intra-articular PIP joint fractures.

Keywords: Proximal interphalangeal joint fractures, Suzuki frame fixation, pins and rubber traction system, dynamic external fixation, hand function outcomes, Duruoz Hand Index

Introduction

Intra-articular fractures of the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints represent one of the most challenging injuries in hand surgery due to their complexity, risk of joint incongruity, and long-term implications for hand function. These fractures are frequently encountered following sports injuries, falls, crush injuries, and road traffic accidents, and are associated with significant morbidity when not managed appropriately. The functional importance of these joints in performing fine motor activities, including grasping, writing, and tool handling, makes their management clinically significant.

The epidemiology of phalangeal fractures suggests that PIP joint injuries account for nearly 40–50% of hand fractures, with a peak incidence among young adults engaged in manual occupations or contact sports. Untreated or improperly managed intra-articular fractures often result in stiffness, persistent pain, reduced grip strength, and early osteoarthritis, thereby impairing both quality of life and occupational productivity.

The management of these injuries has evolved substantially over the past several decades. Conservative techniques such as buddy strapping or splinting remain effective for stable fractures but are inadequate for unstable intra-articular injuries. Traditional surgical options include Kirschner wires, lag screws, plates, and static or dynamic external fixators. Each of these modalities has strengths and drawbacks. While rigid internal fixation may provide anatomical reduction, it often necessitates extensive surgical exposure, increasing the risk of soft tissue damage and postoperative stiffness. Similarly, Kirschner wire fixation, though minimally invasive, requires immobilization, which delays mobilization and contributes to joint stiffness.

Dynamic external fixation techniques, introduced in the late 20th century, represented a paradigm shift. Among these, the Suzuki frame fixation, first described by Suzuki et al. in 1994, gained attention for its simplicity, cost-effectiveness, and ability to permit early mobilization by employing the principle of ligamentotaxis. Unlike rigid fixation methods, this technique maintains continuous traction, allowing fragments to realign dynamically while preventing collapse of the joint surface.

Several studies from both Western and Asian countries have reported promising

outcomes with Suzuki frame fixation, citing improved range of motion, reduced pain, and quicker functional recovery. However, gaps remain in the literature regarding standardized protocols, complication rates, and long-term outcomes. In particular, there is limited prospective evidence from low- and middle-income countries where cost-effective methods are most relevant.

The present study aims to evaluate the functional outcomes of Suzuki frame fixation for unstable intra-articular fractures of the interphalangeal joints using validated tools such as the Duruoz Hand Index (DHI), Visual Analog Scale (VAS), and range of motion (ROM). By focusing on clinical recovery, complications, and patient-reported outcomes, this research seeks to contribute further evidence to the growing body of literature supporting dynamic fixation as an effective treatment modality.

Materials and methods

Study Design and Setting

This was a prospective observational study conducted at **Sri Venkateshwara Medical College and Hospital, Pondicherry, Puducherry**, between April 2022 and September 2022. The institution caters to a mixed urban and rural population, with a high volume of trauma cases, providing an ideal setting for evaluating hand fracture outcomes. Ethical approval was obtained from the Institutional Ethics Committee, and all patients provided informed consent before participation.

Inclusion and Exclusion Criteria

Patients were included if they:

- Were above 18 years of age
- Sustained intra-articular fractures of the base of the middle phalanx or head of the proximal phalanx
- Presented within four days of trauma

Patients were excluded if they had:

- Shaft fractures without joint involvement
- Compound or open fractures
- Thumb fractures
- Associated neurovascular injuries
- Injuries presenting more than four days after trauma

Sample Size

A total of **30 patients** met the inclusion criteria during the study period. Sample size was based on the patient pool available within the timeframe rather than formal statistical power calculations, given the observational nature of the study.

Preoperative Evaluation

All patients underwent clinical examination to assess swelling, deformity, and range of motion at presentation. Radiographs in anteroposterior, lateral, and oblique views were taken to confirm fracture configuration. Preoperative pain was recorded using the **Visual Analog Scale (VAS)**, and baseline hand function was documented with the **Duruoz Hand Index (DHI)**.

Surgical Technique

Under regional anesthesia, 1.2–1.5 mm Kirschner wires (K-wires) were inserted percutaneously into the proximal and distal phalanges. The wires were bent into hooks externally, and **rubber bands** were applied between them to provide continuous dynamic traction. In cases of dorsal fracture-dislocation, an additional “shrinking pin” was inserted to facilitate joint reduction. The construct worked on the principle of **ligamentotaxis**, maintaining articular congruity while permitting early joint motion.

The surgical procedure was minimally invasive, requiring no formal incision, and typically lasted **20–30 minutes**. Sterile precautions were followed to minimize the risk of infection.

Postoperative Protocol

- Patients were encouraged to begin **active range of motion exercises on postoperative day one**.
- Pin tract dressings were performed every 2–3 days, and patients were instructed in home care techniques.
- Analgesics and prophylactic antibiotics were prescribed for the first week.
- The frame was removed at **4–6 weeks**, depending on fracture consolidation.
- Physiotherapy continued for at least six weeks following device removal.

Outcome Measures

Patients were assessed at 4, 8, and 12 weeks using the following tools:

1. **Duruoz Hand Index (DHI):** A validated questionnaire evaluating functional disability in daily activities. Scores range from 0 (no disability) to 90 (severe disability).
2. **Visual Analog Scale (VAS):** Used to quantify pain intensity on a scale of 0–10.
3. **Range of Motion (ROM):** Measured with a goniometer across the PIP and DIP joints.
4. **Complications:** Including pin tract infections, stiffness, malunion, or nonunion.

Statistical Analysis

Descriptive statistics (mean, standard deviation, percentages) were used to summarize demographic and clinical data. Paired t-tests were employed to compare preoperative and postoperative outcome measures (DHI, VAS, ROM) across follow-up intervals. A **p-value <0.05** was considered statistically significant.

Results

Demographic Characteristics

The study included **30 patients** (20 males and 10 females), with a mean age of **32 years** (range: 19–58 years). The majority were manual laborers (40%) and students (30%), reflecting the high incidence of such injuries in younger, active populations. The dominant hand was involved in **60% of cases**.

Mechanism of injury was as follows:

- Sports injuries: 40%
- Road traffic accidents: 30%
- Falls: 20%
- Crush injuries: 10%

Fracture distribution:

- PIP joint fractures: 18 cases
- DIP joint fractures: 8 cases
- Comminuted shaft with articular extension: 4 cases

Functional Outcomes

- **DHI scores:** Improved from a mean of **60 at 4 weeks** → **30 at 8 weeks** → **15 at 12 weeks**.
- **VAS scores:** Improved from a preoperative mean of **8** → **3 at 4 weeks** → **1 at 12 weeks**.
- **ROM:** Increased from **30° at 4 weeks** → **65° at 8 weeks** → **85° at 12 weeks**.

All improvements were statistically significant ($p < 0.01$).

Complications

- **Pin tract infection:** 4 patients (13.3%), managed conservatively with antibiotics and local dressings.
- **Mild stiffness:** 2 patients (6.6%), improved with physiotherapy.
- No cases of malunion, nonunion, or device failure were recorded.

Tables (Draft Versions)

Table 1. Demographic characteristics of study population

Variable	Value
Mean age (years)	32 (range 19–58)
Male:Female ratio	2:1
Dominant hand involved	60%
Occupation (laborers)	40%

Table 2. Mechanism of injury

Cause	n (%)
Sports injury	12 (40%)
Road traffic accident	9 (30%)
Fall	6 (20%)
Crush injury	3 (10%)

Table 3. Functional outcomes over follow-up

Time point	Mean DHI	Mean VAS	Mean ROM (°)
Pre-op	–	8	–

Time point	Mean DHI	Mean VAS	Mean ROM (°)
4 weeks	60	3	30
8 weeks	30	2	65
12 weeks	15	1	85

Figure1 . preoperative image



Figure 2. Intraoperative X-ray

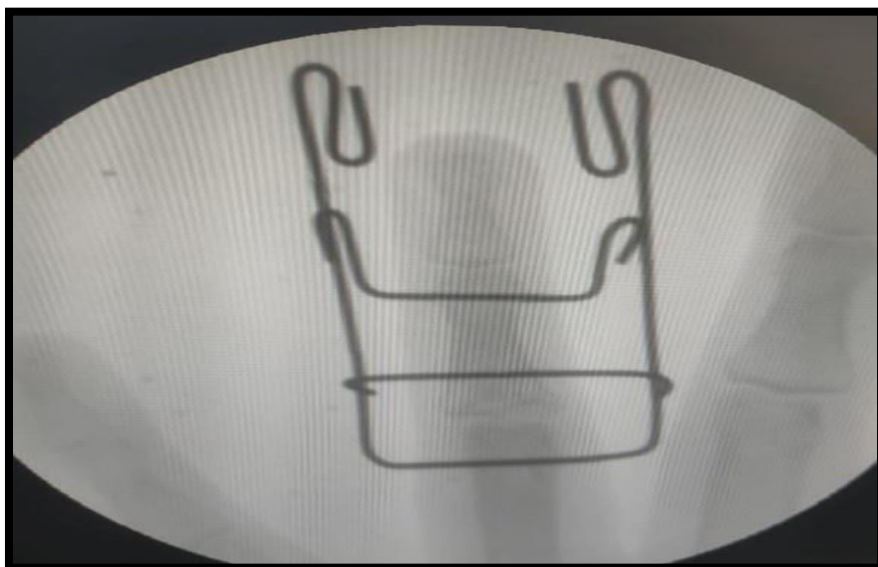
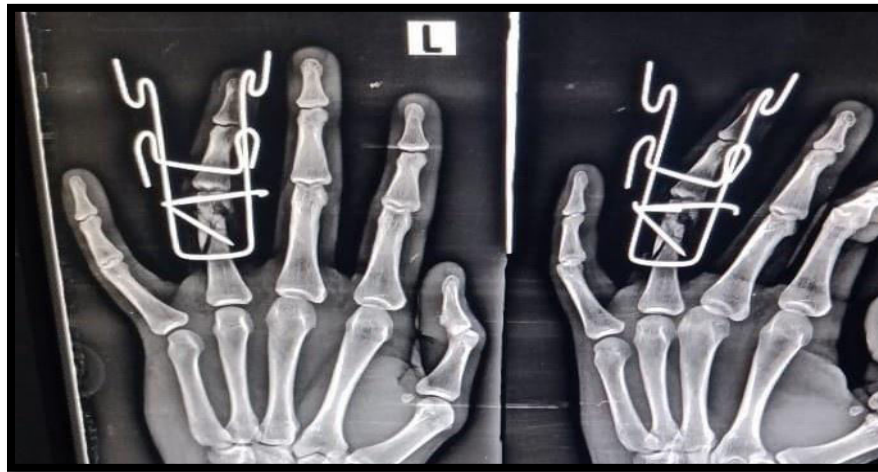


Figure 3. post operative X-ray showing intra-articular fracture of the proximal interphalangeal joint fixed



Discussion

The results of this study demonstrate that Suzuki frame fixation yields excellent short-term functional outcomes in patients with intra-articular fractures of the PIP joint. Patients showed marked improvement in functional ability, pain reduction, and joint mobility over a 12-week follow-up, findings consistent with existing literature.

Comparison with previous studies

Our findings align closely with those of **Nanno et al. (2019)**, who reported significant improvement in hand function and range of motion using the pins and rubber traction system. Similarly, **Khan and Fahmy (2006)** described functional recovery in over 80% of cases treated with dynamic fixation. The progressive reduction in DHI scores observed in our series mirrors reports by **Inanami (1993)**, highlighting the value of early mobilization in preventing stiffness.

In terms of pain relief, our patients' VAS scores improved from 8 preoperatively to 1 at 12 weeks, corroborating the results of **Suzuki et al. (1994)** and **Hastings and Ernst (1993)**, who noted that stable dynamic fixation reduces pain by maintaining joint congruity during motion. Compared with screw fixation, which often requires prolonged immobilization and technical expertise, the Suzuki frame allows patients to regain functionality earlier with minimal surgical morbidity.

Clinical implications

Dynamic fixation offers several distinct advantages:

1. **Cost-effectiveness** – The frame uses inexpensive Kirschner wires and rubber bands, making it feasible in resource-limited settings.
2. **Minimally invasive nature** – Unlike plate or screw fixation, soft tissue dissection is minimal, reducing the risk of scarring and stiffness.
3. **Early mobilization** – By maintaining traction, the system encourages immediate postoperative motion, a critical factor in preserving joint function.
4. **Adaptability** – The construct can be modified intraoperatively depending on fracture configuration, allowing use in both PIP and DIP fractures.

Complications

In our study, minor complications such as pin tract infections and stiffness were observed, consistent with rates reported in earlier studies. **Allan et al. (1996)** described similar infection rates, which were successfully managed with oral antibiotics and pin care. Over-distraction, a rare but serious complication highlighted by **Lad (2021)**, was not encountered in our series, possibly due to meticulous intraoperative tension adjustment.

Limitations and future scope

The limitations of this study include a relatively small sample size, short duration of follow-up, and the absence of a control group treated with alternative fixation methods. Long-term outcomes, including the incidence of post-traumatic arthritis, were not assessed. Future multicenter randomized controlled trials with larger sample sizes are needed to validate these findings. Additionally, biomechanical studies comparing dynamic fixation with newer implants may provide deeper insight into optimal fixation strategies.

Summary

Overall, this study supports Suzuki frame fixation as a reliable, low-cost, and minimally invasive option for managing unstable intra-articular finger fractures. By facilitating early mobilization, it minimizes stiffness and accelerates functional recovery, offering clear advantages over traditional fixation methods.

Conclusion

This prospective study demonstrates that **Suzuki frame fixation**, also known as the pins and rubber traction system (PRTS), is a safe, cost-effective, and reliable method for the management of unstable intra-articular fractures of the interphalangeal joints. The use of dynamic traction permitted early mobilization, which translated into rapid improvement in pain scores, functional ability, and range of motion over a 12-week period.

Compared with conventional methods of fixation such as Kirschner wires, screws, or plates, Suzuki frame fixation offers distinct advantages. The minimally invasive nature of the procedure reduces soft tissue trauma, while the simplicity of its design makes it suitable even in resource-constrained environments. Importantly, the device allows **continuous traction via ligamentotaxis**, thereby maintaining reduction and promoting joint congruity throughout the healing process.

Although minor complications such as pin tract infections and transient stiffness were observed, they were easily managed with conservative measures, and no patient required device removal or reoperation. These findings affirm the technique's practicality and reproducibility in everyday orthopedic practice.

In summary, Suzuki frame fixation should be considered a **primary treatment option** for unstable intra-articular fractures of the PIP and DIP joints. Wider adoption of this technique has the potential to improve functional outcomes, reduce disability, and minimize healthcare costs, particularly in low- and middle-income countries.

◆ Limitations

1. **Sample size** – The relatively small cohort of 30 patients limits the generalizability of the findings.
 2. **Follow-up duration** – The maximum follow-up was 12 weeks; therefore, long-term complications such as post-traumatic arthritis were not assessed.
 3. **Single-center study** – Being conducted at a single tertiary care center, the outcomes may not reflect broader population variability.
 4. **Lack of control group** – The absence of a comparator arm (e.g., screw fixation or plating) prevents direct statistical comparisons.
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◆ Future Scope

Future research should focus on:

- **Multicenter randomized controlled trials** with larger patient populations to establish stronger evidence.
- **Long-term outcome studies** (≥ 1 year follow-up) assessing joint stability, arthritis incidence, and functional durability.
- **Biomechanical studies** comparing ligamentotaxis-based traction devices with newer implants to better understand load distribution.

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