Journal of Southeast Asian Orthopaedics
ISSN 2821-9848 (Print)
ISSN 2821-9864 (Online)
https://doi.org/10.56929/jseaortho-2026-0275 https://jseaortho.org

Biomechanical Comparison of Different Angles of K-wire Fixation Configuration for Management of Proximal Phalanx Fracture by Syringe External Fixators

Valounkone Soukharath, MD, Sunyarn Niempoog, MD

Department of Orthopaedics Surgery, Thammasat University, Pathum Thani, Thailand

Purpose: To optimize the K-wire fixation configuration for managing proximal phalanx fractures using Syringe External Fixators.

Methods: In this biomechanical comparison study, 48 sawbone models of proximal phalanx fractures stabilized with syringe external fixators were tested across eight different K-wire configurations (Groups A–H). Configuration included parallel, nonparallel, or combined patterns at angles of 0°, 30°, or 45°. The models were underwent longitudinal compression and pull-out tensile tests. Data were analyzed using one-way analysis of variance (ANOVA) to overall group comparison and independent t-test for pairwise comparisons.

Results: Compression testing revealed that Group B (two parallel and two crossed K-wires) exhibited the highest mean ultimate strength (11.82 N). In contrast, Group D (two parallel and two crossed K-wires at varying angles) and G (four crossed K-wires) demonstrated the lowest strengths (5.49 N and 5.91 N, respectively). Although pairwise comparison between the highest- and lowest-strength groups showed a significant difference ($p = 0.004$), no statistically significant difference was observed across the eight groups in compression testing ($p = 0.062$). In pull-out testing, Group A (four parallel K-wires) displayed the highest mean ultimate strength (72.14 N), while group F (four cross-K-wires) showed the lowest (32.76 N). Pairwise comparison between these groups showed no statistically significant differences ($p = 0.083$). Similarly, no statistically significant difference in the pull-out tensile strength was observed among groups ($p = 0.235$).

Conclusions: In proximal phalanx fractures stabilized syringe external fixators, nonparallel and parallel K-wire fixation showed not significantly biomechanical different in compression and pull-out tensile testing.

Keywords: Proximal Phalanx fracture, K-wire fixation, Syringe external fixation, Biomechanical comparison study

Article history:
Received: September 19, 2025 Revised: February 22, 2026
Accepted: March 9, 2026
Correspondence to: Valounkone Soukharath, MD
Department of Orthopaedics Surgery, Thammasat University, Pathum Thani, Thailand
E-mail: valounkone_7013@hotlmail.com

Proximal phalanx fractures account for approximately 10% of all upper-extremity fractures. They are more prevalent in young to middle-aged men and are frequently caused by simple injuries. If not properly treated, these fractures can result in significant functional impairment and disability [1]. Therefore, understanding the optimal fixation methods for these fractures is important.

External fixators play a key role in comminuted proximal phalangeal fracture management. However, conventional hand external fixators have certain limitations, including high cost, complex design, and the requirement for expertise. In contrast, external syringe fixators are simple, inexpensive, easy to construct, and easy to use. They can be employed to treat various hand fractures in both emergency and definitive settings. Insulin syringes are readily available in most operating rooms[2].

Recent studies have demonstrated that syringe external fixators have yielded positive outcomes in the treatment of complex phalanges fractures [2-7]. However, research on the optimal degree and configuration of pin placement using this technique is lacking.

Therefore, this study aimed to determine the optimal K-wire fixation pattern for the treatment of proximal phalanx fractures using syringe external fixators.

METHODS

Study Design and Participants

This study employed a combination of experimental and biomechanical methods to address the research question. We evaluated fracture fixation in 48 sawbone models of the proximal phalanx using 1 mL insulin syringes and 1.2 mm diameter smooth K-wires (Fig. 1).

The Human Research Ethics Committee of Thammasat University (Medicine). The committee decided to exempt the study from ethical review as it was in full compliance with international guidelines, including the Declaration of Helsinki, Belmont Report, CIOMS Guidelines, and ICH-GCP. The certificate of exemption was COA No. 193/2566 (Project No. MTU-EC-OT-1-188/66). This research, titled "Biomechanical Comparison of Different Angles of K-wire Fixation Configuration for Management of Proximal Phalanx Fracture by Syringe External Fixators" was conducted independently by investigators from the Department of Orthopaedics, Faculty of Medicine.

Study Interventions

The bone models were fixed using a foam mold guide to ensure stability and alignment. Following fixation, an approximately 4 mm fracture gap was created in the model (Fig. 2).

The specimens were divided into eight groups (A–H) according to their K-wire configuration. The proximal and distal ends of the syringe barrel were removed. K-wires were then placed in parallel, non-parallel, or combined patterns at angles of 0°, 30°, or 45°, as illustrated in Figure 3.

The mechanical properties of the constructs were evaluated using two testing modalities: longitudinal compression testing and tensile pull-out testing using Shimadzu AGX-20, pre-load 1-1.5 N, speed 5 mm/min (Fig. 4).

Outcome Measures

The outcome measure was the loading strength (N/mm) required to produce a fracture gap of > 2 mm and syringe or pin displacement of > 2 mm. Data were recorded directly using the Shimadzu AGX-20 Load cell, which convert electrical signals into numerical values.

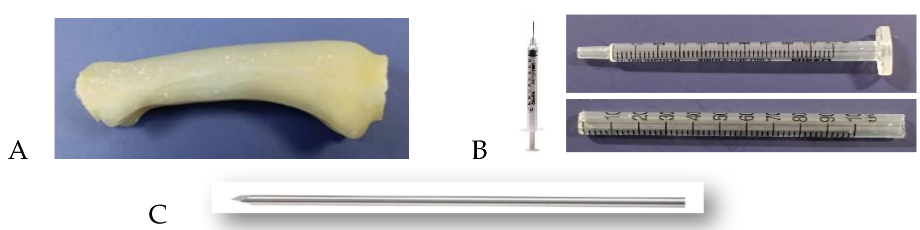

Fig. 1 Research material. A: Solid Sawbone Code 3420: Hand proximal phalange Length: 45mm ± 3mm (Brand Saw Bone form Pacific Research Laboratories, INC. Artificial Bone models for Med Ed), B: Syringe Insulin 1ml (NIPRO disposable syringe U-100 insulin 1ml), and C: Smooth K-wire 1.2 mm in diameter (ORTHOPEASIA CO., LTD)

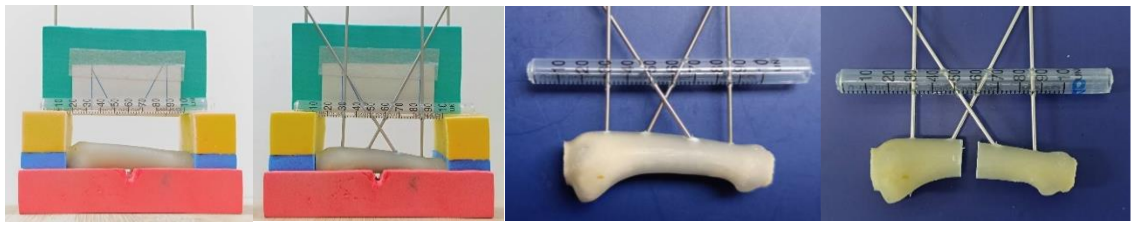

Fig. 2 Sequence of fixation Syringe external fixators. The bone is fixed using a foam mold guide to provide stability and alignment (A, B). Following fixation, a fracture gap of approximately 4 mm was created (C, D).

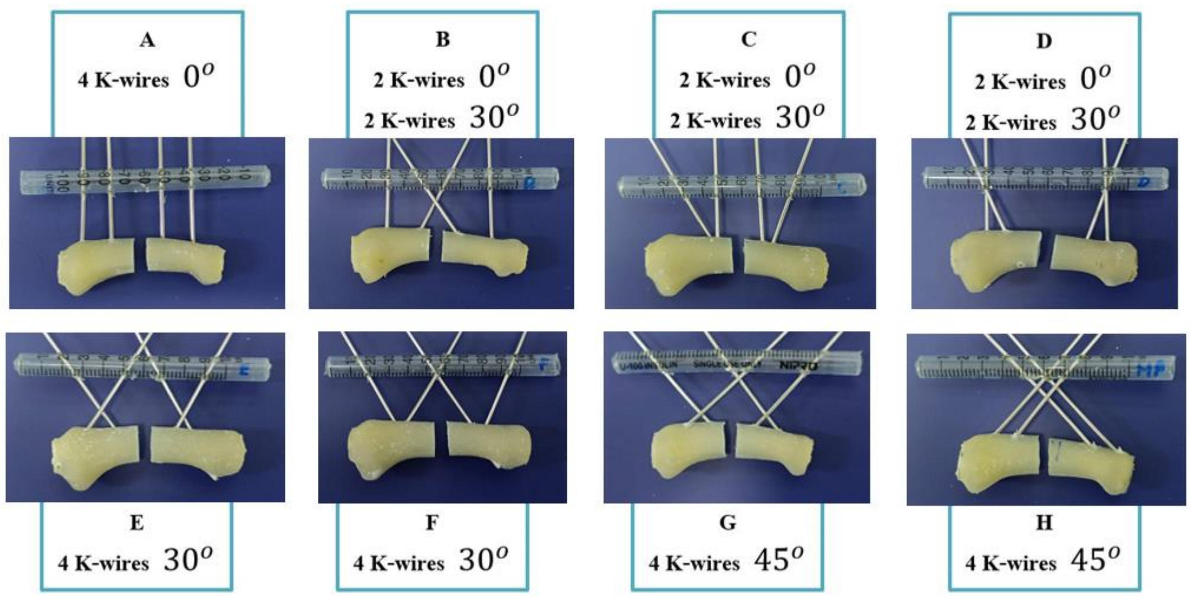

Fig. 3 All 8 groups of the configuration of models before evaluation.

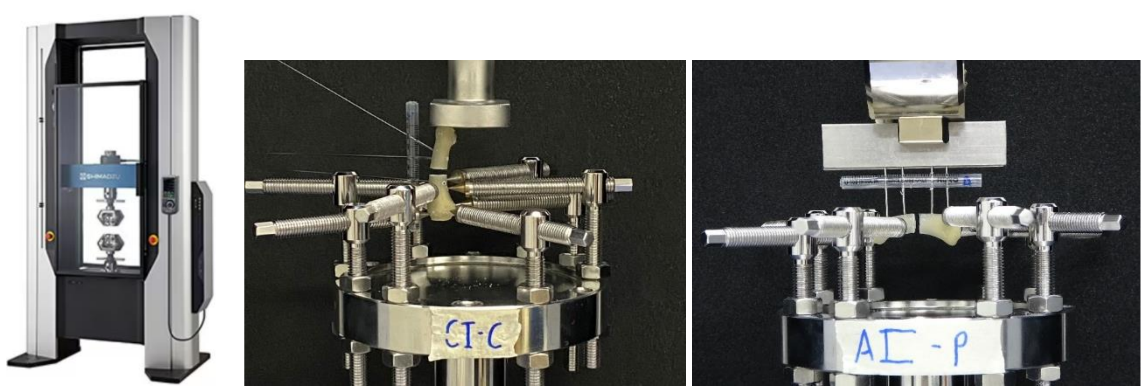

Fig. 4 A. Shimadzu AGX-20, B. Longitudinal compression test, and C. Tensile pull-out test.

Statistical Analyses

Compression and pull-out tensile strengths were compiled using Microsoft Office Excel 2016 software.

The results were analyzed using a One-way ANOVA test when comparing the eight groups, and an Independent T-test (Two-sample Assuming Unequal Variances) was used to compare the two groups.

RESULTS

The mean ultimate compression strengths (N) for the eight k-wire configuration groups were as follows: Group A: 9.124 (range: 5.2269–13.1090), Group B: 11.821 (10.0707–12.7824), Group C: 9.759 (7.3106–11.4063), Group D: 5.912 (3.4764–8.8428), Group E: 9.606 (8.7441–10.7905), Group F: 9.74 (8.26817–12.3868), Group G: 5.494 (4.1442–6.3288), and Group H: 8.135 (6.0804–10.7219).

Compression testing revealed that Group B exhibited the highest mean ultimate strength (11.82 N), while Groups D and G demonstrated the lowest mean ultimate strength (5.49 N and 5.91 N, respectively). Overall, no statistically significant differences in compressive strength was observed among the groups (p = 0.062). However, the compression test between Group B and Group G configurations showed a statistically significant difference in strength between the groups (p = 0.004) (Table 1).

Table 1 Average, variance, and standard deviation data (N), all eight compression groups (A-H). When comparing 8 groups, the strength of the compression test shows no statistical significance across the eight groups (p = 0.062); when comparing the compression test between groups B and G shows a significant difference in strength in each group (p = 0.004).

Groups	*Count*	*Mean*	*SD*
Group A: 4 k-wire 0°	3	9.12483	3.94171
Group B: 2 K-wire 0°, 2 K-wire 30°	3	11.82157	1.51870
Group C: 2 K-wire 0°, 2 K-wire 30°	3	9.759813	2.16260
Group D: 2 K-wire 0°, 2 K-wire 30°	3	5.912583	2.71713
Group E: 4 K-wire 30°	3	9.60657	1.06038
Group F: 4 K-wire 30°	3	9.740193	2.29685
Group G: 4 k-wire 45°	3	5.49478	1.18032
Group H: 4 k-wire 45°	3	8.135627	2.36588

Table 2 Average, variance, and standard deviation data (N), all eight tensile pull-out groups (A-H). When comparing 8 groups, the strength of the compression test shows no statistical significance across the eight groups (p = 0. 0.235); when comparing the tensile pull-out test between groups A and F also show no statistically significant difference in strength in each group (p = 0.083).

Groups	*Count*	*Mean*	*SD*
Group A: 4 K-wire 0°	3	72.1429	29.0583
Group B: 2 K-wire 0°, 2 K-wire 30°	3	46.46547	10.1997
Group C: 2 K-wire 0°, 2 K-wire 30°	3	44.29177	1.0314
Group D: 2 K-wire 0°, 2 K-wire 30°	3	43.49857	15.1499
Group E: 4 K-wire 30°	3	46.34783	30.6570
Group F: 4 K-wire 30°	3	32.7698	5.99260
Group G: 4 K-wire 45°	3	36.60937	13.5174
Group H: 4 K-wire 45°	3	36.08983	6.19158

The mean ultimate pull-out tensile strengths (N) for the eight groups were as follows: Group A, 72.142 (48.8589–104.708), Group B, 46.465 (35.5330–55.7256), Group C, 44.291 (42.2603–46.3232), Group D: 43.498 (32.8307–60.8394), Group E: 46.347 (14.8510–76.0896), F: 32.769 (28.5498–39.6290), Group G: 36.6094 (24.2958–51.0729), Group H: 36.089 (30.2343–42.5701).

Pull-out tensile testing revealed that Group A exhibited the highest mean ultimate strength (72.14 N), while Group F showed the lowest mean (32.76 N). No statistically significant difference in pull-out tensile strength was observed among the groups ($p = 0.235$). Furthermore, the pull-out tensile test between Group A and Group F configurations showed no statistically significant difference in strength between the groups ($p = 0.083$) (Table 2).

DISCUSSION

In 1998, *Godwin Y et al* introduced an inexpensive, disposable external fixator for comminuted phalangeal fractures using a syringe. Recently, several studies on syringe-based external fixators for hand fractures have reported favorable clinical outcomes in comminuted phalangeal fracture management [3]. However, studies on the degree of pinning and configuration fixation are limited.

The compression testing results indicated that group B (2 K-wire at 0° and 2 K-wire at 30°) exhibited superior interlocking properties compared to group G (4 K-wire at 45°). This difference is attributable to the spreading of the angles "0° and 30°". In group B, a larger area of the internal bone structure was involved in interlocking the implant, In contrast, Group G employed a single trajectory (45°) for the implant and was vulnerable to failure at an early stage owing to the increased force on the implant-bone interface.

In the pull-out tensile tests, the differences in fixation strength between Groups A (4 k-wire at 0°) and Group F (4 k-wire at 30°) potentially reflects the mechanics of the syringe–pin interface. The K-wires were secured within plastic syringe barrels. Parallel pins distributed tensile loads evenly across the syringe body. In contrast, angled pins may create "point loading" or shear stress at the plastic entry points, potentially leading to earlier deformation or displacement of the construct compared to pure axial tension experienced by parallel pins. This finding contradicts with a biomechanical study by *Atthakomol P et al* in 2015, which reported that fixation strength significantly increased the pull-out strength only in the non-polymer group, indicating that pinning at 30° was better than that at 0°. Therefore, increasing the degree of Kirschner wire fixation may enhance the stability of external syringe fixator [8].

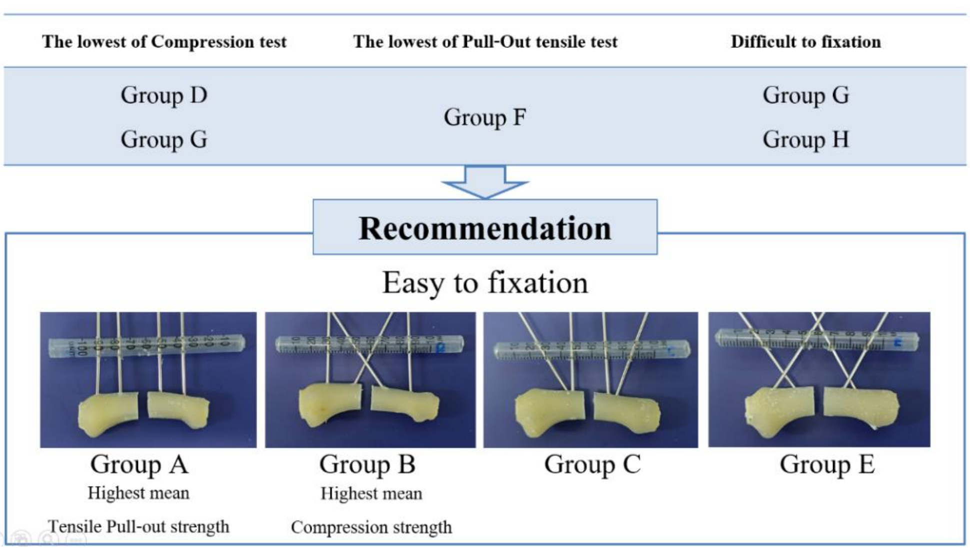

Fig. 5 The diagram illustrates the four configura-tions of the Syringe external fixator recommended by the authors.

In our practice, the degree of pinning fixation was more challenging in groups G and H, both of which employed four K-wire at 45°, compared to configurations using 0° or 30°.

Groups D and G demonstrated the lowest compression strength, while Group F exhibited the lowest pull-out tensile strength. Groups G and H (four K-wires at 45°) posed the greatest difficulty during fixation. Therefore, we recommend four configurations for syringe external fixations: group A (highest mean tensile pull-out strength), group B (highest mean compression strength), group C, and group E (Fig. 5).

The study has several limitations. First, as a biomechanical study, it examined only the mechanical properties of the constructs and did not assess biological healing. Second, the testing protocol evaluated other compression and pull-out strength, reflecting immediate fixation rather than long-term outcome. Third, the created fracture gap may not accurately replicate the normal fracture configuration. Fourth, sample size was limited, with a small number of specimens per group.

CONCLUSIONS

The biomechanical study of stabilizing proximal phalanx fractures with non-parallel K-wire fixation was not significantly different from stabilization with parallel K-wire fixation when managed with syringe external fixators, as evidenced by both compression and pull-out tensile tests.

ACKNOWLEDGEMENTS

The authors thank the Department of Orthopaedics Surgery, Thammasat University, for its support. We are grateful to all participants for providing the study data. Special thanks to Seksan Kukreja, MD, for providing the sawbones.

REFERENCES

1. Azar FM, Canale ST, Beaty JH. Campbell's Operative Orthopaedics. 14th ed. Elsevier; 2020.
2. Yousaf O, Yousaf IS, Giladi AM, et al. Syringe External Fixator: An inexpensive static-to-dynamic treatment for comminuted intra-articular phalangeal fractures. Tech Hand Up Extrem Surg 2020;24:126-30.
3. Godwin Y, Arnstein PM. A cheap, disposable external fixator for comminuted phalangeal fractures. J Hand Surg Br 1998;23:84-5.
4. Margić K. External fixation of closed metacarpal and phalangeal fractures of digits. A prospective study of one hundred consecutive patients. J Hand Surg Br 2006;31:30-40.
5. Thomas RK, Gaheer RS, Ferdinand RD. A simple external fixator for complex finger fractures. Acta Orthop Belg 2008;74:109-13.
6. Dailiana Z, Agorastakis D, Varitimidis S, et al. Use of a mini-external fixator for the treatment of hand fractures. J Hand Surg Am 2009;34:630-6.
7. Shah J, Rahman O, Ahmad R, et al. Phalangeal fractures- management by cost effective syringe fixators. JRMC [Internet]. 2015;19:133-5. Available from: https://www.journalrmc.com/index.php/JRMC/article/view/275.
8. Atthakomol P, Wangjiraphan N, Krudtong S, et al. Pull-out strength of 0°/30° Kirschner wire syringe external fixators with and without polymer augmentation: a biomechanical study. J Med Assoc Thai 2015:98:82-7.