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ARTICLE

Prognostic factors for outcomes of surgical mobilisation in patients with posttraumatic limited range of motion of the proximal interphalangeal joint: a multivariate analysis

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ABSTRACT

This study aimed to identify the prognostic factors for outcomes of surgical mobilisation in patients with posttraumatic limited range of motion (ROM) of the proximal interphalangeal (PIP) joint and determine which procedure actually improves the PIP joint ROM. A total of 71 fingers (57 patients: 49 men, 8 women; mean age, 41 years) with posttraumatic limited passive ROM of the PIP joint (<60°) who underwent surgical mobilisation were reviewed. Possible prognostic factors, including age, injury type, injured finger, injury in the adjacent finger, and procedure types, were assessed. We defined the PIP joint ROM improvement as the primary outcome in the linear regression analysis. To evaluate surgical efficacy, we classified the surgical treatment options into four categories (volar release, dorsal release, volar and dorsal release, and joint distraction with an external fixator) and compared their outcomes. The mean postoperative improvement in the PIP joint ROM was 12°. In the linear regression analysis, advanced age (estimate, −0.41; 95% confidence interval [CI], −0.76 to −0.06), open injury (estimate, −13.54; 95% CI −27.02 to −0.06), and skin defects (estimate, −23.22; 95% CI −34.83 to −11.61) were associated with worse outcomes; however, the volar approach was associated with favourable outcomes. Surgical mobilisation is strongly recommended when limited ROM of the PIP joint is caused by flexion site contracture. To improve the final outcome of fingers with complex injuries, a tailored treatment strategy is required to avoid dorsal release.

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Introduction

Posttraumatic stiffness of the proximal interphalangeal (PIP) joint is frequently caused by fracture, flexor or extensor tendon injury, vascular disruption, or a complex combination of these [1,2]. PIP joint stiffness is categorised into flexion or extension deformities based on the fixed posture [1,3]. Flexion contracture is mainly caused by flexor tendon adhesion and collateral ligament or volar plate contracture. Flexor tendon tenolysis or surgical release of the volar aspect of the joint has been performed to improve the PIP joint range of motion (ROM) [1,4]. Dorsal capsule contracture and extensor tendon adhesion could result in extension contracture, where capsulotomy or extensor tenolysis can be performed to improve PIP joint ROM [1,3]. Houshian *et al.* reported the effectiveness of gradual joint distraction using a mini-external fixator for improving the ROM in patients with posttraumatic flexion contracture of the PIP joint [5,6].

However, the results of these surgical mobilisation procedures are not always favourable [2,4,7–9]. Several authors have demonstrated the efficacy of surgical mobilisation by simply shifting the flexion/extension arc into a more functional range [4,8]. However, to date, none of these procedures have proven effective. Thus, this study aimed to identify the prognostic factors for surgical mobilisation and determine which procedure actually improves PIP joint ROM.

Materials and methods

Patient selection

We retrospectively reviewed the medical charts of patients treated at a single general hospital with a level 1 trauma centre. In our hospital, more than 85% of all orthopaedic surgeries account for trauma cases. We included patients who presented with limited passive ROM of the PIP joint (<60°), according to the definition of the functional ROM reported by Hume *et al.*, who had undergone surgical mobilisation of the PIP joint and postoperative rehabilitation [10]. To align the preoperative condition, we included the PIP joint contractures caused by traumatic injury, such as fracture, extensor/flexor tendon injuries, or soft tissue damages caused by crush injuries. Following the general protocol in our hospital, we initiated passive and active mobilisation exercises on the day after surgery. To prevent flexion contracture or extensor tendon dysfunction caused by either extensor elongation or adhesion to the floor in the flexed posture of the PIP joint, we placed a splint to keep the PIP joint extended for approximately 3 weeks except during rehabilitation. With this splinting, we were able to maintain the type of contracture (either flexion or extension contracture) that was chosen for each finger. We excluded patients who underwent joint transplantation to the PIP joint or tendon transplantation to reconstruct the extensor or flexor tendon around it, those who had complications due to infection around the joint, those whose follow-up periods were less than 12 weeks, and those whose outcome data were not available. Through this

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Table 1. Results of the univariate linear regression analysis.

	Number of cases	Mean postoperative gained ROM of PIP joint (95% CI)	Estimate (95% CI)	p Value
Age	–	–	−0.3 (-0.7–0.1)	0.11
Duration from injury to mobilisation	–	–	0.0 (-0.0–0.0)	0.70
Open wound				
−	14	19 (5–33)	–	–
+	57	10 (4–16)	−9.1 (−23.2–5.0)	0.20
Flexor tendon injury				
−	45	11 (4–18)	–	–
+	26	14 (4–25)	3.5 (−8.3–15.2)	0.56
Extensor tendon injury				
−	27	14 (6–21)	–	–
+	44	9 (0–8)	−4.6 (−16.2–7.0)	0.43
Circulation disruption				
−	49	10 (−1–21)	–	–
+	22	13 (6–20)	−3.4 (−15.6–8.9)	0.58
Skin defect				
−	50	17 (10–23)	–	–
+	21	0.5 (−10–11)	−16.2 (−28.0–4.5)	0.01
Fracture				
−	19	8 (−8–24)	–	–
PIP joint intra−articular	17	4 (−12–20)		0.60
Others	35	7 (−7–20)		0.33
Injury in the adjacent finger				
−	31	13 (3–23)	–	–
+	40	11 (4.5–18)	−2.0 (−13.4–9.4)	0.73
Contracture pattern				
Dorsal	20	8 (−1–17)	–	–
Volar	22	14 (3–25)	5.4 (−9.4–20.2)	0.47
Both	29	13 (3–23)	4.9 (−9.0–18.8)	0.49
Approach				
Volar	24	15 (4–26)	–	–
Dorsal	30	12 (4–20)	−3.2 (−16.3–9.9)	0.63
Percutaneous approach	11	10 (−7–28)	−5 (−22.5–12)	0.57
Lateral	6	2 (−16–19)	−13.7 (−35.6–8.1)	0.21
Surgical procedure				
Extensor tendon tenolysis	13	13 (5–22)	–	–
Extensor tendon tenolysis + dorsal release	21	8 (−3–20)	−4.9 (−22.0–12.19)	0.57
Flexor tendon tenolysis	6	6 (−34–45)	−7.6 (−31.4–16.2)	0.52
Flexor tendon tenolysis + volar release	19	17 (5.5–28)	3.3 (−14.0–20.7)	0.70
External fixator	12	12 (−4–29)	−1.1(−20.4–18.3)	0.91

ROM: range of motion; CI: confidence interval; PIP: proximal interphalangeal.

selection process, we finally included a total of 71 fingers from 57 patients (49 men and 8 women) in this study.

The institutional review board of Nagoya Ekisaikai Hospital approved this retrospective observational study. Considering the retrospective design of the study, the requirement of informed consent was waived.

Outcome evaluation

We collected data on the PIP joint ROM before surgery and at the final follow-up. Possible prognostic factors for the outcome of surgical mobilisation, such as approach (volar, dorsal, percutaneous approach, and lateral), wound type (open or closed), concomitant injuries (such as flexor and extensor tendon injuries), circulation disruption, skin defects, type of fracture (PIP joint intra-articular and others, such as distal phalangeal/metacarpal, diaphyseal, and metacarpophalangeal joint intra-articular), tendon injuries or fractures in the adjacent finger, and the detailed steps performed during the surgical procedure (extensor tendon tenolysis, extensor tendon tenolysis + dorsal release, flexor tendon tenolysis, flexor tendon tenolysis + volar release, and external fixator) were collected. In the tenolysis procedure, we removed all of the adhesion around the tendon tissue to the degree of obtaining perfect tendon gliding. In the dorsal/volar release, we incised or removed the capsule or volar plate of the PIP joint, and if necessary, collateral ligaments were also released to the degree of regaining complete passive ROM. Therefore, the technique of our volar release procedure was similar to that of the total anterior tenoarthrolysis procedure [11–13]. We defined skin defects as fingers that needed an additional procedure for coverage, such as grafting of skin flaps. Fingers that required microsurgical repair were classified as having vascular disruption. Data on patient-related factors, such as age, the interval between injury and the initial surgical mobilisation, and the injured finger were also collected.

Statistical analysis

We defined postoperative improvement of the PIP joint ROM as the primary outcome and performed a linear regression analysis to identify potential risk factors for worse outcomes after surgical mobilisation. To reduce the number of risk factors, we first conducted a univariate linear regression analysis and only included those variables in the multivariate model that were considered clinically relevant or exhibited a p-value <0.20. In the multivariate analysis, we utilised the Akaike information criterion (AIC) to reduce the number of independent variables in order to construct a more suitable model automatically, without any arbitrariness[14]. We considered a smaller AIC to indicate a more discriminatory system. To evaluate the independent variables, we reported the estimated coefficient of regression as the univariate linear regression analysis result. P-values <0.05 were considered statistically significant. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University,

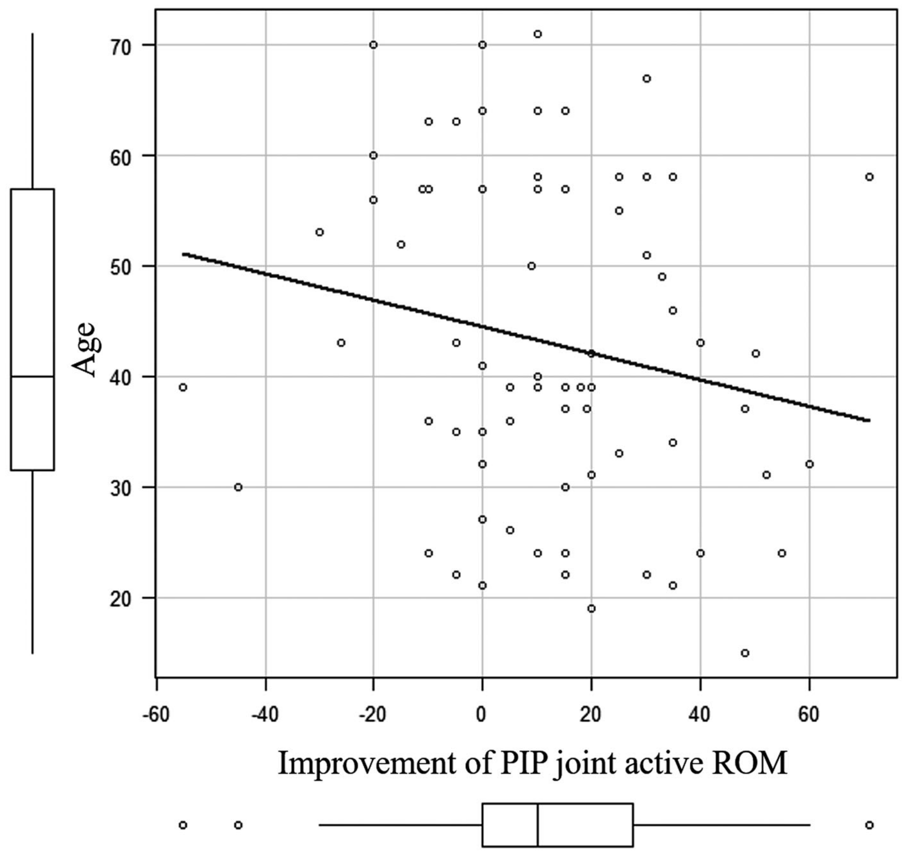

Figure 1. The relationship between patient age and improvement of PIP joint ROM. PIP: proximal interphalangeal; ROM, range of motion. Correlation coefficient = −0.2 (95% confidence interval: −0.4–0.0), *p*-value = 0.12.

Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) [15].

Results

The median follow-up period was 6 (range, 3–49) months, and the mean age of the patients was 41 (range, 15–71) years. The mean improvement of the PIP joint ROM was 12°. A PIP joint ROM improvement of more than 20° was achieved in only 25 fingers (35%). Table 1 shows the results of the univariate linear regression analysis. Advanced age, certain initial injuries (such as open wounds), and skin defects were identified as possible negative prognostic factors. Figure 1 shows the relationship between age and ROM improvement of the PIP joint. In addition to these factors, we included the surgical approach, contracture pattern, and surgical procedure, which were considered clinically relevant, in the multivariate analysis. After applying the AIC model, advanced age, open wounds, and skin defects were again identified as negative prognostic factors after surgical mobilisation (Table 2). The factors with positive and larger estimates in the linear regression analysis can be considered as contributing to improved outcomes. In an analysis of these factors, the volar approach showed significantly better outcomes than the lateral approach. When the aforementioned four categories of procedures were compared, dorsal release showed the worst improvement (Table 3).

Table 2. Results of the multivariate linear regression analysis for ROM gain.

	Estimate (95% CI)	p-value
Age	−0.4 (-0.8– −0.1)	0.03
Approach		
Volar	–	–
Dorsal	−9.1 (-21.2–3.0)	0.15
Percutaneous approach	−12.7 (-28.8–3.3)	0.12
Lateral	−28.0 (-48.7– −7.4)	<0.01
Open fracture		
-	–	–
+	−13.5 (-27.0– −0.1)	0.05
Skin defect		
-	–	–
+	−23.2 (-34.8– −11.6)	<0.01

ROM: range of motion; CI: confidence interval.
The multivariate linear regression analysis indicated that advanced age, complicated skin defects, and open fractures negatively affected the postoperative ROM gain. Compared with the volar approach, the lateral approach resulted in worse postoperative ROM gain.

Discussion

Our study revealed that open wounds and skin defects had a negative effect on the outcome of surgical mobilisation for posttraumatic PIP joint stiffness. The volar approach could contribute to better improvement of ROM of the PIP joint than the other approaches, especially the lateral approach. Among the four surgical procedures, dorsal release showed the worst improvement.

Several authors have compared the postoperative outcomes of dorsal and volar release. Ghidella et al. reported the long-term results of PIP joint surgical mobilisation in 68 fingers [9]. Contrary to our findings, they found worse results in patients with flexion contractures requiring volar release. Their literature review showed that most studies reported better postoperative outcomes with dorsal than with volar release [7,16,17]. Another review revealed that flexion contracture was more difficult to treat than extension contracture [3]. We hypothesize that the difference

Table 3. ROM of the PIP joint.

	Number of cases	Preoperative ROM Mean (95% CI)	Postoperative ROM Mean (95% CI)	Gained ROM Mean (95% CI)
Volar release	22	23 (14–31)	37 (26–47)	14 (3–25)
Dorsal release	20	24 (17–31)	32 (21–43)	8 (-1–17)
Both side release	20	15 (8–23)	28 (16–40)	13 (1–25)
External fixation	9	28 (15–40)	41 (18–64)	14 (-8–35)

ROM: range of motion; PIP: proximal interphalangeal; CI: confidence interval.

in the inclusion criteria among studies may have resulted in these discrepant findings. Moreover, we included all patients with limited passive ROM, even if the stiffness was caused by tendon contracture. Our multivariate analysis indicated that the volar approach is associated with good outcomes of surgical mobilisation. We incorporated this finding into our preoperative clinical decision-making process, as the cause of limited passive ROM of the PIP joint remains unclear until the surgical mobilisation itself. Moreover, we recommend the flexion contracture rather than extension contracture to clinicians who treat acute complicated injuries around the PIP joint, which is expected to be stiff, regardless. This will allow the clinicians to choose specific postures of postoperative splinting, for example.

Ghidella et al. also mentioned that advanced age, number of prior procedures, preoperative flexion, lack of immediate removal of an exostosis after mobilisation, number of targeted structures, and larger preoperative arc of motion are possible negative prognostic factors for surgical mobilisation of the PIP joint [9]. Houshian et al. summarised the studies published up until 2013. They reported that advanced age, a large number of operative procedures, extensive extracapsular release, and severe joint deformity were also negative prognostic factors [4]. Similarly, advanced age was also identified as a negative prognostic factor in our multivariate analysis. However, we did not evaluate the number of prior procedures, as their definition can be unclear. The precise steps performed during the procedure usually vary; thus, to succinctly summarise them using a simple number is quite impossible. Our results indicated that concomitant skin defects or open wounds, suggesting severe injury, were significant negative prognostic factors. Although most previous studies excluded fingers with complex injuries involving the flexor or extensor tendons or vascular injury, we were able to elucidate their impact by including such patients with severe injuries. This difference in our approach to patient inclusion from other studies could be the reason for the discrepancy between our results and those of previous studies [5,9,18–21]. This attempt has allowed us to clarify the actual clinical utility of surgical mobilisation. Another reason for this inconsistency was the poorer results achieved with surgical mobilisation using extensor tenolysis through the dorsal approach. Although this factor was not significant in the linear regression analysis, there was a worse improvement in fingers with extensor than with flexor tendon injury.

Regarding the patients who underwent tenolysis, we obtained contradictory outcomes. Although our results showed superiority of volar release to dorsal release, the patients with flexor tendon release alone showed worse improvement than those with extensor tendon release. We think this contrariety was caused by the different number of cases for each procedure. There were only six cases of patients with flexor tendon release because flexor tendon contracture is often complicated with joint contracture. Considering this result, we do recommend both flexor tendon tenolysis and joint release.

Gradual distraction with external fixation is another option to improve PIP joint ROM. In our study, this approach remarkably improved postoperative PIP joint ROM. Although it takes approximately 4 weeks to perform joint distraction with external fixation, during which the patient is forced to tolerate some discomfort, it can be a valuable treatment option for patients with limited ROM of the PIP joint. This approach is beneficial, especially for those with flexion contracture caused by complex injury, which requires flexibility of the soft tissues [2,4,22].

This study had several limitations. First, the follow-up period was relatively short. Since we completed the follow-up only when the improvement or worsening was considered stable, assessment of the true outcome of surgical mobilisation could have been biased. Second, our sample size was not sufficiently large to perform a multivariate analysis directly. Although we utilised the AIC to circumvent this problem, our approach could have negatively impacted the statistical power of the study. From this perspective, this study could not be a confirmatory research, but an exploratory research. Third, as the surgical approach and procedure have a relatively close association, including both in the analysis can cause confounding bias. Although we believe that this assertion is not always true because the surgical procedure was eliminated from the model through our process of reducing the number of independent variables, this approach could have reduced the quality of this study's statistical analysis. Fourth, the heterogeneity in patient backgrounds, such as the broad range of finger injury severity, makes it difficult to generalise our findings. Although we tried to adjust for these variations in the multivariate analysis, they could have biased the outcome.

Despite these limitations, we identified the possible superiority of volar release and clarified the negative effect of certain factors, such as advanced age, open wounds, and skin defects, on the final outcome of surgical mobilisation. In addition, compared with the lateral approach, based on our results, we recommend the volar approach with flexor tendon release alone as well as both flexor tendon and volar joint release. Considering the inferiority of dorsal release, we may choose a specific strategy for fingers with complex injuries to avoid extensor rather than flexor tendon adhesion or flexion contracture when we have few options in the rehabilitation protocol or postoperative joint positioning, as we cannot access the dorsal aspect through the volar approach. In addition, if the patient seems to be indicated for dorsal release, external fixation could be a better choice. Further research is necessary to improve the outcome of surgical mobilisation for PIP joint contracture. Currently, this procedure cannot be used to improve the active ROM of the PIP; therefore, we cannot recommend it for patients yet. However, our study can provide insights on the optimal approach for the improvement of PIP joint ROM.

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Disclosure statement

No potential competing interest was reported by the author(s).

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References

[1] Yang G, McGlinn EP, Chung KC. Management of the stiff finger: evidence and outcomes. Clin Plast Surg. 2014;41(3): 501–512.
[2] Tuffaha SH, Lee WPA. Treatment of proximal interphalangeal joint contracture. Hand Clin. 2018;34(2):229–235.
[3] Rongieres M. Management of posttraumatic finger contractures in adults. Hand Surg Rehabil. 2018;37:275–280.
[4] Houshian S, Jing SS, Chikkamuniyappa C, et al. Management of posttraumatic proximal interphalangeal joint contracture. J Hand Surg Am. 2013;38(8):1651–1658.
[5] Houshian S, Chikkamuniyappa C, Schroeder H. Gradual joint distraction of post-traumatic flexion contracture of the proximal interphalangeal joint by a mini-external fixator. J Bone Joint Surg Br. 2007;89-B(2):206–209.
[6] Houshian S, Jing SS, Kazemian GH, et al. Distraction for proximal interphalangeal joint contractures: long-term results. J Hand Surg Am. 2013;38(10):1951–1956.
[7] Sprague BL. Proximal interphalangeal joint injuries and their initial treatment. J Trauma. 1975;15(5):380–385.
[8] Hogan CJ, Nunley JA. Posttraumatic proximal interphalangeal joint flexion contractures. J Am Acad Orthop Surg. 2006;14(9):524–533.
[9] Ghidella SD, Segalman KA, Murphey MS. Long-term results of surgical management of proximal interphalangeal joint contracture. J Hand Surg Am. 2002;27(5):799–805.
[10] Hume MC, Gellman H, McKellop H, et al. Functional range of motion of the joints of the hand. J Hand Surg Am. 1990; 15(2):240–243.
[11] Lorea P, Medina Henriquez J, Navarro R, et al. Anterior tenoarthrolysis for severe flexion contracture of the fingers (the "TATA" operation): a review of 50 cases. J Hand Surg Eur Vol. 2007;32(2):224–229.
[12] Saffar P. Total anterior teno-arthrolysis. Report of 72 Cases. Annales de Chirurgie de la Main: organe Officiel Des Societes de Chirurgie de la Main. 1983;2(4):345–350.
[13] Saffar P, Rengeval JP. Total anterior tenoarthrolysis. treatment of the bent fingers (author's transl). Ann Chirurgie. 1978;32:579–582.
[14] DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics. 1988;44(3):837–845.
[15] Harrison DH. The stiff proximal interphalangeal joint. Hand. 1977;9(2):102–108.
[16] Mansat M, Delprat J. Contractures of the proximal interphalangeal joint. Hand Clin. 1992;8(4):777–786.
[17] Akaike H. A new look at the statistical model identification. IEEE Trans Automat Contr. 1974;19(6):716–723.
[18] Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant. 2013;48(3):452–458.
[19] Abbiati G, Delaria G, Saporiti E, et al. The treatment of chronic flexion contractures of the proximal interphalangeal joint. J Hand Surg Br. 1995;20(3):385–389.
[20] Nazerani S, Keramati MR, Vahedian J, et al. Soft tissue distraction using pentagonal frame for long-standing traumatic flexion deformity of interphalangeal joints. Chin J Traumatol. 2012;15(4):206–211.
[21] Hunter E, Laverty J, Pollock R, et al. Nonoperative treatment of fixed flexion deformity of the proximal interphalangeal joint. J Hand Surg Br. 1999;24(3):281–283.
[22] Houshian S, Gynning B, Schroder HA. Chronic flexion contracture of proximal interphalangeal joint treated with the compass hinge external fixator. A consecutive series of 27 cases. J Hand Surg Br. 2002;27(4):356–358.