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Risk factors associated with complications in flexor tendon repairs in zones 1 and 2

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ABSTRACT

Introduction: Flexor tendon injuries in zones 1 and 2 are common in hand surgery and can lead to functional impairment if not managed properly. This study investigates risk factors for complications following primary repair.

Methods: This retrospective study analyzed patient demographics, smoking habits, injury characteristics, surgical techniques, and rehabilitation status to assess their impact on postoperative complications.

Results: Smoking significantly increased the risk of tendon rupture ($p = 0.046$) and was associated with lower TAM scores ($p = 0.003$). High school graduates had a higher complication rate ($p = 0.001$). Patients who underwent rehabilitation had increased complications ($p = 0.048$), though this was likely due to pre-existing adhesions. Return-to-work time was significantly longer in patients with complications ($p < 0.001$). Other variables, including injured fingers, injury subzones, and suture techniques, did not significantly affect outcomes.

Conclusion: Smoking and rehabilitation status are key predictors of complications following flexor tendon repair. Future studies should further evaluate these factors to optimize patient outcomes.

Key words: *Flexor tendon injury, complications, risk factors, smoking, rehabilitation*

Introduction

Flexor tendon injuries in zones 1 and 2 are common in hand surgery and may result in significant functional impairment if not managed properly. Despite advances in surgical techniques and rehabilitation, complications such as adhesions and tendon rupture remain problematic [1-3].

Successful outcomes depend not only on surgical precision—such as suture configuration and core strand number—but also on effective postoperative care [2,4]. Additionally, patient-related factors including age, smoking, comorbidities, and adherence to rehabilitation can significantly influence healing and complication risk [2-5].

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This study investigates risk factors contributing to complications following flexor tendon repair in zones 1 and 2, emphasizing the role of surgical technique, post-operative rehabilitation, and patient-related variables in optimizing results.

Method

This retrospective study examined patients who underwent primary tendon repair for flexor zone 1-2 injuries between June 2023, and June 2024. The exclusion criteria included flexor tendon injuries in zones 3-5, accompanying bone fractures and neurovascular injuries, simultaneous replantation or revascularization, simultaneous volar plate injuries, patients under 18 years old, partial flexor tendon injuries, insufficient documentation, or follow-up. All cases included in the study were operated in the acute phase. The number of patients included in the study after applying the exclusion criteria is presented in Table 1.

Various demographic and clinical data were collected to investigate the risk factors associated with complications following surgical intervention for flexor zone 1-2 injuries. The data collected from the patients included: age, gender, educational status, income level, smoking habits, psychiatric conditions, affected side (right/left), injured tendons and fingers, injury mechanism, injury zones, tendon repair techniques, suture types, classification of complications, rehabilitation status, rehabilitation protocol, Total Active Motion (TAM) score, timing of tendon repair, timing of complications, return-to-work time, and follow-up duration. Patients' demographic characteristics are shown in Table 2.

Table 1. The table presenting the exclusion criteria for the patients.

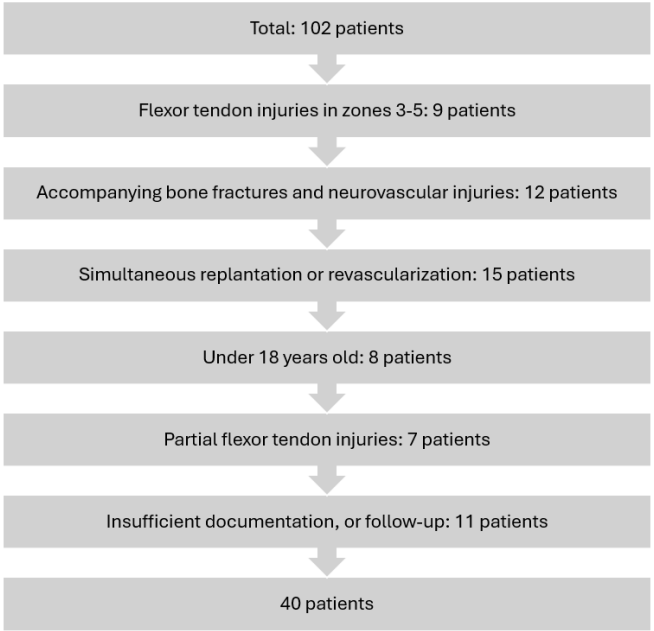

Table 2. The demographic data of the patients.

Age, mean ± SD	34.62 ± 16.72
Age groups, n (%)	
0-30	16 (40)
30-60	20 (50)
60+	4 (10)
Sex, n (%)	
Female	12 (30)
Male	28 (70)
Education, n (%)	
Primary school	10 (25)
Middle school	9 (22.5)
High school	17 (42.5)
University	4 (10)
Income, n (%)	
Low	12 (30)
Centre	117 (42.5)
High	11 (27.5)
Smoking, n (%)	
Absent	25 (62.5)
Present	15 (37.5)
Diabetes, n (%)	
Absent	39 (97.5)
Present	1 (2.5)
Psychiatric referral, n (%)	
Absent	38 (95)
Present	2 (5)
Antidepressant use, n (%)	
Absent	37 (92.5)
Present	3 (7.5)

SD: Standart Deviation

Table 3. The characteristics of the tendon injury, and the details of the methods used during and after surgery.

Side, n(%)	
Right	19 (47.5)
Left	21 (52.5)
Zone, n (%)	
1	7 (17.5)
2	33 (82.5)
Zone subtypes, n (%)	
2B	12 (36.4)
2C	18 (54.5)
2D	3 (9.1)
Mechanism of injury, n (%)	
Incision	39 (97.5)
Crush	1 (2.5)
Injured finger, n (%)	
1	9 (19.6)
2	12 (26.1)
3	5 (10.9)
4	6 (13)
5	14 (30.4)
Injured tendon, n (%)	
FDP	18 (45)
FDS	1 (2.5)
FDP+FDS	12 (30)
FPL	9 (22.5)
Repaired tendon, n (%)	
FDP	25 (62.5)
FDS	1 (2.5)
FDP+FDS	5 (12.5)
FPL	9 (22.5)
Repair technique, n (%)	
Modified kessler	25 (62.5)
Criss cross	11 (27.5)
Pull out	4 (10.0)
Suture types, n (%)	
Prolene	8 (20)
Ethibond	6 (15)
PDS	26 (65)
Epitendinous suture, n (%)	
Absent	22 (55)
Present	18 (45)
Rehabilitation, n (%)	
Absent	17 (42.5)
Present	23 (57.5)
Duran Hauser protocol, n (%)	
Absent	6 (15)
Present	34 (85)
St. John protocol, n (%)	
Absent	34 (85)
Present	6 (15)
TAM score, n (%)	
Excellent	19 (47.5)
Good	13 (32.5)
Fair	7 (17.5)
Poor	1 (2.5)
Complication, n (%)	
None	26 (57.8)
Adhesion	5 (11.1)
Joint contracture	9 (20)
Tendon rupture	3 (6.7)
The quadriga effect	1 (2.2)
Infection	1 (2.2)
Injury repair time (days), median (min, max)	1 (0, 420)
Duration of complication, median (min, max)	2 (1, 3)
Return to work period (months), median (min, max)	2.5 (1, 8)
Follow-up period (months), median (min, max)	9 (4, 15)

TAM is defined by the American Society for Surgery of the Hand (ASSH) as the sum of the active MCP, PIP, and DIP arc of motion in degrees in a single figure. This calculation is then compared to the TAM of the contralateral hand to obtain a percentage value.[2]

The data were collected retrospectively from patient files and outpatient follow-up records. The surgical interventions were performed by a by orthopedic senior residents with at least 1 year of hand surgery practice under supervision of a hand surgery resident, and all patients were referred for physical therapy at the third postoperative week.

Table 4. Association between the presence of complications and clinical-demographic characteristics.

	Total Active Motion Score				
	Excellent (n=19)	**Good (n=13)**	**Fair (n=7)**	**Poor (n=1)**	**p value**
Smoking, n (%)					
Absent	17 (89.5)	6 (46.2)	2 (28.6)	0	0.003[c]
Present	2 (10.5)	7 (53.8)	5 (71.4)	1 (100)	
Diabetes mellitus, n (%)					
Absent	18 (94.7)	13 (100)	7 (100)	1 (100)	0.99[c]
Present	1 (5.3)	0	0	0	
Rehabilitation, n (%)					
Absent	9 (47.4)	7 (53.8)	1 (14.3)	0	0.281[c]
Present	10 (52.6)	6 (46.2)	6 (85.7)	1 (100)	
Repair technique, n (%)					
Modified Kessler	11 (57.9)	9 (69.2)	3 (50)	1 (100)	0.713[c]
Criss cross	6 (31.6)	2 (15.4)	3 (50)	0	
Pull out	2 (10.5)	2 (15.4)	0	0	
Suture types, n (%)					
Prolene	3 (15.8)	3 (23.1)	2 (28.6)	0	0.39[c]
Ethibond	3 (15.8)	1 (7.7)	1 (14.3)	1 (100)	
PDS	13 (68.4)	9 (69.2)	4 (57.1)	0	
Rehabilitation protocol, n (%)					
DH	16 (84.2)	11 (84.6)	6 (85.7)	1 (100)	0.99[c]
JS	3 (15.8)	2 (15.4)	1 (14.3)	0	

[c] Pearson Chi-Square Test

Statistical Analysis

Descriptive statistics were presented as mean ± standard deviation and as median (minimum, maximum, IQR) whereas they were presented as number and percentage (%) for nominal variables. The significance of the difference between the groups in terms of the median values was analyzed by Mann-Whitney U Test and Kruskal-Wallis Test. Categorical variables were evaluated using Pearson Chi-Square Test and Fisher's Exact Test as appropriate. A p value of less than 0.05 was considered statistically significant and the analyses were conducted using the Statistical Package for Social Sciences (SPSS, Version 11.5, Chicago, IL).

Results

The demographic data of the patients, the characteristics of the tendon injury, and the details of the methods used during and after surgery are summarized in Tables 3 and 4.

In Table 4, when smoking status was examined based on TAM score groups, a statistically significant relationship was found between smoking status and TAM scores ($p = 0.003$).

When smoking status was examined in relation to the presence of complications, it was found that 100% of smokers experienced complications, while 96.2% of non-smokers did not experience complications ($p<0.001$).

The Impact of Smoking on Complications

According to Tables 5 and 6, when the effects of smoking on rupture and adhesion were examined, it was found that non-smokers had significantly lower rates of these complications, while smokers had high rates of both complications. A statistically significant relationship was found between smoking and both rupture and adhesion ($p = 0.005$ and $p = 0.046$). There was no significantly relationship found between smoking and rehabilitation as seen in Table 7 ($p = 0.187$).

Return-to-Work Duration

There was a statistically significant difference in return-to-work time between patients with and without complications ($p < 0.001$). The median return-to-work time for patients with complications was 4 months[1-4] whereas the median return-to-work time for patients without complications was 2 months[1,2,3,6,7]. Patients with complications had a significantly longer return-to-work time, emphasizing the clinical impact of postoperative outcomes.

Education/Income Status and Complications

In Table 8, a statistically significant relationship was found between educational status and the presence of complications ($p = 0.001$). This result suggests that patients with lower educational levels are more likely to experience complications.

Table 5. Smoking habits and demographic features based on rehabilitation status.

	Rupture		
	Absent (n=37)	Present (n=3)	p value
Smoking, n (%)			
Absent	25 (67.6)	0	0.046[d]
Present	12 (32.4)	3 (100)	
Rehabilitation, n (%)			
Absent	17 (45.9)	0	0.248[d]
Present	20 (54.1)	3 (100)	
Rehabilitation protocol, n (%)			
DH	31 (83.8)	3 (100)	0.999[d]
JS	6 (16.2)	0	

IQR:Interquartile Range, [c]Pearson Chi-Square, [d]Fisher's Exact Test

Table 6. Analysis of repair time by types of repaired tendons.

	Adhesion		
	Absent (n=35)	Present (n=5)	p value
Smoking, n (%)			
Absent	25 (71.4)	0	0.005[d]
Present	10 (28.6)	5 (100)	
Rehabilitation, n (%)			
Absent	17 (48.6)	0	0.061[d]
Present	18 (51.4)	5 (100)	
Rehabilitation protocol, n (%)			
DH	29 (82.9)	5 (100)	0.999[d]
JS	6 (17.1)	0	

IQR:Interquartile Range, [c]Pearson Chi-Square, [d]Fisher's Exact Test

Table 7. Association between adhesion formation, smoking habits, and rehabilitation factors.

	Rehabilitation		
	Absent (n=17)	Present (n=23)	p value
Smoking, n (%)			
Absent	13 (76.5)	12 (52.2)	0.187[d]
Present	4 (23.5)	11 (47.8)	

IQR:Interquartile Range, [c]Pearson Chi-Square, [d]Fisher's Exact Test

Discussion

This study aimed to investigate the risk factors associated with complications following surgical intervention for flexor zone 1-2 tendon injuries. The findings indicate that various demographic and clinical factors can influence the development of complications.

The Impact of Smoking on Complications

Smoking significantly increases the risk of complications and acts as a negatives predictor of TAM scores. These findings underscore the harmful effects of smoking on tendon healing and the increased risk of tendon rupture. Previous studies have also demonstrated the detrimental impact of smoking on tendon repair and recovery[8]. In contrast to our study, Samona et al. found that the overall recovery rate of TAM was 70% in smokers and 75% in non-smokers, with no significant difference between the two groups. Smoking has also been linked to reduced healing in conditions such

Table 8. Relationship between tendon rupture, clinical factors, and rehabilitation regimens.

	Complication		
	Absent (n=26)	Present (n=14)	p value
Education, n (%)			
Primary school	10 (38.5)	0	0.001[c]
Middle school	8 (30.8)	1 (7.1)	
High school	7 (26.9)	10 (71.4)	
University	1 (3.8)	3 (21.4)	
Income, n (%)			
Low	7 (26.9)	5 (35.7)	0.102[c]
Centre	9 (34.6)	8 (57.1)	
High	10 (38.5)	1 (7.1)	
Smoking, n (%)			
Absent	25 (96.2)	0	<0.001[d]
Present	1 (3.8)	14 (100)	
Diabetes mellitus, n (%)			
Absent	25 (96.2)	14 (100)	0.99[d]
Present	1 (3.8)	0	
Rehabilitation, n (%)			
Absent	14 (53.8)	3 (21.4)	0.048[d]
Present	12 (46.2)	11 (78.6)	
Repair technique, n (%)			
Modified kessler	16 (61.5)	9 (64.3)	0.99[c]
Criss cross	7 (26)	4 (28.6)	
Pull out	3 (11.5)	1 (7.1)	
Suture types, n (%)			
Prolene	5 (19.2)	3 (21.4)	0.791[c]
Ethibond	3 (11.5)	3 (21.4)	
PDS	18 (69.3)	8 (57.2)	
Antidepressant use, n (%)			
Absent	25 (96.2)	12 (85.7)	0.276[d]
Present	1 (3.8)	2 (14.3)	
Repaired tendon, n (%)			
FDP	16 (59.2)	9 (69.2)	0.169[c]
FDP+FDS	2 (7.4)	3 (23.1)	
FDS	1(3.7)	0	
FPL	8 (29.7)	1 (7.7)	
Zone subtypes, n (%)			
2B	9 (40.9)	3 (27.3)	0.858[c]
2C	11 (50)	7 (63.6)	
2D	2 (9.1)	1 (9.1)	
Return to work period, median (min, max, IQR)	2 (1, 6, 2)	4 (1.5, 8, 3)	<0.001[a]
Injury repair time, median (min, max, IQR)	1 (0, 210, 10.25)	4 (1.5, 8, 3)	0.408[a]

IQR: Interquartile Range, [a] Mann-Whitney U Test, [c] Pearson Chi-Square, [d] Fisher's Exact Test

as rotator cuff repair, shoulder pain, distal biceps tendon rupture, and Achilles tendon healing [8]. Smoking can impair the nutrition of tendon tissues, making the healing process more difficult and increasing the risk of complications. Tendons and ligaments have relatively poor vascularity and rely heavily on the diffusion of synovial fluid to provide essential nutrients. One of the most widely discussed theories today is the negative impact of smoking on vascularity. Nicotine reduces the vascular supply to tendons and ligaments, preventing the delivery of the reparative factors necessary for healing[9]. Experimental studies, such as the rat model study by Abraham et al., demonstrated that nicotine exposure significantly impairs tendon healing, leading to decreased collagen organization and mechanical strength in injured tendons [10].

Rehabilitation and Complications

A significant relationship was found between rehabilitation status and the presence of complications ($p = 0.048$). A detailed examination revealed that most patients who underwent rehabilitation had already developed adhesions before being referred to a physiotherapist by their surgeon. Therefore, the complications had developed before rehabilitation began, and patients started physical therapy afterward. From another perspective, this result suggests that the effects of rehabilitation on recovery may be complex and, in some cases, may increase the risk of complications. A review of all flexor tendon zones indicated that passive protocols were associated with a higher risk of complications related to decreased range of motion after surgery, while early active motion protocols had a higher risk of rupture [11]. In modern practice, with WALANT (Wide Awake Local Anesthesia No Tourniquet) techniques in flexor tendon repair and reconstruction, complications related to early active motion protocols have significantly decreased as the formation of gaps at the repair site is prevented [12,13]. Complications are inevitable in patients who undergo flexor tendon repair with general anesthesia or regional block. In these cases, prop-

erly applied rehabilitation and patient compliance with the process can support the healing process. A review on flexor tendon repair with WALANT indicated that involving therapists in the surgery helps improve patient compliance by creating a team approach, leading to better outcomes [14]. However, it may not always be possible for busy hand surgeons to collaborate closely with physiotherapists. This study emphasizes the importance of personalizing rehabilitation programs and monitoring them carefully.

Our findings emphasize the importance of individualized rehabilitation programs tailored to patient characteristics and injury severity. Future studies should aim to stratify PT referral criteria and evaluate rehabilitation outcomes in more homogeneous patient groups to better understand its direct impact on flexor tendon healing [15].

Education/Income Status and Complications

A significant relationship was found between educational status and the presence of complications ($p = 0.001$). This finding suggests that patients with lower educational levels are more likely to experience complications. Social and economic barriers may limit the patient's access to necessary postoperative care. One study showed that socially disadvantaged patients attended fewer physical therapy sessions after flexor tendon repair and achieved lower AROM[16]. Educational status can influence patients' health knowledge and their adherence to treatment. Patients with lower educational levels may have difficulty understanding and complying with treatment processes. Non-compliant patients may remove their orthotics as they wish, seeking to return to an active lifestyle as soon as possible. In a prospective study of patients with acute traumatic tendon repairs, only one-third of the patients fully adhered to the orthosis program. Depression during the acute phase of injury significantly disrupted orthosis compliance [17].

Return-to-Work Duration

A significant difference was found between patients with and without complications regarding return-to-work duration ($p < 0.001$). The median return-to-work duration for patients with complications was 4 months, while for those without complications, it was 2 months. In this study, complications increased the need for physical therapy, and when physical therapy reached a plateau, reoperation was performed. As a result of this close follow-up, the cost of a flexor tendon repair to the social security institution and consequently to the state increases significantly. A review of 94 articles on flexor tendon repairs in one or two regions reported return-to-work information in only eighteen studies [18]. Consequently, complications prolong return-to-work duration, and issues encountered during the recovery process delay reintegration into the workforce.

This study provides crucial data for understanding the factors that increase the risk of complications in flexor tendon injuries. The increased risk associated with smoking and educational level highlights important factors that need attention during surgical and rehabilitation processes. Future studies should support these findings and aim to improve treatment strategies with larger and more diverse patient populations. Additionally, personalizing rehabilitation programs and tailoring them according to educational levels may be effective in reducing complication risks.

Factors With No Effect on Complications

In this study, factors such as injured fingers, injury subzones, suture types, suture techniques, rehabilitation regimens, patients' income status, and psychiatric conditions were examined for their impact on complications. However, it was found that these factors did not significantly affect the risk of complications. This suggests that the effects of these factors on complications might not be as strong as anticipated or may interact with other variables. The results indicate that the risk of complications may arise from the interaction of multiple factors, and some factors may have indirect effects in this study.

This study was organized as a retrospective cohort and followed patients for a median duration of 9

months, which was adequate for assessing early complications as the primary outcome. The secondary outcome was the total active motion (TAM) score, and this duration was sufficient for measuring the TAM score as well. While the impact of surgical technique details was analyzed in this study, no significant differences were found. Region 2 injuries (especially those with the tightly constricted 2C sheath) are commonly accepted to have worse functional outcomes [19]. However, in this study, subzones did not affect complications or outcomes. Literature based on experimental and clinical studies widely recommends stronger suture materials, more robust repair techniques, and limited use of pulley release [20], and Tang's technical recommendations were also considered in this study. Important limitations of this study include the lack of anesthesia with WALANT and inability to access loop sutures. Additionally, the study could not address the discussion on the treatment of concurrently injured FDS tendons, as FDS repairs were a technique applied to a select few patients in the clinic. The study also did not focus on the surgeon's experience, which is increasingly considered a significant factor affecting the outcome of tendon surgery, although all surgeons had experience in orthopedics and were at level 1 in hand surgery [21]. Therefore, it was noted that the excellent and good outcome rates in our series (%80) were generally slightly lower than in another series[22].

Conflict of interest statement

The authors have no conflicts of interest to declare.

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