Turk J Phys Med Rehab 2026;72(x):i-viii
DOI: 10.5606/tftrd.2026.16177
Available online at www.turkishjournalpmr.com

Original Article

Predictors of postoperative complications in extensor tendon repairs

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ABSTRACT

Objectives: This study aims to evaluate the factors contributing to postoperative complications in patients undergoing extensor tendon repair, focusing on the relationship between injury zones and outcomes.

Patients and methods: This retrospective cohort study included 206 patients (178 males, 28 females; mean age: 33.7±13.1 years; range, 16 to 74 years) with extensor tendon injuries treated at a single center using standardized surgical and rehabilitation protocols between January 2013 and December 2016. Data on demographics, injury characteristics, and postoperative complications were analyzed. Logistic regression was employed to identify predictors of complications.

Results: The complication rate was 22.3%, with adhesions and extensor lag being the most common. Smoking (odds ratio = 0.161) and higher modified Hand Injury Severity Score values were identified as significant predictors of complications. Complication rates varied across injury zones, with zones 1 and 2 exhibiting the highest rates (26.1%), although the differences were not statistically significant.

Conclusion: Smoking and injury severity emerged as key predictors of complications, highlighting the need to address modifiable risk factors through targeted interventions such as smoking cessation programs and intensive follow-up for high-risk patients. The findings suggest no specific injury zone is consistently associated with poor outcomes, underscoring the need for further research into zone-specific surgical and rehabilitation strategies.

Keywords: Adhesions, complications, extensor, repair, smoking, tendon.

Extensor tendon injuries of the hand occur more frequently than flexor tendon injuries, primarily due to their superficial anatomical location and proximity to underlying osseous structures, which increases their susceptibility to trauma.[1] These injuries predominantly affect young individuals engaged in manual labor, contributing to a significant socioeconomic burden on communities.[2] Moreover, postoperative complications exacerbate these adverse economic outcomes, highlighting the need for improved management strategies.

Although the superficial nature of extensor tendons facilitates surgical access, preserving their function and anatomical continuity is challenging.[3] This difficulty arises from the anatomical complexity of the dorsal hand. The tendons' relatively thin, flat structure makes them weaker and less capable of holding sutures compared to flexor tendons.[4] Despite these challenges, research on extensor tendon injuries is comparatively limited. Most studies have focused on flexor tendon injuries, leaving a critical gap in our understanding of the risk factors influencing outcomes in extensor tendon repair.

Complications following extensor tendon repair may include loss of motion due to adhesions or tendon imbalance, re-rupture or extensor lag, infections, nail deformities, and suture-related adverse reactions.[5] Existing studies suggest that variables such as injury severity, surgical technique, rehabilitation protocols, and injury location may

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Received: December 08, 2024 **Accepted:** August 29, 2025 **Published online:** December 19, 2025

Cite this article as: Çalışkan Uçkun A, Yurdakul FG, Ergani HM, Güler T, Yaşar B, Başkan B, et al. Predictors of postoperative complications in extensor tendon repairs. Turk J Phys Med Rehab 2026;72(x):i-viii. doi: 10.5606/tftrd.2026.16177.

significantly contribute to these complications.[6] Therefore, employing standardized surgical and rehabilitation procedures performed by the same experienced team can minimize confounding variables and provide a clearer understanding of the factors influencing postoperative complications.

While flexor tendon injuries have been extensively studied, extensor tendon repairs, despite their clinical relevance and higher complication risk, remain underexplored, particularly in terms of factors influencing postoperative outcomes. Therefore, the present study aimed to investigate the determinants of complications in patients with extensor tendon injuries who underwent standardized surgical and rehabilitation protocols at a single center. By identifying factors contributing to postoperative complications, this study sought to enhance the ability to predict clinical outcomes and optimize the initial intensity of rehabilitation and follow-up care.

PATIENTS AND METHODS

This retrospective study was conducted at Ankara Numune Training and Research Hospital, Department of Physical Therapy and Rehabilitation and included patients treated for extensor tendon injuries between January 2013 and December 2016. The study included patients who underwent extensor tendon repair and subsequent rehabilitation under the supervision of a specialized surgical and rehabilitation team. All patients had a minimum follow-up period of 12 months. The exclusion criteria were as follows: *(i)* rheumatoid arthritis, *(ii)* flexor tendon repairs, *(iii)* congenital finger deformities, *(iv)* nerve injuries (except digital nerve injuries), *(v)* hand fractures, *(vi)* age below 16 years, *(vii)* severe systemic diseases affecting return to work, and *(viii)* incomplete medical records. The study identified 953 patients. Of these, 206 (249 digits; 178 males, 28 females; mean age: 33.7±13.1 years; range, 16 to 74 years) met the inclusion criteria and were analyzed (Figure 1). Written informed consent was obtained from all participants. The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (Date: 17.07.2024, No: TABED 1-24-426). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The surgical procedure was carried out using either a brachial plexus block or general anesthesia. For zones 1 and 2, a running suture incorporating both skin and tendon was used, while for other zones, tendons were repaired using an interlocking horizontal mattress technique. All sutures were placed using 4-0 Prolene.[7] Two cases required palmaris longus transfer, and two required a tendon graft.

Our clinic developed and standardized the rehabilitation protocols applied in this study, following the relevant literature. Rehabilitation strategies were adjusted and implemented based on the injury zone.

In zones 1 and 2, the distal interphalangeal (DIP) joint was immobilized continuously in extension using a stack or custom thermoplastic splint for six weeks, followed by two weeks of nighttime use. The splinting duration was extended in the presence of extensor lag. During immobilization, patients were instructed on skincare and splint hygiene to prevent complications such as maceration or pressure sores. Following immobilization, gradual DIP joint flexion exercises were initiated under supervision. Initially, active exercises were initiated. After the 12th week, the rehabilitation program continued with passive flexion exercises.[8-10]

In zones 3 and 4, rehabilitation began with short arc motion protocols during the first-week after repair. The proximal interphalangeal (PIP) and DIP joints were maintained in extension using a dorsal extension block splint, allowing controlled flexion to avoid stress on the repair. Based on clinical follow-up, PIP flexion was gradually increased every seven to 10 days, typically reaching full flexion by four to five weeks. Splinting was usually continued until six weeks.[8-10]

In zones 5 through 8, injuries were treated using a controlled mobilization protocol. Patients

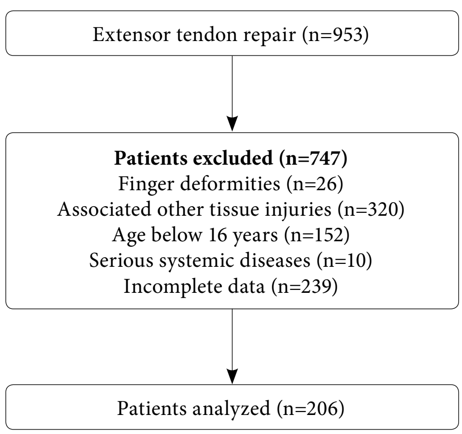

Figure 1. Study flowchart.

were immobilized with a volar short arm splint, positioning the wrist in 30-45° extension and the metacarpophalangeal (MCP) joints in 20-30° flexion. The interphalangeal joints were initially immobilized, but the splint was shortened distally starting from the first week (DIP joint) and then the second week (PIP joint) to allow active and passive ROM exercises. The splint that immobilized the MCP joint while leaving the PIP and DIP joints free was used until the sixth week. During this period, the splint was removed during exercise sessions to allow controlled mobilization of the MCP joint at regular intervals. In addition, wrist exercises were initiated from the fourth week using the tenodesis principle. Strengthening exercises were started at the sixth week, followed by stretching exercises at the eighth week.[8-10]

Data on demographics and injury characteristics included sex, age at injury, occupation (categorized as white-collar workers, blue-collar workers, or nonemployed), smoking status, substance abuse history, cause of injury, comorbidities, injury zone, side of injury (dominant or nondominant hand), mechanism of injury, concomitant digital nerve injury, time interval from injury to surgery, type of surgery, injury severity, the time to return to work, and history of reoperation. Injury severity was assessed using the modified Hand Injury Severity Score (mHISS). This standardized and widely used scoring system evaluates hand injuries based on the number and type of injured anatomical structures (skin, skeletal, motor, and nerve components).[11] Each category is assigned a weighted score depending on the extent and complexity of the damage, and the cumulative score reflects the overall severity of the injury. Higher mHISS scores are associated with increased functional impairment and prolonged recovery times, making it a valuable tool for clinical and research evaluation.

Occupational categories were defined: white-collar workers included professionals, managers, clerical staff, sales, and service personnel; blue-collar workers referred to as manual laborers. Retirees, unemployed individuals, homemakers, and students were categorized as nonemployed. Injuries were classified based on official records, which included work-related incidents, self-harm, traffic accidents, assaults, and cases with unspecified causes. Injury mechanisms were further divided into "crush injuries" (e.g., involving saws, fans, and lathes) and "sharp injuries" (e.g., involving glass, knives, and metals).

Postoperative complications were classified as re-rupture, adhesions, tendon imbalance, surgical site infections, loss of motion, nail deformities, or suture reactions. These complications were primarily assessed during routine clinical follow-up visits by the treating team. Ultrasonography was used selectively when differentiation between adhesion and re-rupture could not be made through clinical examination alone. Patients were subsequently grouped into complication and noncomplication categories for analysis. The severity of complications was not graded.

Statistical analysis

All analyses were performed using IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the sociodemographic and clinical variables. Normally distributed continuous variables were reported as mean ± standard deviation (SD), while nonnormally distributed variables were presented as median and interquartile range. Group comparisons were conducted using the Mann-Whitney U test or Student's t-test for continuous variables, and the chi-squared or Fisher exact test for categorical variables, as appropriate. Variables with a p-value ≤0.05 (e.g., MHISS score, smoking status, dominant hand injury, and type of surgery) were included in a binary logistic regression model to evaluate their association with postoperative complications.

RESULTS

Active smoking was reported in 89 (43.2%) participants, and 14 (6.8%) had a history of drug abuse. Comorbidities were present in 14.1% of patients, mainly psychiatric disorders (4.36%) and hypertension (2.42%). Patients in the complication group had significantly longer medical leave durations (60.59±78.37 days) compared to the noncomplication group (20.77±31.24 days; p=0.013).

The majority of participants were blue-collar workers (52.4%). The mean mHISS score was 15.90±11.28. The dominant hand was affected in 107 (51.9%) participants, and work-related injuries accounted for 30.1% of cases. Sharp instrument lacerations were the leading cause of injuries (67%). Single-digit injuries were observed in 180 (87.4%) patients, with the index finger being the

TABLE 1
Demographic data of patients

	No complication (n=160)			Complication (n=46)			Total (n=206)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			33.8±13.6			33.4±11.2			33.7±13.1	0.702[a]
Sex										
Female	21	13.1		7	15.2		28	13.6		0.807[b]
Occupation										
White-collar workers	21	13.1		5	10.9		26	12.6		
Blue-collar workers	80	50		28	60.9		108	52.4		
Unemployed	59	36.9		13	28.3		72	35		
Current smoker	54	33.8		35	76.1		89	43.2		<0.001[b]*
Drug abuse history	10	6.3		4	8.7		14)	6.8		0.520[b]

SD: Standard deviation; [a]: Mann-Whitney U test; [b]: Pearson chi-square test; * p<0.05 was considered statistically significant.

most commonly injured digit (30.62%). The most frequently injured zone was zone 6 (25.7%). The mean time to surgery was 1.58±4.63 days.

The complication group included 46 (22.3%) patients. Tendon adhesions were the most common complication (n=25), followed by extensor lag (n=7) and nail deformities (n=6). Tendon rupture occurred in five patients. Additionally, suture reaction was detected in two patients, and surgical site infection was documented in one patient.

Zones were grouped into three categories (zones 1-2, 3-4, and 5-8) based on anatomical proximity, similarities in surgical techniques, and rehabilitation protocols to allow for a more meaningful analysis of outcomes. Zones 1 and 2 had a complication rate of 26.1%, predominantly nail problems (n=6) and adhesions (n=3). Zones 3 and 4 had a complication rate of 18.86%, with adhesions (n=6) and extensor lag (n=4) being the most common. Zones 5 through 8 had a complication rate of 17.91%, primarily adhesions (n=16).

TABLE 2
Injury characteristics of patients

	No complication (n=160)			Complication (n=46)			Total (n=206)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Timing of surgery (days after injury)			1.60±4.95			1.52±3.31			1.58±4.63	0.181[a]
Digital nerve injury	0	0		4	2.5		4	2		0.578[c]
Sharp mechanism of injury	110	68.8		28	60.9		138	67		0.316[b]
Work-related injury	45	28.1		17	37		62	30.1		0.063[b]
Dominant hand injury	89	55.6		18	39.1		107	51.9		0.048[b]*
mHISS value			14.48±7.37			20.84±18.87			15.90±11.28	0.001[a]*
Type of surgery										
Tendon repair	159	93.5		43	99.4		202	98.1		0.019[c]*
Tendon transfer	0	0		2	4.3		2	1		
Tendon graft	1	0.6		1	2.2		2	1		
Zone										
1-2	31	19.4		11	23.9		42	20.4		0.694[b]
3-4	43	26.9		10	21.7		53	25.7		
5-8	86	53.8		25	54.3		111	53.9		

SD: Standard deviation; MHISS: The Modified Hand Injury Severity Score; [a]: Mann-Whitney U test; [b]: Pearson chi-square test; [c]: Fisher exact test; * p<0.05 was considered statistically significant.

TABLE 3
Binary logistic regression results for the complication group

Independent variables	B	SE	*p**	Exp(B)	95% CI
Smoking	–1.823	0.395	0.000*	0.161	0.074-0.350
mHISS	–0.062	0.023	0.006*	0.940	0.899-0.982
Constant	3.288	0.520	0.000	26.796	

SE: Standard error; Exp(B): Odds ratio. B: Beta coefficient; * p<0.05 was considered statistically significant; mHISS: The modified Hand Injury Severity Score.

Tendon adhesiolysis was performed in four (16.0%) of the 25 patients with adhesions, while reoperation was required in six (50.0%) of the 12 patients with tendon rupture or extensor lag.

No significant group differences were found for age, sex, surgery timing, occupation, digital nerve injury, drug use, injury mechanism, zone, or work-related status (Tables 1, 2). However, smoking status (p<0.001), dominant hand involvement (p=0.048), mHISS score (p=0.001), and type of surgery (p=0.019) were significantly associated with the development of complications. Logistic regression showed smoking [odds ratio (OR)=0.161, p<0.001] and mHISS (OR=0.940, p=0.006) as significant predictors of complications (Table 3).

DISCUSSION

Extensor tendon repair is frequently accompanied by postoperative complications, posing substantial clinical and socioeconomic challenges. In this study, the overall complication rate was 22.3%. Logistic regression analysis identified active smoking [OR=0.161, 95% confidence interval (CI) 0.074-0.350, p<0.001) and greater injury severity measured by mHISS (OR=0.940, 95% CI: 0.899-0.982, p=0.006) as independent risk factors. Patients with complications also experienced significantly longer medical leave (mean duration: 60.6±78.4 days), underscoring the economic burden of prolonged recovery.

Consistent with prior research, tendon injuries were most prevalent among young males (mean age: 33.66±13.10 years) and blue-collar workers (52.4%).[4,12,13] Although age, sex, and occupation type were not significantly associated with complications, the predominance of blue-collar workers and longer recovery times underscore the necessity of tailored strategies to minimize workday loss and enhance functional recovery.

In zones 1 and 2, the complication rate observed in this study (26.10%) was higher than the 14.5% reported in the systematic review by Lin and

Figure 2. Postoperative application of a relative motion extension splint combined with a wrist splint for a zone 8 extensor tendon injury. The splint positions the third and fifth fingers in 15° to 20° of extension relative to adjacent fingers, while the wrist is maintained at slight extension within a wrist orthosis.

Samora.[14] However, previous studies have reported significantly higher rates, with some reaching as high as 53%.[15] The most frequent complication in this zone was nail deformity, consistent with findings from prior research.[14] This variability across studies may be attributed to several factors, including differences in rehabilitation protocols, surgical technique, complication definitions, assessment methods, and whether or not nail bed injuries were considered within the definition of complications. Our study adopted a broad definition of nail deformity, which may have contributed to the higher complication rate.

For zones 3 and 4, the complication rate was 18.86%. The literature on these zones has predominantly focused on joint range of motion as an outcome measure, with limited emphasis on complications. Notably, in zone 3, good or excellent functional outcomes were found to be lower compared to other zones.[16,17] In zones 5 through 8, the complication rate was 17.91%, with adhesion-related motion loss being the most common issue. Previous case series and randomized controlled trials examining extensor tendon repairs in zones 4 through 8 have reported a total of 14 complications (including adhesion, rupture, infection, and swelling) across 337 repairs, with complication rates ranging from approximately 0 to 8%.[18-22] These relatively low complication rates may be explained by methodological differences, particularly in defining complications. In these studies, conditions such as loss of joint range of motion and extensor lag were not classified as complications but were generally assessed as part of functional outcome measures. As such, direct comparison with the current study is limited due to differing definitions and evaluation frameworks. Additionally, one study documented a 35% mild complication rate, including tendon tethering, infection, or edema.[23] Although our study also reported higher complication rates in distal zones, consistent with previous zone-based studies indicating poorer outcomes in these areas,[16,17] this difference was not found to be statistically significant, limiting the strength of the conclusions that can be drawn regarding the impact of injury zone on complication risk. The lower complication rates observed in proximal zones may be explained by the greater tissue stability and biomechanically favorable conditions in these areas.[6,24] The high adhesion rates observed in zones 5 through 8 in this study may be attributed to the more restrictive rehabilitation protocols for early active motion that were in place during the study period. In current clinical practice, however, relative motion extension splints are more widely implemented to manage injuries in these zones. This approach allows for controlled early mobilization and has been associated with improved clinical outcomes (Figure 2).[22,23]

Given the limited number of studies on extensor tendons, small sample sizes, variations in surgical and rehabilitation protocols, and the diversity in methods of complication assessment, the focus should shift from merely reporting incidence rates to identifying factors contributing to postoperative complications. This approach aims to enhance the ability to predict clinical outcomes, manage modifiable factors, and optimize the initial intensity of rehabilitation and follow-up care. This study highlights two key factors associated with complications: injury severity, a nonmodifiable factor, and smoking, a modifiable risk factor.

Higher mHISS scores reflect more severe trauma and extensive tissue damage, which can trigger an intensified inflammatory response and granulation tissue formation. These biological processes increase the likelihood of adhesion development, the most frequently observed complication following tendon repair.[25] This finding is in line with the results of Urso-Baiarda et al.,[11] who reported that mHISS scores significantly predicted return-to-work duration in hand and forearm injuries. Similarly, Gong et al.[26] also demonstrated that higher mHISS scores were significantly associated with an increased risk of tendon adhesion formation and longer recovery times in patients with extensor tendon injuries. Consistent with these results, the present study found that greater injury severity predicted postoperative complications as quantified by mHISS. Accordingly, patients with high initial injury severity scores should be prioritized for intensive rehabilitation and monitored under strict follow-up protocols to reduce complication rates and improve functional outcomes.

Smoking was also identified as a critical factor associated with complications, in line with existing literature.[13,27] Smoking adversely impacts tissue healing by reducing blood supply and causing tissue hypoxia, which accelerates fibroblast degeneration and disrupts fibril organization, increasing the likelihood of gaps at the repair site.[28] These gaps allow infiltration of inflammatory tissues and infected lesions, resulting in edema at tendon ends and eventual adhesion formation during the fibroblastic phase.[29] Moreover, toxic components of cigarette smoke, particularly nicotine, carbon monoxide, and hydrogen cyanide, contribute to impaired healing through various mechanisms. Nicotine acts as a potent vasoconstrictor, reducing nutritional blood flow to the skin and soft tissues and causing ischemia. It also increases platelet adhesiveness, promotes microvascular thrombosis, and suppresses the proliferation of fibroblasts, macrophages, and red blood cells, all essential for tissue repair. Carbon monoxide decreases oxygen transport and utilization, while hydrogen cyanide inhibits oxidative metabolism at the cellular level, further exacerbating hypoxia and tissue degeneration.[30] Addressing smoking as a modifiable risk factor is not merely a recommendation but an imperative for improving the standard of care in tendon repair surgery and ensuring better long-term functional outcomes. In the management of patients with tendon injuries, it is imperative to begin by educating them about the adverse effects of smoking on healing. When appropriate, referring the patient to smoking cessation clinics, including during the perioperative period, should be considered an essential part of the treatment strategy.

This study had several limitations. First, the retrospective design inherently carries risks of selection bias and limits the ability to establish causal relationships. Second, complications such as adhesions, tendon tethering, or nail deformities were assessed clinically, which may have introduced observer bias. Third, the severity of complications was not graded, limiting the ability to analyze the clinical impact of each complication in more detail. Finally, smoking status was self-reported, which may have underestimated its true impact on complications due to reporting bias. The current study's strengths included large sample size and consistent surgical and rehabilitation procedures conducted by the same team, thereby minimizing confounding factors related to surgery and rehabilitation. Additionally, patients with concomitant nerve, bone, and flexor tendon injuries were excluded, allowing for focused examination solely on extensor tendon injuries.

In conclusion, this study highlights the critical role of both modifiable and nonmodifiable factors in determining postoperative outcomes following extensor tendon repair. Smoking and injury severity were identified as significant predictors of complications, emphasizing the necessity of targeted strategies such as smoking cessation and intensive rehabilitation for high-risk patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Research design: A.Ç.U., F.G.Y., H.M.E., B.B., H.B.; Data collection: A.Ç.U., T.G., B.Y.; Supervision: B.B., H.B., R.E.Ü.; Validation: F.G.Y., H.M.E., T.G.; Visualization: H.M.E., B.Y., R.E.Ü.; Writing-original draft: A.Ç.U., F.G.Y., H.M.E., T.G.; Writing-review & editing: B.B., H.B., R.E.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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