Factors predicting reoperation after hand flexor tendon repair

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ABSTRACT

BACKGROUND: This single-center, retrospective study aims to analyze the sociodemographic, injury characteristics, and the total number of lost working days of patients undergoing hand flexor tendon repair and to identify factors predicting reoperation.

METHODS: Hand flexor tendon repairs conducted using a four-strand modified Kessler core suture with early rehabilitation from January 2013 to December 2016 were included in this study. The variables evaluated in this study were patient sociodemographic and injury characteristics, number of lost working days, and reoperations because of rupture and/or adhesion formation. Injury severity was determined using Modified Hand Injury Severity Scoring (MHISS). Binary logistic regression analysis was conducted to identify the predictors of reoperation.

RESULTS: A total of 194 patients were included in this study, who had experienced 329 tendon injuries. Participants were young (mean age, 31.8), mostly male (79.4%), and mostly blue-collar workers (50.0%). Most patients had a zone 2 injury affecting a single digit of the dominant hand. The mean MHISS value was 46.6, and the mean time to return to work was 114.0 days. A total of 37 (19.1%) patients required reoperation because of rupture and/or adhesion formation. Smoking, zone 2 injury, and high MHISS value were negative predictors of reoperation.

CONCLUSION: To minimize the need for reoperation, surgeons and rehabilitation teams should take special care of patients with zone 2 injuries, high MHISS values, and smoking history.

Keywords: Flexor tendon repair; hand; outcome; reoperations; return to work; trauma.

INTRODUCTION

The outcomes following flexor tendon repair of a finger are sometimes suboptimal, despite proper management, including the appropriate surgical method and rehabilitation program, and further surgery may be required.[1,2] The average reoperation rate is approximately 6% but can be as high as 20% or more.[3,4] Rupture and adhesion formation following an initial repair are two common reasons for reoperation.[5] Secondary surgery produces a higher economic burden, which comprises the direct cost associated with treatment and the indirect cost of lost working days.[6] In addition to the economic burden of secondary surgeries on the health-care system, they generally have less favorable results than primary surgeries.[7,8] Therefore, a better understanding of the variables that may contribute to the need for reoperation is helpful in predicting the risks of poor outcomes and determining their proper management. Several individual, injury, and work-related factors, such as smoking, concomitant injuries, the zone of injury, mechanism of injury, and age, in addition

to the surgery and rehabilitation program, may be associated with poor outcomes and reoperation. However, many potential factors seem to have inconsistent and even contradictory associations with complications and reoperations.[2,7–11]

The aims of this study were to identify the sociodemographic and injury characteristics of patients who underwent primary flexor tendon repair with a four-strand modified Kessler core suture and received early rehabilitation and to determine the prevalence of and risk factors for reoperation because of rupture and/or adhesion formation. In addition, this study aimed to compare the total number of lost working days among patients with and without reoperations, to evaluate whether reoperation resulted in more lost working days and, consequently, a higher indirect economic burden.

MATERIALS AND METHODS

This study was approved by the local ethics committee of Ankara Numune Training and Research Hospital (date: 12.07.2017, no: E-17-1441).

Study Design

A retrospective study was conducted, which included patients who were treated for flexor tendon injuries from January 2013 to December 2016. All patients who underwent flexor tendon repair and rehabilitation by an experienced surgical and rehabilitation team, and who had at least a 12-month follow-up, were identified from medical records. Inclusion criteria were defined as having primary flexor tendon injury repair using a four-strand modified Kessler core suture and early rehabilitation (combined Kleinert and Duran protocols).[4] Exclusion criteria were rheumatoid arthritis, severe comorbidities that were expected to have an extensive influence on time off work, extensor tendon repair, associated phalangeal fractures or nerve injuries, incomplete data, amputations, replantation and bilateral injuries, non-adherence to treatment, or age below 16 years. Patients were also excluded from this study if they had complications other than rupture or adhesion formation, but not if they had associated digital nerve and unilateral digital vessel injuries.

Assessments

Sociodemographic characteristics were recorded from patient files and included age at injury, gender, occupation, employment type, smoking status, drug abuse history, and comorbidities. Data on occupation status were categorized into the blue-collar (laborers, production, tradespeople, and transport workers), white-collar (professionals, service, clerical, and sales workers), and non-employment groups. Economically inactive patients, such as students, housewives, or retired individuals, were classified into the non-employment group. The employment type was categorized into two further groups (self-employed or employee).

The clinical and injury characteristics included in this study were

the nature of injury, mechanism of injury, hand dominance, side of the injured hand, number of involved digits and tendons, severity of injury, concomitant digital nerve injury, timing of surgery, zone of injury, distribution of fingers and tendons affected, and number of lost working days based on formal documentation in patient records. Data about the nature of injury were grouped into work-related injury, traffic accidents, suicide, assault, and unspecified reasons based on the formal records. Data pertaining to the mechanism of injury were categorized into either the crush group, which included saw, fan, lathe, and crush mechanisms, or the sharp group, which included glass, knives, metal, and broken porcelain mechanisms.

The Modified Hand Injury Severity Score (MHISS) was used to evaluate the severity of the injury.[12] Patient medical notes of the injury that were recorded upon arrival at the emergency room, and those of the findings during surgery, were reviewed. These notes were translated into scores using the MHISS system, which assesses four domains of the forearm, wrist, and hand anatomies, including integument (nail and skin), skeletal (bone and ligament), motor (tendon), and neurovascular (vascular and nerve). Each injured structure was assigned an absolute value, which was weighted according to functional importance. The MHISS value was classified as minor (<20), moderate (21–50), severe (51–100), or major (>101).

Surgical Technique

All flexor tendon repairs were carried out under general anesthesia or an axillary block using a four-strand modified
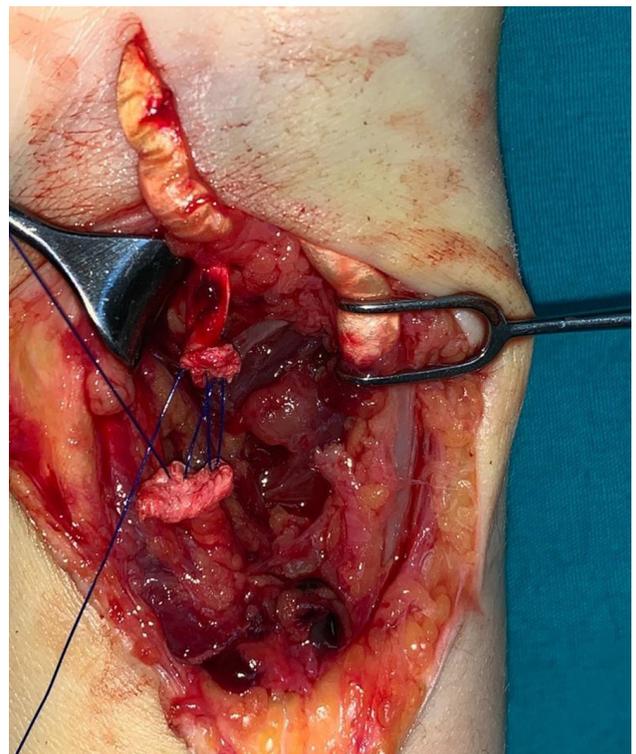
Figure 1. Flexor tendon repair with a four-strand modified Kessler suture technique.

Kessler technique with 3.0 polypropylene (Fig. 1). The core repair was strengthened using a running circumferential suture with 6.0 polypropylene. In all cases, both the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS), or the flexor pollicis longus (FPL), were repaired and the pulleys A2, A3, and A4 were preserved or repaired. All digital nerve and arterial injuries were repaired using a standard microsurgical technique with 9.0 polypropylene.

Postoperative Rehabilitation Protocol

After surgery, a forearm splint was applied with the wrist in 10°–30° flexion, metacarpophalangeal joints in 50°–80° flexion, and interphalangeal joints in full extension. Rehabilitation combining "controlled passive motion" and "passive flexion and active extension" protocols" were used (combined Kleinert and Duran protocols). All patients commenced finger motion on postoperative day 3, regardless of digital nerve repairs, and received regular visits that were scheduled at least 1–2 times per week. During the first three weeks of the postoperative period, patients were instructed to perform 10 each of active extension, passive flexion, and controlled passive extension exercises of the interphalangeal joint. After the sutures were removed, the incision zone was massaged. Active finger hook flexion and fist formation in the splint were commenced at the end of week 3. Active wrist exercises were added to the program at the end of week four. The splint was removed at the end of week six but was used when sleeping or outdoors for an additional two weeks. After week eight, progressive strengthening exercises commenced. Edema control and scar massage were continued as needed.

Outcome Assessment

Our aim was to identify factors associated with complications of flexor tendon injury that necessitated reoperation. Participants requiring secondary surgery (re-repair, tenolysis, and tenolysis with re-repair) because of rupture and/or adhesion formation that arises from the primary tendon repair were recorded. The number, type, and timing of reoperations were described.

Statistics

Sociodemographic and injury characteristics were reported using descriptive statistics (mean, standard deviation, range, number, and percentage). The Shapiro–Wilk test was used to evaluate the normality of the data distribution. The Mann–Whitney U test, Student's t-test, and Chi-squared or Fisher's exact test were used to compare continuous or nominal variables between groups, as appropriate.

Variables that were at least moderately associated with reoperation in univariate analysis (MHISS value, current smoker, zone 2 injury, and work-related injury) were selected and assessed using binary logistic regression analysis. Analyses were performed using IBM SPSS version 21.0 software (IBM Corporation, Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

RESULTS

Patient Sociodemographic Characteristics

A total of 821 patients who underwent primary flexor tendon repair were identified in this study. After exclusion criteria were applied, 329 digits were included from 194 patients with an age range of 16.0 to 72.0 years (mean, 31.8 years). A detailed flowchart of patients included in the study is provided in Fig. 2. Overall, 153 patients dropped out of the follow-up rehabilitation without specifying a reason; their characteristics were similar to the other patients, except for MHISS values, which were significantly lower (mean, 29.9, range, 11–93; $p < 0.001$).

Overall, 154 (79.4%) patients were male. Regarding the occupation status, 97 (50.0%) patients were blue-collar workers, nine (4.6%) were white-collar workers, and 88 (45.4%) were unemployed; among the workers, 27 (25%) were self-employed. Overall, 97 (50.0%) patients were current smokers, six (3.1%) patients were drug abusers, 32 (16.4%) patients had at least one comorbid diagnosis, five (2.5%) patients had at least two comorbid diagnoses, and 6 (3.1%) patients had diabetes mellitus.

Injury Characteristics

The causes of injury were work-related accidents among 34 patients, assaults among 12 patients, suicide attempts among two patients, and traffic accidents among one patient. Overall, 147 patients were categorized into the sharp injury mechanism group, and most were injured by glass objects (n=88, 45.3%), followed by knives (n=54, 27.8%). The dominant hand was affected in 98 patients (50.5%). Single- or multiple-digit injuries occurred in 116 and 78 patients, respectively. The mean number of involved tendons was 2.33 (range, 1–8), and the mean MHISS value was 46.6 (range, 11–100). Minor, moderate, and severe injuries occurred in 20, 105, and 69
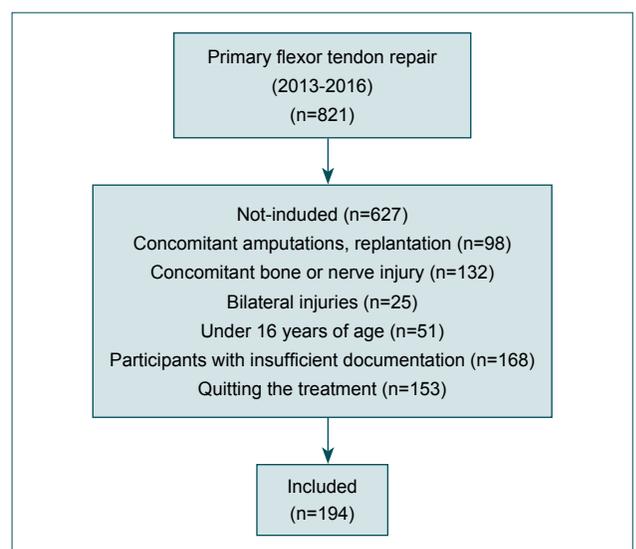

Figure 2. A detailed flowchart of patients.

patients, respectively. Overall, 54 (27.8%) patients had unilateral or bilateral digital nerve injuries. The mean time period between injury and repair was 2.68 days (range, 1–26 days); 83 patients underwent repair on the day of injury (Table 1).

Zone 2 injuries were most common (58.2%), followed by zone 5 (20.1%), zone 1 (9.3%), zone 3 (7.7%), and zone 4 (4.6%). The little finger was most frequently affected (83 patients, 27.3%), followed by the middle finger (77 patients, 25.4%). Injuries affected only the FPL in 48 digits, only the FDS tendon in 42 digits, only the FDP tendon in 98 digits, and a combination of the latter two tendons in 141 digits.

The overall rate of reoperation was 19.1% (n=37). Re-repair, tenolysis and combined tenolysis with re-repair were performed in 32.4% (n=12), 51.4% (n=19), and 16.2% (n=6) of reoperations, respectively, after a mean of 27.4 days (range, 2–60), 124.9 days (range, 60–365), and 69.8 days (range, 30–104) following the primary tendon repair, respectively. A total of nine patients (24%) had at least two reoperations after the primary repair.

Group Comparisons

Data on the number of lost working days were available from the formal documentation of only 79 patient records. The mean time to return to work was 114.0 days (range, 10–400) overall, and was significantly higher among the patients who underwent reoperation (mean, 189.0; range, 20–400) compared with the patients who did not (mean, 86.8; range, 10–365; p<0.001, Fig. 3).
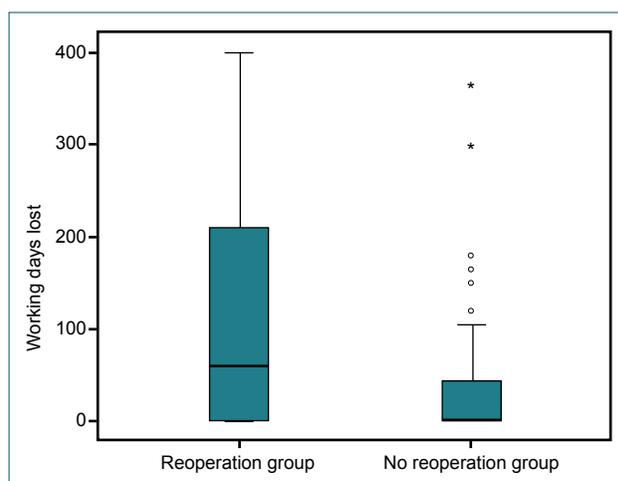

Figure 3. Comparison of time to return to work between the group with reoperation and with no reoperation. Box limits indicate the 25th and 75th quartile, and the whiskers show the maximum and minimum scores. The line within boxes is the median. Circle and star indicate outlier data.

Patients who underwent reoperation were more likely to be current smokers, have higher MHISS values and have zone 2 injuries than the patients who did not. Data reflecting the nature of the injury were categorized into "work-related" and "non-work related" based on formal records because there were inadequate numbers to perform Chi-squared tests. Work-related injuries were significantly more common among patients who underwent reoperation (32.4%) compared with the patients who did not (14.0%; p=0.008). There

Table 1. Group comparisons of the sociodemographic and injury characteristics

	No reoperation	Reoperation	Total	p
Age (years), mean±SD	34.3±13.9	31.7±13.1	31.8±13.3	0.210
Female gender, n (%)	35 (22.6)	5 (12.5)	40 (20.6)	0.235
Occupation				0.593
White-collar workers, n (%)	7 (4.5)	2 (5.4)	9 (4.6)	
Blue-collar workers, n (%)	76 (48.4)	21 (56.8)	97 (50.0)	
Unemployed, n (%)	74 (47.1)	14 (37.8)	88 (45.4)	
Current smoker, n (%)	71 (45.2)	26 (70.3)	97 (50.0)	0.021*
Drug abuse history, n (%)	6 (3.8)	0 (0)	6 (3.1)	0.227
Comorbidity, n (%)	26 (16.6)	6 (16.2)	32 (16.5)	0.960
Work-related injury, n (%)	22 (14.0)	12 (32.4)	34 (17.5)	0.008*
Sharp mechanism of injury, n (%)	26 (70.3)	121 (77.1)	147 (75.8)	0.385
Dominant hand injury, n (%)	76 (48.4)	22 (59.5)	98 (50.5)	0.226
MHISS value, mean±SD	44.0±22.0	57.3±23.6	46.6±22.9	0.001*
Digital nerve injury, n (%)	40 (25.5)	14 (37.8)	54 (27.8)	0.131
Timing of surgery (days after injury), mean±SD	2.8±4.9	1.9±2.4	2.6±4.5	0.927
Zone 2 injury, n (%)	79 (50.3)	32 (86.5)	113 (58.2)	0.002*

MHISS: Modified Hand Injury Scoring System; SD: Standard deviation.

Table 2. Logistic regression analysis to identify factors that predicted reoperation

Independent variables	Beta	Standard error	Exp(B)	p
Reoperation group (n=37)				
Constant	4.891	0.781	133.148	<0.001
Current smoker	-1.020	0.431	0.361	0.018
Modified Hand Injury Scoring System value	-0.027	0.009	0.974	0.003
Zone 2 injury	-1.908	0.531	0.148	<0.001
Work-related injury	-0.774	0.477	0.461	0.105

Exp(B): Odds ratio.

were no significant differences between the two groups concerning age, gender, occupation, drug abuse history, comorbidity, mechanism of injury, dominant hand injury, concomitant digital nerve injury, or timing of surgery (Table 1).

The binary logistic regression analysis demonstrated that higher MHISS values, smoking, and zone 2 injuries were associated with reoperation (Table 2).

DISCUSSION

Rupture and adhesion formation after flexor tendon repair remain challenging complications despite developments in surgical techniques and postoperative rehabilitation protocols. The sociodemographic and injury data reported in this study were mostly similar to others; however, the 19.1% rate of reoperation was higher than previous reports in general. Patients who underwent reoperation had a significantly longer time off work compared with the patients who did not. The logistic regression analysis demonstrated that smoking, zone 2 injuries, and high MHISS values had significant and independent negative impacts on reoperation. The work-related injury was univariately associated with reoperation but did not significantly contribute to the regression model. Moreover, age, the timing of surgery, comorbidity, and presence of digital nerve injury, which had previously been found to affect the risk of reoperation, did not differ between groups.[6]

Consistent with the previous studies, the findings obtained in this study demonstrated that most of the patients with flexor tendon injuries were young (mean age, 31.8), male (79.4%), and blue-collar workers (50.0%).[13,14] Proper injury management to optimize the long-term functional outcomes and economic burden are important among patients with these characteristics, who potentially have a prolonged working life expectancy requiring adequate hand function.[15] The rate of work-related injuries based on formal records in our study was 17.5%, which was markedly lower than that reported in previous studies.[13,16] Hand injuries frequently occur when performing a manual task at home or, in particular, at work.[13,17] The reason for our low rate of work-related injuries may be a lack of available formal records, which may be explained by various legal or economic challenges, and the unavailability

of patient self-reported data. These records must be very strictly maintained to enable the application of sanctions to employers and prevent future work-related accidents.

We found that the dominant hand (50.5%) was affected somewhat more often than the non-dominant hand, which was similar to the findings reported by Thangavelu et al.,[14] although other studies reported similar or less frequent rates.[13,17,18] The dominant hand is usually injured when using a sharp object directly or catching a falling object. The non-dominant hand provides support when performing tasks, such as using a knife or saw, and is often injured while assisting the dominant hand. Therefore, the different rates of injury to either hand across studies are not surprising because patients with different mechanisms of injury were included.

Similar to previous studies, zone 2 injuries (58.2%) were most common, which is probably because this is the longest zone, which had tendons confined to a narrow area and no protective tissues.[13] The second most frequently affected zone was 5 (20.1%). We found that little and middle fingers were injured the most. The index or little finger in zone 2 is most injury prone, whereas, in zone 5, injury is more likely to affect the middle finger.[19] Our findings supported the association between affected zones and fingers.

Combined FDS and FDP injuries were most common in our study, followed by isolated FDP injuries, then isolated FDS injuries. These findings, which are generally compatible with the existing literature, can be explained because the FDP tendon is more superficial in zone 2, which is the longest and most injured zone, and zone 1 only contains the FDP tendon.[13,20]

The overall reoperation rate in our study was 19.1%, which is generally higher than previous reports.[6,21] Patients who dropped out of the follow-up rehabilitation had lower MHISS values; therefore, these patients would be more likely to have good functional results or only small residual functional deficits with little follow-up required. This situation may have presumably resulted in bias leading to the overestimation of the reoperation rate.

The mean time to return to work was 114.0 days, based on the formal records for 79 patients, which was higher than previous studies.[22,23] Only the patients who had available data reflecting their time off work from National Health Insurance records in our country were evaluated. Our findings may be explained by the substantial number of blue-collar workers (87.3%) included, who have been found to return to work later than white-collar workers and the patients who are self-employed.[24] Blue-collar workers engage in more manual labor compared with white-collar workers and receive greater disability benefits through insurance compared with self-employed patients, which may reduce their ability to return to work. Consistent with previous studies, the time off work was significantly higher in the reoperation group.[17] Therefore, to reduce time off work and the overall cost of health insurance, it is necessary to determine the factors affecting reoperation.

Various sociodemographic, injury, psychosocial, and economic factors, as well as surgical and rehabilitation protocols, may be associated with the occurrence of complications and the need for reoperation after flexor tendon repair.[6,25] However, as a result of the limitations of our dataset, we focused our evaluation on the effects of sociodemographic and injury characteristics on reoperation in patients who underwent similar surgical and rehabilitation protocols. We found that the reoperation group had significantly higher MHISS values, smoking rates, zone 2 injuries and work-related injuries than the group who did not undergo reoperation. Logistic regression analysis demonstrated that work-related injuries did not contribute to the overall results.

In the combined model, zone 2 injuries, higher MHISS values, and smoking had significant negative effects on reoperation. Zone 2 injury is a well-known risk factor for poorer outcomes.[2,7] This is related to the difficult anatomy of this zone, which includes the FDS and FDP within its narrow fibro-osseous sheath.[26] Therefore, our finding that zone 2 injury was associated with complications and reoperation compared with other zones was expected.

MHISS, which indicates the initial anatomic injury severity, provides an objective and comprehensive assessment.[27] MHISS is useful for predicting the duration of lost working time,[28] functional recovery[29] and future health-related quality of life.[30] We demonstrated that it is also useful to predict reoperation. This is reasonable, as the injury severity probably increases the edema, pain, and subsequent fibrosis, leading to an increased risk of complications and associated reoperations. The relationship between hand injury severity and reoperation could be helpful for the initial identification of higher-risk patients who might benefit from additional support.

The negative effects of smoking on tendon healing have been demonstrated in many studies.[2,31,32] Our results confirmed that smoking was a negative predictor of reoperation after flexor tendon repair, and was the only modifiable factor in our study. A single cigarette has been implicated in reduced blood supply and volumetric flow, leading to increased vascular resistance and overall tissue hypoxia.[33] In our clinic, patients are given personal advice and encouragement to stop smoking. However, some patients do not attempt to stop smoking, which may be because they do not understand its importance, have had negative life events that reinforce smoking, or have personal traits associated with continued smoking, such as decreased self-esteem, increased depression, or maladaptive coping and health behaviors. The high rate of reoperations in smokers may be explained by these features, rather than the direct effect of smoking. Therefore, it might be more appropriate to evaluate smoking together with personal factors that affect adherence to rehabilitation. In addition to advising patients to stop smoking, the complications and associated operations could be reduced by supporting smoking cessation, for example, by providing counseling for nicotine replacement or behavioral therapy.

Our study has several limitations. First, we did not evaluate functional results but only analyzed reoperation because of the data that were available. The need for reoperation is an acceptable outcome indicator, but may not be optimal. In addition, subjective and individual factors that might affect the decision to undergo reoperation could not be evaluated because of the limitations of our dataset. Finally, data were obtained from a single center; therefore, it is difficult to generalize our results.

Our study has some strengths. We included patients who underwent surgery and rehabilitation by the same experienced team in a single-center, thereby eliminating confounding variables related to the surgical technique or rehabilitation protocol. We also measured the number of lost working days based on formal records rather than self-reported data, which prevented bias.[34] In addition, the severity of the injury was measured using the MHISS, which is an objective assessment that is designed specifically for hand injuries. A higher severity injury score was correlated strongly with higher functional impairment.[28,29]

Conclusion

Zone 2 injuries, high MHISS values, and smoking were predictors of reoperation after primary flexor tendon repair. However, zone 2 injuries and high MHISS values cannot be modified, and can only be used as predictive indicators for the initial selection of patients who should be followed-up closely and managed comprehensively. However, the complications and associated operations can be reduced by supporting smoking cessation. In routine practice, many extra approaches, rather than just advice for stopping smoking, may lead to more positive results.

Ethics Committee Approval: Approved by the local ethics committee (date: 12.07.2017, no: E-17-1441).

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ORİJİNAL ÇALIŞMA - ÖZET

El fleksör tendon onarımı sonrası reoperasyonu öngören faktörler

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AMAÇ: Bu tek merkezli, geriye dönük çalışma, el fleksör tendon onarımı geçiren hastaların sosyodemografik, yaralanma özelliklerini ve toplam kayıp iş günlerini analiz etmeyi ve reoperasyonu öngören faktörleri tanımlamayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Ocak 2013–Aralık 2016 tarihleri arasında erken rehabilitasyona tabi, dört geçişli modifiye Kessler kor dikiş kullanılarak yapılan el fleksör tendon onarımları dahil edildi. Bu çalışmada değerlendirilen değişkenler; hasta sosyodemografik ve yaralanma özellikleri, kayıp iş günü sayısı ve rüptür ve/veya adezyon oluşumu nedeniyle yapılan reoperasyonlardı. Yaralanma ciddiyeti, Modifiye El Yaralanması Ciddiyet Skorlaması (MEYCS) kullanılarak belirlendi. Reoperasyonun öngörücülerini belirlemek için ikili lojistik regresyon analizi yapıldı.

BULGULAR: Toplam 329 tendon yaralanması geçirmiş 194 hasta çalışmaya dahil edildi. Katılımcılar genç (ortalama yaş, 31.8), çoğunlukla erkek (%79.4) ve mavi yakalı çalışanlardı (%50.0). Hastaların çoğu dominant elin tek parmağını etkileyen zon 2 yaralanmasına sahipti. Ortalama MEYCS değeri 46.6 ve işe geri dönüş süresi 114.0 gündü. Toplam 37 (%19.1) hastaya rüptür ve/veya adezyon oluşumu nedeniyle reoperasyon gerekti. Sigara içimi, zon 2 yaralanması ve yüksek MEYCS değeri, reoperasyonun negatif belirleyicileriydi.

TARTIŞMA: Reoperasyon ihtiyacını en aza indirmek için, cerrahlar ve rehabilitasyon ekibi, bölge 2 yaralanması, yüksek MEYCS değerleri ve sigara içme öyküsü olan hastalara özel dikkat göstermelidir.

Anahtar sözcükler: El; fleksör tendon onarımı; işe dönüş; reoperasyonlar; sonuç; travma.