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Is microsurgical experience essential in Zone II flexor tendon injuries?

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ABSTRACT

Objectives: This study aims to investigate whether microsurgical experience was necessary for the treatment of Zone II flexor tendon injuries.

Patients and methods: Between October 2018 and October 2021, a total of 73 Zone II flexor tendon injuries in 71 patients (53 males, 18 females; mean age: 39.6±12.1 years; range, 21 to 57 years) who underwent surgical intervention in our center were retrospectively analyzed. All patients in the study had flexor digitorum profundus (FDP) tendon injury. The clinical outcomes of patients with digital artery injury, nerve injury or phalanx fracture accompanying FDP tendon injury were evaluated separately according to the American Society for Surgery of the Hand (ASSH) scores. The scores of multiple injuries accompanying FDP tendon injury in patients with FDP+flexor digitorum superficialis (FDS)+digital nerve injury and FDP+FDS+digital artery+nerve injury were evaluated.

Results: The mean ASSH score was 69.4±28.2 in the group with FDP tendon injury accompanying digital nerve injury and 62.9±19.7 in the group with FDP tendon injury and digital artery injury. The clinical outcomes were significantly lower in patients with digital nerve injury and digital artery injury respectively, compared to patients without accompanying injuries ($p=0.029$ and $p=0.012$, respectively). The lowest mean score (45.3±10.2) was in patients with fracture accompanying FDP tendon injury and ASSH score was significantly lower than in patients without fracture ($p<0.001$).

Conclusion: Zone II flexor tendon injuries are frequently accompanied by digital artery or nerve injuries, which usually require microsurgical repair. If left untreated, treatment outcome may be poor. Surgical centers and departments undertaking the treatment of flexor tendon injuries should be able to perform microsurgery.

Keywords: Arterial injury, bone fractures, flexor tendon injury, microsurgery, nerve injury, treatment outcome.

Flexor tendon injuries account for 1% of hand injuries and occur in 4.9 to 7.0 of 100,000 individuals.[1,2] Although they are not the most common hand injuries, the treatment of flexor tendon injuries can be challenging. In particular, during and after surgery of Zone II injuries, surgery and rehabilitation protocols must be strictly followed. Previous studies have repeatedly shown that the suture technique used during the repair, suture material, preservation of the pulley system, and patient demographics significantly affect the outcomes.[3-5]

There are digital artery and nerve structures at a proximity of 1 to 2 mm to the flexor tendons of the hand.[6] Due to this anatomical proximity, flexor tendon injuries are likely to be accompanied by digital artery and nerve injuries. Although there are studies reporting how functional outcomes are affected when flexor tendon injuries are accompanied by digital nerve and digital artery injuries, there are no studies reporting how often injuries of these microsurgically-treated structures accompany tendon injuries.[7-9]

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Flexor tendon injuries are primarily treated by hand surgeons in many countries; however, this is not always possible in routine clinical practice and such patients may be treated by orthopedic surgeons, general surgeons, and rarely emergency room physicians who do not prioritize microsurgery training during their residency training.[10,11] However, in flexor tendon injuries, it is unacceptable that a digital nerve injury that may be missed in the preoperative examination of the patient is noticed intraoperatively, and the patient is left untreated due to the lack of microsurgery training.

In the present study, we, therefore, aimed to investigate the frequency of digital artery and nerve injuries accompanying flexor tendon injuries and to identify whether microsurgery experience is necessary in the treatment of flexor tendon injuries.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Private Silivri Anadolu Hospital, Department of Orthopedics and Traumatology between October 2018 and October 2021. Patients who were operated for Zone II flexor tendon injury were included. Demographic characteristics of the patients, site of injury, accompanying injuries, surgical procedures, postoperative range of motion (ROM), and treatment outcomes of additional injuries were evaluated.

Inclusion criteria were patients aged >18 years with Zone II flexor tendon injuries and those with accompanying injuries such as vascular and nerve injuries, bone fractures, and skin defects. Exclusion criteria were patients who underwent surgery but were not followed postoperatively, patients who did not consent to participate, patients with bilateral digital artery injury or crush injury with no extremity circulation, and patients with intraarticular fractures. The minimum follow-up period was six months for each patient. A total of 10 patients, including two who were operated but were not followed postoperatively and eight with no extremity circulation were excluded from the study. Finally, a total of 73 fingers of 71 patients (53 males, 18 females; mean age: 39.6±12.1 years; range, 21 to 57 years) were included in the study.

Surgical procedures

All patients were operated by a single orthopedics and traumatology specialist who is experienced in hand and microsurgery. In all flexor tendon injuries (flexor digitorum profundus [FDP] and flexor digitorum superficialis [FDS]), core sutures were placed with the four-strand cruciate suture technique using 4-0 polydioxanone (Ethicon Inc., PDS©, Johnson & Johnson Medical N.V., Machelen, Belgium) and epitendinous repair was performed with 6-0 polydioxanone. The incisions were enlarged with zig-zag incisions according to the state of exploration during the operation. Accompanying digital nerve injuries were repaired with the epineural technique using appropriate sutures. Grafting was performed acutely in cases requiring nerve grafts. End-to-end anastomosis was performed for accompanying digital artery injuries. The vein graft was interposed in cases where the vascular damage was in the long segment. Kirschner wires were used for the osteosynthesis of all bone fractures. A dorsal blocking orthosis was used in all injuries. Early mobilization, according to the early active motion protocol, was carried out beginning from day three after the operation as tolerated by the patient. Although the rehabilitation protocol was usually the same for each patient, the final decision was made considering the accompanying injuries and the patient's level of pain and edema. Dorsal blocking orthoses were used in all patients for four to five weeks after surgery.

Clinical evaluation

The digital ROM was evaluated at the six-month controls of the patients by the treating surgeon. The total active motion (TAM) was determined as the sum of the ROM values of the metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints. A percentage was obtained by comparing the TAM value with the uninjured side. These percentage values were evaluated as follows: 100% excellent, >75% good, >50% fair, and <50% poor according to the American Society for Surgery of Hand (ASSH) scoring system. Nerve healing levels of patients with digital nerve injury were evaluated with the static Two-Point Discrimination (s2PD) test. In addition, the results of patients with and without bone fractures and the effect of digital artery injury were compared. Additional complications during the follow-up period were recorded.

Statistical analysis

A *post-hoc* power analysis revealed that 73 participants yielded 96% power. Statistical analysis was performed using the SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD), while categorical data were expressed in number and frequency. Continuous variables were analyzed using the Student t-test for normally distributed data or Mann-Whitney U test for non-normally distributed data. A simple linear regression analysis was used to examine bivariate relationships between each variable and the outcome variable (ASSH score). A p value of <0.05 was considered statistically significant.

RESULTS

Demographic characteristics of the patients are shown in Table I. All patients were operated within the first 24 h after injury. The minimum follow-up time was six months. The finger most commonly injured was the index finger with a frequency of 31.50%. Two fingers were injured in two of the patients. A total of 90.42% of the patients had injuries requiring a microsurgical intervention. The

TABLE I
Demographic and clinical characteristics of patients (n=71)

	n	%	Mean±SD	Range
Age (year)			39.6±12.1	21-57
Sex				
Male	53	74.65		
Female	18	25.35		
Follow-up time (month)			9.3±7.5	6-21
Hand dominance				
Dominant	56	76.76		
Non-dominant	17	23.23		
Injured finger				
Thumb	5	6.84		
Index	23	31.50		
Middle	19	26.02		
Ring	15	20.54		
Little	11	15.06		
Multi digit injury	2			

SD: Standard deviation.

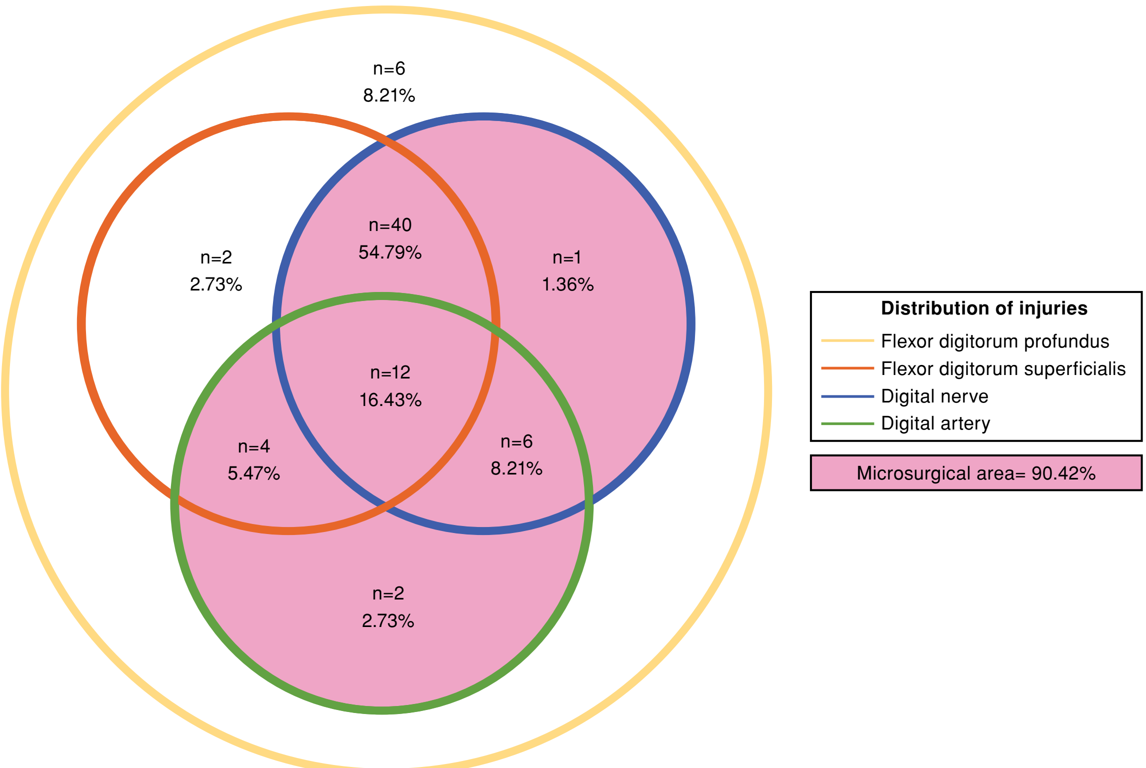

FIGURE 1. Classification of injury location.

distribution of accompanying injuries in FDP tendon injury is shown in Figure 1.

Table II shows the results of the bivariate analysis of injuries accompanying FDP tendon injury and ASSH mean scores. A total of 80.82% of FDP tendon injuries were accompanied by digital nerve injuries, while 79.45% of them were accompanied by FDS tendon injuries. In addition, 93.22% of digital nerve injuries were repaired by direct repair, and nerve autografts were used for the rest. There was an accompanying bone fracture in 10.96% of the patients. The group with the lowest mean ASSH score was the group with bone fracture with a mean of 45.3±10.2, and this group had a significantly lower ASSH score than the patients without bone fracture (p<0.001). Patients without accompanying FDS tendon injury had a significantly higher score than those with FDS injury (p=0.003), and FDS repair did not affect the results in patients with FDS tendon injury (p=0.075). The mean ASSH score was lower in the group with nerve injury than in the group without nerve injury (p=0.029). Among the group with injury, those who were repaired with a graft had a significantly lower score (p<0.001). In cases with accompanying digital artery injury, the results were significantly worse

TABLE II
Bivariate analysis of injuries accompanying FDP tendon injury

	Frequency		ASSH Score		
Injured structure	n	%	Mean±SD	SEβ	*p*
FDS uninjured	15	20.54	72.4±25.4	7.18	**0.003**
FDS injured	58	79.45	67.2±22.8		
FDS repaired	47	81.03	66.6±24.7	8.36	0.075
FDS unrepaired	11	18.96	70.2±26.9		
Digital nerve uninjured	14	19.17	74.6±30	7.6	**0.029**
Digital nerve injured	59	80.82	69.4±28.2		
Direct repair	55	93.22	70.8±25.6	4.2	**<0.001**
Graft repair	4	6.77	50.2±10.8		
Digital artery uninjured	49	67.12	72.8±22.8	6.48	**0.012**
Digital artery injured	24	32.87	62.9±19.7		
Digital artery repaired	11	45.83	58.8±18.2	5.66	0.186
Digital artery unrepaired	13	54.16	66.5±21.4		
Fracture					
Present	8	10.95	45.3±10.2	0.406	**<0.001**
Absent	65	89.04	70.6±24.9		

FDP: Flexor digitorum profundus; ASSH: American Society for Surgery of Hand; SD: Standard deviation; SE: Standard error; FDS: Flexor digitorum superficialis.

TABLE III
Multiple injuries accompanying FDP tendon injury

	Frequency		ASSH Score		
Injured structure	n	%	Mean±SD	SEβ	*p*
Flexor digitorum superficialis					
Digital nerve injury	52	71.23	66.2±21.8	8.46	
Flexor digitorum superficialis					
Digital nerve injury					
Digital artery injury	12	16.43	58.6±16.9	6.18	**0.124**

FDP: Flexor digitorum profundus; ASSH: American Society for Surgery of Hand; SD: Standard deviation; SE: Standard error.

(p=0.012); however, digital artery repair had no significant effect (p=0.186).

There was no significant difference in the ASSH score between the group with FDS and digital nerve injury and the group with FDS and digital artery-nerve injury (p=0.124). The results of this comparison are shown in Table III.

The mean s2PD score of 59 patients with digital nerve injury was 5.27±1.92 during follow-up. In this group, painful neuroma was observed in four patients. Neurolysis was performed in one patient and tenolysis was performed in eight patients due to tendon adhesions.

DISCUSSION

In this study, we investigated how accompanying injuries could affect treatment outcomes in patients with flexor tendon injuries. In our study, 80.82% of flexor tendon injuries were accompanied by digital nerve injury and 79.45% of them were accompanied by digital artery injuries; therefore, the ability to perform microsurgery in flexor tendon operations should be necessary. Taken together, the structure requiring microsurgical intervention was injured at a rate of 90.42%. Previous studies have reported the percentage of associated digital nerve injuries, but there were no other studies evaluating from the point of view of microsurgical need. In contrary to studies in which digital nerve injuries were reported as 61%,[7] this rate was reported to be much higher in our study. When digital artery injuries are unilateral, the blood circulation in the finger is often sufficient; thus, the repair is at the surgeon's discretion. However, according to the microsurgical approach, it is essential to repair a body structure that can be repaired. This is of greater importance in digital nerve injuries. Considering the function of the hand, innervation is as important as the tendons and, therefore, digital nerve injuries need to be repaired.[12,13]

In a previous single-center study, the ROM was found to be significantly lower in cases where flexor tendon injuries were accompanied by digital nerve injury.[14] In addition, flexion contractures were seen more frequently and the outcomes were relatively less satisfactory. In our study, consistent with the literature, the mean ASSH scores were found to be lower in patients with digital nerve injury and even lower in patients requiring graft repair. We believe that this situation is mostly related to the severity of the injury and the outcomes are negatively affected by a greater trauma. The fact that the outcomes were adversely affected by other multiple injuries support our opinion. Also, in studies investigating flexor tendon injuries in more proximal regions in the past, it has been reported that the size of the injury and accompanying vascular nerve injuries adversely affect clinical outcomes.[15] On the other hand, there are studies reporting that there is no significant relationship between digital nerve injury and flexor tendon repair outcomes.[7,16,17] In these studies, digital nerve injury did not affect the TAM value in patients with flexor tendon repair, but this does not indicate that digital nerve repair is not required in these cases.

Another important accompanying injury is digital artery injury. It is a matter of debate whether repair of unilateral digital artery injury is necessary. In a previous single-center study with 24 patients with a different perspective on this subject, digital artery repair did not affect digital nerve healing, if digital nerve injury was accompanied by digital artery injury.[18] It has been shown that finger vascular flow volume decreases in cases of finger replantation and unilateral repair of the digital artery. The relationship of this condition with cold intolerance, which is one of the most common complications of hand injury, was investigated and artery repair was not found to be associated with it.[19] Meanwhile, this situation has also been reported in studies investigating the results of patients undergoing replantation and revascularization.[20] In our study, arterial repair did not have a significant effect on the ROM and the development of postoperative complications in digital artery injuries accompanying flexor tendon repair.

The early active motion protocol is widely accepted as influences outcome in flexor tendon injuries.[21] In this protocol, adhesions and contractures are minimized with the tendon gliding movement inside the pulley system. Therefore, among the accompanying injuries, bone fracture is the one that most severely influences the results. Although there are various osteosynthesis methods for treatment, rigid osteosynthesis and early motion are recommended.[22] In this study, patients with concomitant bone injuries had a significant decrease in ROM and 50% of the patients in which tenolysis was performed had fractures. Orthopedic surgeons have more experience in the treatment of fractures than other specialties. From this perspective, finger injuries should be evaluated as a whole and all departments that operate in this field should be given the knowledge, skills, authority, and responsibility of surgical intervention related to all structures of the finger.

According to the European Curriculum in Orthopedics and Trauma guideline, to which the national orthopedic associations of 29 countries are members, orthopedic specialists are authorized at the observer level for the revascularization of a limb without circulation, while full authorization is given for digital nerve repair.[23] Likewise, the Trauma and Orthopedic Surgery Curriculum of the United Kingdom examines this issue in more detail, and orthopedic surgeons are authorized to be an observer for digital arterial repair and have full authority for repair of hand nerve injuries and treatment of complications.[24] In a patient with nerve or arterial injury, it is controversial for an orthopedic surgeon to perform flexor tendon operations without receiving microsurgical training or intraoperative support.

Nonetheless, this study has some limitations. First, the study has a single-center, retrospective design without randomization. In addition, all operations were performed by an orthopedist experienced in microsurgery, and no comparison was made with tendon repairs performed by a surgeon without microsurgery experience. However, the main objective of the study was to evaluate whether there were accompanying injuries beyond what was visible at first assessment, and possibly, to assess the requirement for microsurgery in flexor tendon surgery. Also, the minimum follow-up period in our study was more than 10 weeks, in line with the literature recommendations.[5,21,25]

In conclusion, the patients with flexor tendon injuries have many problems, and with tendon injury, we can see only the tip of the iceberg related to the structural complexity of the fingers. In light of these findings, it is not possible to consider to separate hand surgery and microsurgery from each other. All departments that have the authority and skills to perform flexor tendon surgery should receive microsurgery training.

Ethics Committee Approval: The study protocol was approved by the Istanbul Medipol University Non-Invasive Clinical Research Ethics Committee (date: 14.10.2022, no: E-10840098-772.02-6196). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

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

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