

## ORIGINAL ARTICLE

## Comparison of Suture Techniques in Forearm and Wrist Flexor Tendon Injury

## Önkol ve El Bilek Fleksör Tendon Yaralanmalarında Dikiş Tekniklerinin Karşılaştırılması

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## How to cite ?

Özdemir B. , Elma T. Comparison Of Suture Techniques In Forearm And Wrist Flexor Tendon Injury. Genel Tıp Dergisi. 2023; 33(2): 182-187.

## ABSTRACT

**Background/Aims:** Different suturing techniques are performed in tendon repairs after forearm flexor tendon injury. However, there is not much information about their results in the literature. The main goals of flexor tendon repairs are strong repair and early mobilization. The aim of this study was to compare the results of the modified Kessler technique alone and modified Kessler suture with a running epitendon suture technique in flexor tendon repairs in this region and to evaluate the postoperative success rates.**Methods:** This study was conducted between March 2017 and November 2020. The study comprised of 68 patients. Repair was performed only by the modified Kessler technique on 34 of these patients. The other 34 patients underwent reinforcement with modified Kessler suture with a running epitendon suture. Passive flexion exercises accompanied by a physiotherapist started on the 5th day after surgery. After the 10th day, active flexion exercise started again under the supervision of a physiotherapist. Wrist immobilization was performed for one month. The function of the tendons was evaluated according to Tang grading during 12-month follow-up of the patients.**Results:** Patients in the modified Kessler suture with a running epitendon suture group showed better results than those in the Modified Kessler group, for the adhesion, limitation of motion and Tang grading variables.**Conclusions:** Good results were obtained in most of the patients following forearm flexor tendon repair. Especially the modified Kessler suture with a running epitendon suture technique provides a stronger repair in these patients and improves outcomes by facilitating rehabilitation.**Key words:** Tendon Repair, Modifiye Kessler sutur, Running suture, Forearm.

## ÖZ

**Giriş/Amaç:** Ön kol fleksör tendon yaralanması sonrası tendon onarımlarında farklı dikiş teknikleri uygulanmaktadır. Ancak literatürde sonuçları hakkında fazla bilgi yoktur. Fleksör tendon onarımlarının ana hedefleri güçlü onarım ve erken mobilizasyondur. Bu çalışmanın amacı bu bölgede fleksör tendon onarımlarında tek başına modifiye Kessler tekniği ile çalışan epitendon sütür tekniği ile modifiye Kessler sütür sonuçlarını karşılaştırmak ve postoperatif başarı oranlarını değerlendirmektir.**Yöntemler:** Bu çalışma Mart 2017-Kasım 2020 tarihleri arasında gerçekleştirildi. Çalışma 68 hastadan oluştu. Bu hastaların 34'üne sadece modifiye Kessler tekniği ile onarım uygulandı. Diğer 34 hastaya, devam eden bir epitendon sütür ile modifiye Kessler sütür ile takviye uygulandı. Ameliyat sonrası 5. günde fizyoterapist eşliğinde pasif fleksiyon egzersizlerine başlandı. 10. günden sonra fizyoterapist gözetiminde tekrar aktif fleksiyon egzersizlerine başlandı. Bir ay boyunca bilek immobilizasyonu uygulandı. Hastaların 12 aylık takiplerinde tendonların fonksiyonları Tang derecelendirmesine göre değerlendirildi.**Bulgular:** Devam eden epitendon sütür grubu ile modifiye Kessler sütür grubundaki hastalar, adezyon, hareket kısıtlılığı ve Tang derecelendirme değişkenleri açısından Modifiye Kessler grubundaki hastalardan daha iyi sonuçlar gösterdi.**Sonuç:** Ön kol fleksör tendon onarımı sonrası hastaların çoğunda iyi sonuçlar elde edildi. Özellikle çalışan epitendon sütür tekniği ile modifiye Kessler sütür bu hastalarda daha güçlü bir onarım sağlamak ve rehabilitasyonu kolaylaştırarak sonuçları iyileştirmektedir.**Anahtar Kelimeler:** Tendon Onarımı, Modifiye Kessler sütür, Running sütür, Önkol

## Introduction

The hand is the most actively used organ of our body in our daily work. The continuation of our normal daily activities depends on the normal functioning of the hand. The bones, tendons and neurovascular structures in this area must maintain normal integrity in order for the hand and fingers to function in full capability. Injuries to any part of these structures can disrupt the normal functioning of the hand and moreover, can limit our daily activities due to loss of work and strength. Flexor tendon injury are important among hand injuries due to their high complications. Flexor tendon injuries can be observed in a wide range, from partial injuries to complete rupture. Some surgeons just follow partial injuries while others argue

tendon repair even with partial injury. The flexor tendons of the hand are analyzed in five anatomical zones. Zone 5 extends from the proximal border of the transverse carpal ligament to the musculotendinous junction in the proximal part of the forearm. (1,2) Arterial and nerve injuries are often associated with flexor tendon injuries in the forearm, leading to an increase in complication rates and more impairment in hand functions.

Many different surgical techniques and rehabilitation programs have been described for forearm flexor tendon injuries. However, despite all these, adhesion formation and loss of function in the fingers may be observed after flexor tendon injuries (3,4). Acute intervention is

very important in tendon injuries and delayed repairs adversely affect repair outcomes. Postoperative success in flexor tendon injuries depends on many factors such as type of injury, associated nerve injury, repair technique and type, surgeon's experience and postoperative rehabilitation. Although this type of forearm injury is very common, no study has been conducted in our region to evaluate the functional results.

The aim of this study was to compare patients who underwent flexor tendon repair with two different suture techniques after surgery and to evaluate the results of these different suture techniques.

## Patients and methods

### Patients

This study included patients with forearm injuries in Adana province, between March 2017 and November 2020. We analyzed 68 patients who underwent acute zone 5 flexor tendon repair operation within the first 24 hours of injury. Patients who could not be followed up for 12 months, patients who were operated 24 hours after injury, patients with severe crush injuries, patients with concomitant hand or forearm fractures were excluded from the study. In addition, laceration results of flexor carpi radialis, flexor carpi ulnaris and palmaris longus tendons were also excluded. After excluding patients who did not meet the inclusion criteria, 68 patients were included in the study. Ethics committee approval was retrieved from Medline hospital with 05 number and 06/10/220 date.

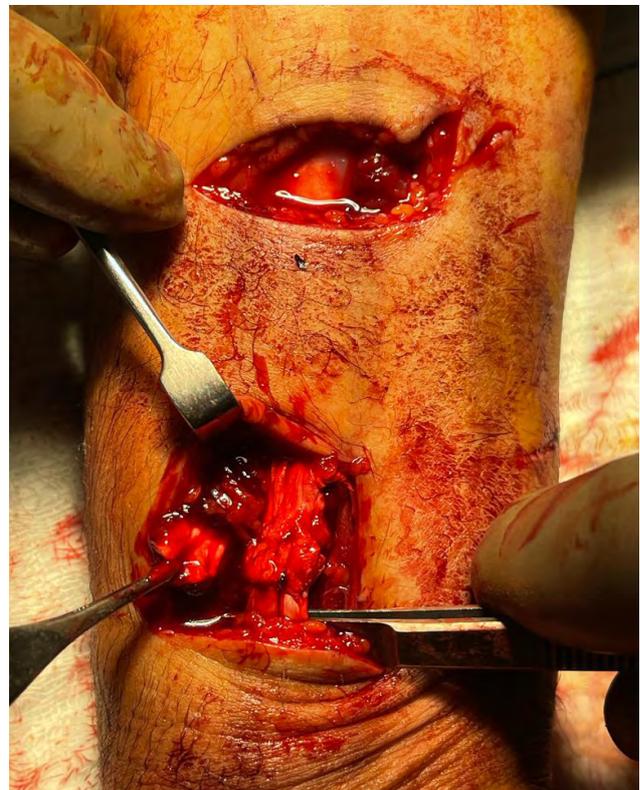
The type of injury, age, gender, the dominant hand, the injured hand, the follow-up period, which tendons were cut, adhesions and Tang grading scores were recorded in both groups. The tang grading system is a functional rating system based on the sum of the active range of motion of the proximal interphalangeal joint and distal interphalangeal joint, excluding the metacarpophalangeal joint (5).

### Surgical techniques

All patients undergoing flexor tendon repair underwent regional anesthesia via axillary block or local intravenous anesthesia. General anesthesia was administered to 1 non-compliant patient. During anesthesia, tourniquet was applied at 100 mmHg above systolic blood pressure to all our patients. S-shaped incision was extended distally and proximally as needed in all patients with flexor tendon 5th zone cut. Tendons were repaired with sutures using absorbable monofilament Polydioxanone monofilament (PDS® etc.) that have a 4/0 blunt-tipped needle with 3/8 (135 degrees) bevel. Although the knot security of these sutures is not very good, their tension lasts for a very long time (up to 60-90 days). In one group, tendon repair was performed with 4/0 nylon sutures with modified Kessler suture technique and then strengthened by performing a continuous suture over the existing suture, while leaving the knot inside (Figure 1). The other group underwent

repair only with modified Kessler suture technique using 4/0 nylon sutures. Radial or ulnar vessel injuries were repaired or ligated with 7-0 monofilament nylon sutures according to the condition of the wound and time passed after injury. Injuries to the median or ulnar nerve were repaired with 7-0 monofilament nylon sutures.

Safety of repair was assessed by making the patients (if they did not receive general anesthesia) perform active and passive finger movements after suturing. A static dorsal wrist cast extending from the tips of the fingers to below the elbow and maintaining the wrist in neutral position was applied. The metacarpophalangeal (MCP) joints were positioned in 50 of flexion and the interphalangeal (IP) joints in full extension. All surgeries were performed by the first author.



**Figure 1.** Surgical view of tendon repair with the modified Kessler suture technique and strengthening by continuous suturing with the existing suture.

### Rehabilitation

After postoperative 5th day, the dorsally applied cast was opened up to the metacarpophalangeal joint and passive flexion was started under the guidance of a physiotherapist. Patients repeated this exercise 3-4 times a day at home. After the exercise, the opened part of the cast was wrapped with a 5 cm elastic bandage to keep the fingers in extension. After the 10th day, active flexion movement was started at a level that the patient could tolerate the pain. Active and flexion range of motion exercises were

performed by patients once a day for 1 month under the supervision of a physiotherapist. Passive and active flexion exercises were recommended to be performed 4-5 times a day. Movements in the cast continued until the 4th week. The cast was removed after the 4th week and exercise continued with soft palm balls. After the 6th week, the fingers and wrist were forced into dorsiflexion. At the end of the 8th week, full range of motion was aimed to be achieved (Figure 2).



**Figure 2.** Image of hand functions of our patient in group 1 who underwent repair 6 months later

Patients were called for follow-up at 3rd, 6th, 9th and 12th months, postoperatively. Hand functions of the patients were evaluated according to Tang grading, and significant differences were found. This study was approved by the ethics committee of our hospital and informed consents were obtained from the patients.

### Statistical Analysis

Descriptive statistics were used to describe continuous variables (mean, standard deviation, median, minimum, maximum).

Categorical variables were defined by frequency (n) and percentages.

The relationship between two non-normal independent variables was analyzed by Mann-Whitney U test. The relationship between categorical variables was

analyzed by Chi-Square test.

The level of statistical significance was defined as  $P < 0.05$ . Analyses were performed using MedCalc® Statistical Software version 19.7.2 (MedCalc Software Ltd, Ostend, Belgium; <https://www.medcalc.org>; 2021).

### Results

Demographic results of our patients are presented in Table 1.

**Table 1.** Demographic Data

	Modified Kessler Suture	Modified Kessler Suture with a Running Epitenon Suture	All Patients	p
<b>Age</b>				0.922 <sup>1</sup>
Mean±SS	30.3±14.1	30.2±12.3	30.2±13.1	
Med(min-max)	26(9-75)	26(16-66)	26(9-75)	
<b>Gender n (%)</b>				1,000 <sup>2</sup>
Male	30 (90.9)	32 (91.4)	62 (91.2)	
Female	3(9.1)	3(8.6)	6(8.8)	
<b>Dominant Hand (%)</b>				0.735 <sup>2</sup>
Right	29 (87.9)	29 (82.9)	58 (85.3)	
Left	4 (12.1)	6 (17.1)	10 (14.7)	
<b>Affected Hand (%)</b>				0.303 <sup>3</sup>
Right	22 (66.7)	18 (51.4)	40 (58.8)	
Left	11 (33.3)	17 (48.6)	28 (41.2)	
<b>Type of Injury (%)</b>				0.415 <sup>4</sup>
Punching Glass	29 (87.9)	32 (91.4)	61 (89.7)	
Spiral	4 (12.1)	2 (5.7)	6 (8.8)	
Sharp Object	-	1 (2.9)	1 (1.5)	

<sup>1</sup>Mann-Whitney U, <sup>2</sup>Fisher's Exact Test, <sup>3</sup>Continuity Correction, <sup>4</sup>Pearson's Chi-Square

When the repair groups with Modified Kessler suture technique and modified Kessler suture with a running epitenon suture technique were analyzed, it was found that the median age was 26 years in both groups. There was no statistically significant difference between the age values of the two groups.

Male gender ratio was 90.9% in the repair group with the modified Kessler suture technique while this ratio was 91.4% in the repair group with the modified Kessler suture with a running epitenon suture. There was no statistically significant difference between two groups in terms of gender distribution.

In the repair group with Modified Kessler suture technique, 87.9% of the dominant hand was the right hand whereas this ratio was 82.9% in the repair group with modified Kessler suture with a running epitenon suture technique. There was no statistically significant difference according to dominant hand distribution

between groups.

In the repair group with modified Kessler suture technique, 66.7% of the affected hand was the right hand while this ratio was 51.4% in the repair group with modified Kessler suture with a running epitenon suture technique. There was no statistically significant difference according to the distribution of the affected hand between two groups

Among the patients, 87.9% of those in the repair group with modified Kessler suture technique and 91.4% of those in the repair group with modified Kessler suture with a running epitenon suture technique were injuries by "punching the glass."

All patients were followed up for 12 months. At the end of 12-month follow-up, patients were evaluated for adhesions, restriction of motion, re-operation and Tang grading (Table 2).

**Table 2.** Adhesions, Restriction of Movement, Reoperation, Tang Grading Results

	Modified Kessler suture	Modified Kessler Suture with a Running Epitenon Suture	All Patients	P
<b>Adhesion (%)</b>				<b>0.002<sup>2</sup></b>
Not present	11 (33.3)	25 (71.4)	36 (52.9)	
Present	22 (66.7)	10 (28.6)	32 (47.1)	
<b>Movement limitation (%)</b>				<b>0.001<sup>2</sup></b>
Not present	8 (24.2)	25 (71.4)	33 (48.5)	
Present	25 (75.8)	10 (28.6)	33 (51.5)	
<b>Re-operation (%)</b>				0.485 <sup>3</sup>
No	32 (97)	35 (100)	67 (98.5)	
Yes	1(3)	-	1 (1.5)	
<b>Tang rating at 12th month (%)</b>				<b>&lt;0.001<sup>2</sup></b>
Poor	1 (3) <sub>a</sub>	0 <sub>a</sub>	1 (1.5)	
Fair	4 (12.1) <sub>a</sub>	1 (2.9) <sub>a</sub>	5 (7.4)	
Good	17 (51.5) <sub>a</sub>	3 (8.6) <sub>b</sub>	20 (29.4)	
Excellent	11 (33.3) <sub>a</sub>	31 (88.6) <sub>b</sub>	42 (61.8)	

1Mann-Whitney U, 2Contiguity Correction, 3Fisher's Exact Test

Adhesions were seen in 66.7% of the patients in the repair group with the modified Kessler suture technique while this ratio was 47.1% in the repair group with modified Kessler suture with a running epitenon suture technique. The difference is statistically significant ( $p < 0.05$ ). Restriction of motion was seen in 75.8% of the patients in the repair group with the modified Kessler suture technique while this ratio was 28.6% in the repair group with modified Kessler suture with a running

epitenon suture technique. The difference is statistically significant ( $P < 0.05$ ). Re-operation was performed in 1 patient in the repair group with modified Kessler suture technique because of re-rupture. There was no need for reoperation in patients with adhesions in both groups.

When Tang gradings at 12th month were analyzed, 33.3% of the patients in the repair group with the Modified Kessler suture technique were found in the "excellent" category; while 88.6% of the patients in the repair group performed with modified Kessler suture with a running epitenon suture technique were in the same category. The difference between two groups in terms of Tang grading is statistically significant ( $P < 0.05$ ). When the results are analyzed in general;

Patients in the repair group with modified Kessler suture with a running epitenon suture were determined to show better results than patients in the repair group with Modified Kessler suture technique for the variables of adhesion, limitation of motion and Tang grading.

## Discussion

The hand is the most actively used organ of our body, in our daily work. Injuries to the hand and wrist are seen very commonly in young working adults. Many factors such as time after injury, suture technique, associated injuries, surgeon experience and postoperative rehabilitation, affect the results of flexor tendon repairs. In our study, we compared the success rates of flexor tendon repairs performed with two different suturing techniques and found that the rate of excellent results according to Tang grading was significantly higher in modified Kessler suture with a running epitenon suture technique than the other group at the 12-month follow-up of the tendon repair patients ( $P < 0.005$ ). Again, in our study, no re-rupture was seen in the patients in the repair group with modified Kessler suture with a running epitenon suture while re-rupture was seen in 1 patient in the other group. Moreover, adhesion ratios were found low in patients with continuous suture over Modified Kessler technique. This low complication ratio may be due to strong tendon repair, complete tendon restoration and early mobilization of the fingers.

There are few studies in the literature on 5th region flexor tendon repairs in the forearm (6,7,8,9,10,11). Yi et al. reported that they obtained good and excellent results in 90% of the patients whom underwent flexor tendon repair in the 5th region (6). Hung LK and Pang KW studied 32 patients who underwent flexor tendon repair using a modified Kessler suture technique. They reported good to excellent results in 77% of patients with dorsal splint and early active movement of the fingers (12). Wilhelm et al. examined 168 patients, among which 29 underwent repair after flexor tendon injury in the 5th region, and obtained good and excellent functional results in 85% of the cases on whom they used an early active movement protocol

after surgery (13).

Olivier et al. compared flexor tendon repairs performed with modified Kessler suture and stable wire suture techniques. They started early movement without splinting in the SWST group and found similar functional results in both groups (14).

Avoiding gap formation during tendon repairs is important to prevent post-repair tendon weakness. As a result, even a small gap may adversely affect functional and clinical outcomes (15). We think that repair with modified Kessler suture with a running epitendon suture will minimize these gaps by surrounding the tendon, also will increase the tendon's resistance to tensile force.

It is very important to start movement early after flexor tendon repairs. Because early movement reduces adhesion formation (16). The tendon repair must be strong enough to minimize the risk of rupture in order to start active movement early. In particular, the reinforcement we perform with the modified Kessler suture with a running epitendon suture technique provides a strong tendon repair, hence reduces the ratio of adhesions and safely allows early rehabilitation. Therefore, we started early active and passive movements, similar to other studies in the literature (17,18). As a result, we believe that the early onset of active and passive movement increases the rate of our excellent and good results as in other 5th region cuts in the literature.

The operations were performed by a single surgeon. We think that the fact that the patients were young and most of the injuries were caused by sharp objects had a positive effect on our results. In addition, we think that the fact that all patients were regularly trained by the same physiotherapist once a day for 1 month and their rehabilitation processes were regularly followed by a single person, contributed to our success rates. Chang et al. and Chen et al. reported that there is no disadvantage of placing suture knots outside the tendon surface as core sutures (19,20). However, there are studies showing the opposite. Some biomechanical studies have shown that placement of multiple loops and knots on the outer tendon surface may result in increased shear resistance after tendon repair (21). For this reason, we leave the knots inside the modified Kessler suture with a running epitendon suture technique that we perform. Hence, we prevent knots from remaining outside the tendon after tendon repair. We think that, this has a positive effect on our results.

In addition to flexor tendon lacerations, injuries to the median or ulnar nerve may also be seen in forearm cuts. It is obvious that nerve cuts will worsen functional outcomes in terms of grip and holding strength of the hand. Poor results were seen mostly in cases with nerve cuts, especially the ulnar nerve in our patients. However, different studies are needed to

evaluate median or ulnar nerve repair.

In our study, the long-term results of the modified Kessler suture with a running epitendon suture technique were significantly better according to the Tang grading. In particular, this technique reduces the gap formation, thereby increases the tendon's resistance to tensile force. Again, in this technique, the knot is left inside in order to prevent the increase of slide resistance. In addition, early postoperative rehabilitation with close follow-up plays an important role in the success after tendon repair.

### Authorship Contributions

Bülent Özdemir: Contributed data or analysis tools, performed the analysis, surgeon performing surgeries. Tarık Elma: Conceived and designed the analysis, collected the data, wrote the paper

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