

## Results of 4-strand modified Kessler core suture and epitendinous interlocking suture followed by modified Kleinert protocol for flexor tendon repairs in Zone 2

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### ABSTRACT

**Objective:** There has been no consensus in literature for the ideal flexor tendon repair technique. The results of zone 2 flexor tendon lacerations repaired primarily by 4 strand Modified Kessler core suture and epitendinous interlocking suture technique followed by Modified Kleinert protocol were investigated.

**Methods:** 128 fingers of 89 patients who had flexor tendon laceration in zone 2 built the working group. Functional outcomes were evaluated using the Strickland formula. A statistical analysis was made between Strickland scores and some parameters such as age, gender, follow-up time, co-existing injury existence, repair time, single or multiple finger injury, tendon rupture and the effect of FDS injury and repair.

**Results:** Excellent, good, fair, poor results were obtained from 71 (55.5%), 46 (35.9%), 8 (6.3%), 3 (2.3%) fingers, respectively. Time of the repair has a significant effect on the strickland scores. Surgery performed within the first 24 hours following the injury gave better results. 3 fingers (2.3%) had tendon ruptures. Existence of ruptures affected the results significantly. Co-existing injuries were found that they did not have any effect on the results. In the fingers in which both FDP and FDS tendons were lacerated, no significant relationship was found between only FDP repair, both FDP and FDS repair and single FDS slip repair. Additionally no significant relationships between follow-up time, gender, single or multiple finger injury and Strickland scores were observed. 13 fingers (10.1%) had PIP joint contracture above 20°.

**Conclusion:** The low rupture rate (2.3%) and 91.4% 'good' and 'excellent' scoring rates in our series support the idea that modified Kessler 4-strand core suture and epitendinous interlocking suture repair combined with modified Kleinert protocol gives satisfactory results. Repair time is one of the most important factors affecting the functional results and surgery should not be delayed if there is an experienced surgeon available.

**Level of evidence:** Level IV, therapeutic study.

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### Introduction

Flexor tendon lacerations are one of the most common hand emergencies. Recent studies regarding flexor tendon repair, focus on reducing adhesion and rupture of repaired tendon.<sup>1,2</sup> Yet, physiotherapy protocols focus on obtaining better functional results.<sup>3</sup> There has been no consensus in literature for the ideal repair technique. This is because flexor tendon repairs are under the influence of various factors.

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Ideal tendon repair requires having the gliding characteristics of tendon at optimum level by keeping the gliding resistance and work of flexion low.<sup>4,5</sup> That time zero resistance resists to the stress, which it was exposed until biologic healing is observed, reduces rupture risk. In this case, repair techniques and postoperative rehabilitation protocols come into prominence.<sup>6,7</sup> Several factors having influence over the results have been identified. These factors can be counted as mechanism of injury, core suture technique and material, number and strength of strand, the gap in the repair zone, physiotherapy protocols and patient compliance.<sup>2,8–10</sup> A gap resistant strong suture technique ensuring intrinsic healing and adhesion-preventing early motion protocols generally give satisfactory results.<sup>3,11–13</sup>

The aim of the study is to retrospectively examine the results of 4-strand modified Kessler core suture and epitendinous interlocking suture repair technique followed by modified Kleinert protocol and the effects of the factors such as follow-up time, co-existing injury existence, time of repair, single or multiple finger injury, tendon rupture and flexor digitorum superficialis (FDS) repair over Strickland evaluation results.

## Materials and methods

Patient records between January 2007 and January 2017 were scanned in order to reach the flexor tendon repair cases. Inclusion criteria were determined as zone 2 flexor tendon lacerations repaired by 4-strand modified Kessler core suture and epitendinous interlocking suture technique. Post-operative early controlled passive motion protocol (Kleinert) was another inclusion criterion. Exclusion criteria were determined as patients under 9 years of age, secondary tendon repairs, co-existing injuries such as skin defects, phalangeal fractures, proximal or distal interphalangeal joint (PIP, DIP) dislocations and extensor tendon injuries, quitting the treatment, flexor pollicis longus lacerations and crush injuries. According to this, patients who did not meet the inclusion criteria or whose registered data could not be obtained, were not included in the study. 128 fingers of 89 patients built the working group.

Average follow up duration was 5.09 months (minimum 3 months and maximum 12 months). All of the operations were performed by hand surgeons with at least 5 years of experience.

51 of the patients had right hand injuries, whereas 38 of them had left hand injuries. Dominant side data was not homogeneous. There were 73 male and 16 female patients in the working group. Average age of the patients was 28.9 years old (minimum 9 and maximum 60). While 63 of the patients had single finger injury, 26 of the patients had multiple finger injury. Average duration of operation was calculated as 83 min (minimum 40 min and maximum 260 min). Injured tendons were ordered as flexor digitorum profundus (FDP) 5 (35.2%), FDP 4 (24.2%), FDP 3 (21.1%) and FDP 2 (19.5%).

Both FDP and FDS lacerations were detected on 70 fingers. In 40 of these 70 fingers (57.2%), both of these two tendons were repaired. In 24 fingers (34.3%), only FDP was repaired. In 6 fingers (8.5%), only a single slip of FDS was repaired.

Tendon repairs were performed within the first 24 hours in 43 patients, within 2 weeks in 40 patients and within 6 weeks in 6 patients. When taking the late repair decision, it was checked by means of ultrasonography if the proximal end of the tendon was retracted.

In our series, 84 fingers (65.6%) were observed to have co-existing injuries such as digital nerve, digital artery, volar plate, pulley and chiasma injuries.

## Surgical technique

Surgeries were performed using regional block anesthesia and pneumatic tourniquet. Laceration zones were explored by means of

Brunner incision. After detecting the injured tendon and pulleys, A2 and A4 pulleys were preserved and tendons were repaired by bringing them towards the laceration zone. When the tendon ends were of poor quality, trimming was performed not exceeding 0.5–0.6 cm. As suture technique, first 6/0 Ethilon® (Nylon Suture, Ethicon) epitendinous interlocking suture and then double modified Kessler 4 strand core suture technique<sup>14</sup> was used. 4/0 PDS core suture material was used (PDS® polydioxanone Suture, Ethicon). Tendon purchase for core suture was over 7 mm. We paid attention to have the sutures equally tight and to have tendon 10% more tight. If FDS tendon injury was around distal attachment in zone 2A, it was not repaired. When repairing the FDS tendon, M. Kessler and epitendinous sutures were preferred depending on the thickness of the tendon for the lacerations proximal to the chiasma; and vertical mattress suture was preferred for the lacerations distal to the chiasma. Following the tendon repair, the gap that tendon form by the passive motion of finger and its excursion were checked peroperatively. When the repair zone caused impingement under the pulleys, pulley venting or v-y pulley-plasty were performed, not exceeding 50%. Flexor sheath was left open to cover the tendon.

## Rehabilitation protocol

Injured extremity was kept inside a plaster cast after the operation. Between the 2nd and the 5th days of the post-operative period, dorsal splint and Kleinert protocol began to be implemented. Kleinert splint was used in a modified form. Modifications are as follows:

- Decrease in wrist flexion 0-30
- Increase in metacarpophalangeal joint (MP) flexion 60-80
- Palmar pulley usage
- Combined nylon thread and elastic band usage
- Loosening the nylon threads and elastic bands from pulleys at night
- Including all of the fingers in elastic band traction
- Including passive range of motion in the program

During the first 3 weeks of the post-operative period, passive flexion by the help of the band traction and active extension was performed hourly in Kleinert splint. After removing stitches, incision region was massaged. At the end of the 3rd week, light active flexion exercises in splint were added to the program. At the end of the 4th week, active wrist exercises were performed without having splint on. At the end of the sixth week, dorsal block splint was removed for the day time. By the end of the 8th week, splint was continued to be used at night. Minimal resisted exercises and smooth activities were suggested as of the 8th week. In those weeks, particularly the patients who had extension limitation with their PIP joints were made to use extension mobilization splint for the night use. In the tenth week, the patients became totally independent while doing their daily activities. The patients who were occupied with desk work were permitted to work. The patients who were occupied with heavy duties were permitted to work only in the 12th week. We performed the same protocol for all of the patients, concomitant digital nerve injuries didn't postpone the rehabilitation program.

During control examination, functional outcomes were evaluated using the Strickland formula [(pip flexion + dip flexion)-(pip extension lag + dip extension lag)] × 100/175. The results were evaluated as 'excellent' with 75–100%, 'good' with 50–74%, 'fair' with 25–49% and 'poor' with 0–24%.

A statistical analysis was made between Strickland results and some parameters. These parameters were age, gender, follow-up time, co-existing injury existence, repair time, single or multiple finger injury, tendon rupture, the effect of FDS injury and repair.

The normal distribution of numerical variables were tested by Shaphiro wilk test. Mann whitney u test was used to compare non-normally distributed data between 2 independent groups and Kruskal wallis and all pairwise multiple comparison tests were performed to compare non-normally distributed data across more than 2 groups. Relationship between numerical variables was tested by Spearman rank correlation coefficient. Mean ± standard deviations were given for numerical variables and the numbers and % values for categorical variables. SPSS for windows version 24.0 package was used for statistical analysis and P < 0.05 was considered as statistically significant.

**Results**

Among the 128 fingers, ‘excellent’, ‘good’, ‘fair’, ‘poor’ results were obtained from 71 (55.5%), 46 (35.9%), 8 (6.3%), 3 (2.3%) fingers, respectively according to the Strickland scores. So the overall rate of excellent and good results was 91.4%. None of the patients experienced a wound healing problem. No infection was observed. Results of the analysis of factors is shown in the Table 1.

There is a weak negative correlation between age and strickland scores. Younger patients seem to have better results.

Time of the repair has a significant effect on the strickland scores. We also grouped the patients according to the time of the surgery after the injury such as first 24 h, first two weeks and first six weeks. The mean Strickland scores for these groups were 80.53, 74.76 and 59.13 respectively. The difference between groups was

**Table 1**  
Results of the analysis of factors.

Analysis Of Factors	P Value
Time of repair	<b>p 0,002</b>
Single/multiple finger injury	p 0,888
Co-existing injury	p 0,992
Rupture	<b>p 0,002</b>
Effect of FDS injury	p 0,469
Effect of FDS repair	p 0,169
Follow-up time	p 0,827
Age	<b>p 0,041</b>
Gender	p 0,084

Bold values indicates statistically significant difference.

significant as well (p 0,004). The mean strickland score distributions for the repair time groups is shown in Table 2. Surgery performed within the first 24 h following the injury significantly gave better results.

3 fingers (2.3%) had tendon ruptures. Existence of ruptures affected the results significantly (p 0,002). Results with the ruptured tendons were found to be poorer.

Co-existing injuries were found that they did not have any effect on the results. In the fingers in which both FDP and FDS tendons were lacerated, no significant relationship was found between only FDP repair, both FDP and FDS repair and single FDS slip repair. Additionally no significant relationships between follow-up time, gender, single or multiple finger injury and Strickland scores were observed.

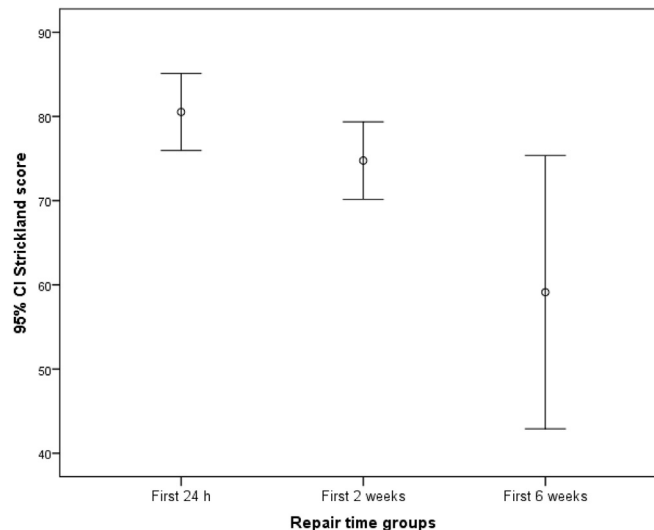
In our series, 75 fingers (58.6%) were observed to have PIP flexion contracture, in variable degrees (minimum 5 and maximum 35). 13 fingers (10.1%) had contracture above 20°.

**Discussion**

In a recent meta-analysis, there has not been found any statistical difference between multiple/double strand core suture repair and early passive/active motion protocols.<sup>15</sup> Kleinert controlled passive motion protocol is still a frequently used protocol.<sup>11,13</sup> In literature, ‘excellent’ and ‘good’ results around 70–100% have been reported drawing upon Kleinert protocol.<sup>12,13</sup> Active motion protocols have given 70–96% ‘excellent’ and ‘good’ results.<sup>7,16</sup> Frueh et al,<sup>17</sup> did not observe any difference between early mobilization and controlled active motion in terms of total active motion (TAM). None of the physiotherapy protocols have been superior to another in literature. Our study discussed the results of 4-strand core suture and epitendinous interlocking suture repair, considering a standard physiotherapy protocol. We tried to demonstrate retrospectively if the results varied considering several parameters. According to this, 91.4% ‘excellent’ and ‘good’ results were obtained. 2.3% rupture was observed.

Nowadays, multi-strand repair and early active motion protocols, in order to reduce adhesion, gap and rupture, are used together.<sup>18</sup> If it is considered that stress that occurs due to active tendon movement is around 0.2–50 N, it can be thought that multi-

**Table 2**  
The mean strickland score distributions for the repair time groups. (CI: confidence interval).



strand suture is rather safe in terms of rupture.<sup>19</sup> It is compatible with the early active motion protocols. In our study, 4-strand core suture was used because we didn't perform early active motion protocols.

Gibson et al.<sup>18</sup> mentioned that at least 4 strand sutures were preferred by ASSH members with 94%. Primary disadvantage of M. Kessler is that fewer strands and transverse segment forms a gap by tightening under load. As transverse section of double Kessler suture is less contracted, gap formation possibility is not high.<sup>20</sup> 2-strand Kessler's yield point load in peripheral suture before rupture occurred was found as 16–20 N.<sup>21</sup> Lawrence and Davis<sup>22</sup> showed that 50% of the locking Kessler sutures had ruptures due to forces less than 29 N, whereas all 4-strand repairs were resisted this degree of force without gap formation. Gil et al.,<sup>23</sup> stated that passive motion generates up to 17 N and passive place hold manoeuvres generate up to 9 N. It would not be wrong to deduce that 4-strand M. Kessler suture could meet the load of 17 N which is generated by controlled passive motion. That is why we prefer 4 strand m. Kessler over the 2-strand m. Kessler.

The disadvantage of multi-strand repairs is increasing work flexion due to bulky repair. For this reason, multi-strand repairs generally require pulley venting.<sup>15</sup> Pulley incision and FDS excision were found equally efficient.<sup>24,25</sup> In our series, FDS tendons were left unrepaired in 24 fingers either FDP was bulky or we were worried that FDS would increase the possibility of impingement. If FDS repair would not become bulky, it would be preferred in order to form a smooth surface. Having the same aim, single slip FDS repair was preferred in our series for 6 fingers. No negative effects of these two conditions on the results were observed.

The most important problem with Kleinert technique is flexion contractures in PIP joint. Rates of flexion contracture more than 15° in PIP joint were reported as 29–40% in Kleinert technique, 13–28% in early passive motion and 10–24% in early active motion.<sup>13</sup> We observed PIP contractures in our series as well with 58.6% at ranging degrees, no matter how we tried to reduce it by means of modifications. 17.3% of the contractures were more than 20°. Among all the fingers 10.1% had flexion contracture more than 20°.

It is accepted that early primary repair results in better functional outcome compared with secondary tendon repair (more than 3 weeks after the primary injury).<sup>26</sup> Tang stated that the ideal situation for the timing of repair is that a patient with flexor tendon injury is brought into the clinic soon after injury and surgery begins within a few hours if an experienced surgeon is available. If not, the repair can be delayed until an experienced surgeon is available. Preferred period of deliberate delay is 4–7 days.<sup>7</sup> We selected the time intervals according to our practice. First 24 h means the immediate surgery. First 2 weeks is the period of time for acceptable results. We couldn't be able to achieve a primary repair after 6 weeks, so the third interval is first 6 weeks. In our study we found that when the surgery is delayed, functional results get poorer. There is also significant differences between three repair time groups (first 24 h, first 2 weeks and first 6 weeks). We think repair time is one of the most important factors affecting the functional results and surgery should not be delayed if there is an experienced surgeon available.

Apart from the good and excellent results, 11 fingers (8.6%) had fair and poor results. When we tried to understand the reasons for the insufficient results, we observed that 2 of these fingers had ruptured tendons and refused the revision surgery, 3 of them had been operated after 2 weeks and 2 of them belonged to a patient who didn't follow the therapy program properly. The reason for the other fingers were unclear but we think that late surgery and inaccurate postoperative therapy are predictors of poor and fair results.

There are limitations of this study. First of all there is no comparison made with early active motion protocols and core suture types. It was also a disadvantage that sub-zones which were defined for Zone II were not used for injury levels.

## Conclusion

Functional results following flexor tendon repair are under the influence of multifactorial effects. The low rupture rate (2.3%) and 91.4% 'good' and 'excellent' scoring rates in our series support the idea that modified Kessler 4-strand core suture and epitendinous interlocking suture repair combined with modified Kleinert protocol gives satisfactory results. Repair time is one of the most important factors affecting the functional results and surgery should not be delayed if there is an experienced surgeon available.

## Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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