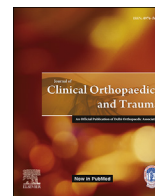




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# Repair of flexor tendon injuries by four strands cruciate technique versus two strands kessler technique

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## ABSTRACT

**Background:** Flexor tendon injuries are commonly encountered and the surgical repair still represents a challenging problem. Many repair techniques are present but there is still no ideal one that achieves the best functional outcome. This study was undertaken to compare four-strand locked cruciate repair technique and modified Kessler technique in forty eight patients by assessing the functional outcome.

**Methods:** Forty eight patients (114 digits) with flexor tendon injury were assigned into two groups based on suture repair technique; Group A: 24 cases by Modified Kessler repair (50%). Group B: 24cases by 4-strand cruciate repair (50%). Adults in Both groups were rehabilitated by combined Duran protocol and early active mobilization while no specific rehabilitation program was used for pediatric age group. Follow up was from 6 to 36 months (mean 21.5). Functional outcome was assessed by White criteria to all patients after 6 months.

**Results:** Functional outcome was better in 4 strand cruciate repair with excellent result in 66.6%, good in 29.1% and fair in 4.1%, as compared to modified Kessler technique in which excellent results were found in 45.8%, good in 37.5%, fair in 12.5% and poor in 4.1% of cases. A better functional result was achieved in 4 strand cruciate repair especially in zone II, with excellent results in 33.3%, good in 50% and fair in 16.6% of cases, as compared to modified Kessler repair with no excellent results, 33.3% good, 50% fair and 16.6% poor results. In zone III, 4 strand cruciate technique showed a better functional outcome with 77.7% excellent and 22.2% good results, as compared to 55.5% excellent and 44.4% good results found in Modified Kessler repair. Zone V showed almost comparable results between the two types of repairs.

**Conclusion:** The 4-strand cruciate repair technique had better functional outcome compared to modified Kessler repair technique, especially in zone II and III.

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## 1. Introduction

Flexor tendon injuries of the hand is commonly encountered problem, affecting both gender and different age groups due to different types of injurious agents, sometimes associated with fractures of phalanges and/or nerve or vessel injuries that could result in significant functional disabilities that have a negative impact on working ability and life style.<sup>1</sup> Re-establishment of normal hand and wrist function with normal range of finger and wrist movement and normal grip strength after flexor tendon repair remain one of most difficult goals to achieve. Complications associated with tendon repair like tendon rupture, gapping, adhesions and joint stiffness are influenced by a number of factors including age, mechanism and level of injury, repair technique and

rehabilitation protocol<sup>2–4</sup> There has been great advances in the understanding of tendon anatomy, mechanics, and biology of healing as well as in surgical repair techniques and rehabilitation protocols in order to avoid the complications associated with tendon repair like tendon rupture, gapping, adhesions and joint stiffness.<sup>5–7</sup> Despite this, there is still no consensus of opinion about the ideal surgical repair technique that can avoid those complications and offer the patient the best functional result that bring him back to normal active life. This study was done to compare the functional outcome of two surgical repair techniques for flexor tendon injuries: Modified Kessler technique and four strands locked cruciate technique. Adults of both groups were rehabilitated by combined Duran protocol<sup>8</sup> and early active movement.

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### 1.1. Patients and methods

This is a prospective case control study which was conducted at the Orthopaedics Department of Basra General Hospital, between April 2015 and November 2018. Forty eight patients (114 digits) with flexor tendon injuries involving zone II, III and V with or without vessels or nerve injuries were included. Patient age, occupation, site of injury, duration from injury to surgery and associated injuries were recorded. Physical examination was done looking for signs of flexor tendon injury, peripheral nerve injury and the state of the circulation of the injured hand and digits. Cases presented more than 14 days after injury, those associated with fracture, major vascular injury with ischemic change to part or whole of the hand, presence of soft tissue loss, flexor tendon injury of zone I and IV and thumb flexor injuries were excluded. Time between the onset of the injury and surgical repair was 4 h–14 days, mean 5.9 days (5.2 days for group A and 6.6 days for group B).

Cases were divided into 2 groups according to the type of surgical repair with equal distribution of cases in zone II, III and V in each group.

- Group A: 24 cases (55 fingers) were repaired by modified Kessler technique, knot-in with epitendinous circumferential suture.
- Group B: 24 cases (59 fingers) were repaired by 4 strand locked cruciate knot-in with epitendinous circumferential suture.

### 1.2. Operative procedure

All cases were operated under general anesthesia except one case which was done under axillary block. Pneumatic tourniquet was used for all. Preoperative prophylactic antibiotics were given 10 min before tourniquet application. Tendons were exposed using original wound which was enlarged as necessary up and down using the standard surgical technique. The tendon ends were recovered and sutured by modified Kessler, core suture knot inside with epitendinous circumferential suture in 24 cases (55 digits, 50%) and by 4 strand locked cruciate repair, knot inside with epitendinous circumferential suture in 24 cases (59 digits, 50%), using 4/0 polypropylene stitch for core suture, and 5/0 polypropylene for epitendinous repair in all cases (Fig. 1). Flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) were both repaired in all cases. Tourniquet was deflated and haemostasis was secured fully before skin closure. Back slab (Extension block) splint was applied with wrist in 20–30° palmar flexion, metacarpophalangeal (MP) joint in 50° flexion and interphalangeal (IP) joints in extension.

**Table 1**  
Distribution of tendon injury according to the zones.

Zones	Patients	%	Digits
II	12	25	24
III	18	37.5	32
V	18	37.5	58
Total	48	100	114

### 1.3. Post-operative protocol

All cases received antibiotics for 5 days. Adults patients were rehabilitated by combined Duran and early active movement protocol,<sup>5</sup> the patients were instructed to do passive flexion of distal interphalangeal joint (DIP) and proximal interphalangeal joint (PIP) followed by active finger extension which was started at the first post-operative day. At the seventh post-operative day active flexion and extension of the finger was started. No specific rehabilitation program was used for children.

Stiches were removed after 14 days and back slab removed after 4 weeks. Extension stretching exercise started after 6 weeks in order to improve finger extension. Physiotherapy to improve hand function was continued for 3 months. Follow up range from 6 to 36 months (mean 21.5).

After removal of stiches the patients was seen at 2 weekly interval for 6 weeks and then at monthly interval.

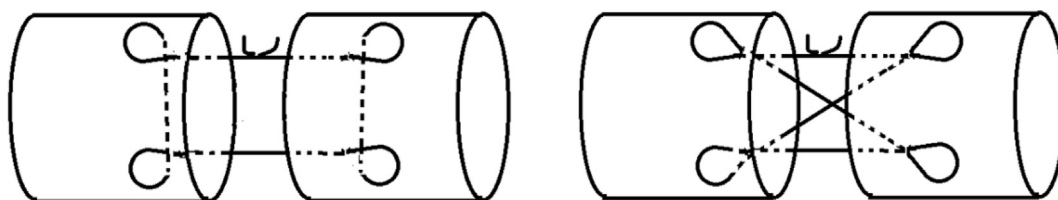
Six months after surgery, distance between finger pulp and distal palmar crease on maximum flexion of the fingers, the tip-to-palm distance (TPD) was measured as well as the total active motion (TAM) which is the sum of active flexion at the MP, PIP and DIP joints minus their extension lag was recorded. The final functional outcome was recorded according to white criteria<sup>6</sup> (depending on the recordings of the last visit) as follows:

1. **Excellent:** TPD less than 1 cm, TAM more than 200°.
2. **Good:** TPD less than 2 cm, TAM more than 180°.
3. **Fair:** TPD less than 4 cm, TAM more than 150°.
4. **Poor:** TPD more than 4 cm, TAM less than 150°.

## 2. Results

Forty eight patients (114 digits) with flexor tendon injuries were assessed: 8 females and 40 males patients (male/female ratio 5:1). Age range from 2 to 49 years (average 25.5). Dominant hand affected in 30 cases (62.5%). Tendon injuries according to the zones are shown in Table 1.

In all cases both Flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) were injured. Out of 114 fingers affected, there were 35 middle, 33 index, 27 ring, and 19 little fingers. Cases with single digit involvement were 14 (29.17%), while in 34 cases (70.83%) more than one digit were involved (Table 2).



A: Modified Kessler technique

B: Four strand cruciate repair technique

**Fig. 1.** Repair techniques.

**Table 2**  
Frequency of injured digits.

Injured digits	Patients	Percent
Single digit	14	29.17
Multiple digits	34	70.83
Total	48	100

**Table 3**  
Frequency of associated nerve injury and related zones.

Nerve	Patients (%)	Zone V	Zone III	Zone II
Median	12 (25)	8	4	0
Ulnar	6 (12.5)	6	0	0
Both	4 (8.3)	4	0	0
Nil	26 (54.2)	0	14	12
Total	48 (100)	18	18	12

**Table 4**  
Total functional outcome.

Functional Outcome	Patients	Digits	Percent	P value
Excellent	27	61	56.25	0.001
Good	16	37	33.33	
Fair	4	12	8.33	
poor	1	4	2.09	

Cases associated with major nerve injury were found in (22) cases (45.8%). Distribution in different zones are shown in (Table 3).

Cases were divided into 2 groups; Group A: 24 cases (55 digits, 50%) were repaired by modified Kessler technique, knot inside with circumferential epitendinous suture, while Group B: 24 cases (59 digits, 50%) were repaired by 4 Strand locked Cruciate, knot inside. Total functional outcome was assessed according to White criteria (Table 4).

According to the type of repair, functional outcome was significantly better (P value 0.001) in 4 strand cruciate repair technique as compared to modified Kessler repair technique (Table 5).

Functional outcome according to the injured zone is shown in (Table 6). Chi-squared test was done for the "Excellent and good versus Fair and poor" for the three zones ( $X^2 = 16.781$ ,  $df = 2$ ,  $P < 0.001$  highly significant), with better functional outcome in zone III and V as compared to zone II.

### 3. Discussion

Despite the significant studies and better knowledge in the area of flexor tendon anatomy, nutrition, biomechanics, healing and adhesion formation, regain of adequate digital function following flexor tendon repair remain one of the most challenging and difficult to achieve in hand surgery.

Most of the cases in our series 75% were involving zone III and V, this is because they present as a major injury, so they present early. Many of those cases were associated with a major nerve or vessel

**Table 6**  
Functional outcome according to the injured zone.

Functional outcome	Zones			Total
	Zone II (%)	Zone III (%)	Zone V (%)	
Excellent	2 (16.7)	12 (66.7)	13 (72.2)	27
Good	5 (41.7)	6 (33.3)	5 (27.8)	16
Fair	4 (33.3)	0	0	4
Poor	1 (8.3)	0	0	1
Total	12	18	18	48

injury. Injuries to zone II usually present late because they are misdiagnosed and regarded as minor injury and treated inadequately by inexperienced personnel. Cases presented after 14 days were excluded from our study. Delay in presentation was inversely proportional to the functional outcome. Increasing the number of strands in core suture and anchor points increases the tensile strength, repair stiffness, gap resistance and allows early active mobilization without risk of gapping and rupture<sup>(7–9)</sup> but this is associated with bulkier repair<sup>(10)</sup> which may interfere with glide and increases the work of flexion<sup>(11)</sup>. Four strands cruciate locked suture has the advantage of increased strength without producing a bulky repair, thus it looks ideal repair technique which allows early active mobilization without increased risks of rupture or gap formation<sup>(12–14)</sup>.

Most of the studies comparing 2 strands to 4 or more strands were measuring the biomechanical outcome<sup>(7–9,13,15–17)</sup> and showed the superiority of multiple strands over 2 strands in terms of tensile strength and gap resistance, but the studies comparing the clinical outcome of 2 strands versus multiple strands repair technique show a variable results. Navali and Rouhani<sup>(2)</sup> compared active range of finger movement and rupture rates of 2 strands and 4 strands repair technique in zone II flexor tendon injuries in children, they were unable to show significant difference in active range of finger motion achieved with 2 strand and 4 strands repair techniques. Hoffmann, Buechler and Voegelin<sup>(3)</sup> compared functional results of six strands double loop technique with modified Kessler followed by early active mobilization and found significantly better total active motion in 6 strands repair technique with lower complication rate and shorter average time of treatment. Tendon injuries in zone V represent 37.5% of our cases, usually involving multiple tendons, median, ulnar or both nerves as well as radial or ulnar vessels (Spaghetti wrist). This pattern of involvement requires a longer operative time, the presence of nerve injury will represent an additional challenge to the operative technique and final functional outcome. We reported 72.2% excellent and 27.8% good results in this zone and this is similar to other studies<sup>(18)</sup>. Associated Median nerve injury was found to have no negative effect on the final functional outcome because this injury has no effect on the long tendon glide<sup>(19)</sup>, while ulnar nerve injury will cause intrinsic muscle paralysis with loss of flexion at metacarpophalangeal (MP) joint with resultant effect on long tendon glide, this fact requires attention to the splint applied to prevent PIP joint stiffness and clawing, as well as intensive physiotherapy while

**Table 5**  
Functional outcomes according to the type of repair.

Functional outcome	Repair type		Total	P Value	
	M. Kessler	%			4 strands cruciate
Excellent	11	45.8	16	66.7	0.001
Good	9	37.5	7	29.2	
Fair	3	12.5	1	4.1	
Poor	1	4.2	0	0	
Total	24	100	24	48	

waiting for the nerve function to return. Two cases associated with ulnar nerve injury were associated with some degree of clawing of ring and little finger which hampers full range of finger extension. Zone III injuries occur in 37.5% of our cases with 66.7% excellent and 33.3% good results obtained. Four strand cruciate repair in this zone show a better functional outcome as compared to Modified Kessler repair. Al-Qattan MM. <sup>(4)</sup> reported 90% excellent and 4.7% good results in Zone III flexor tendon repair using 'figure of eight' core sutures and a continuous epitendinous suture followed by an immediate active range of motion protocol, while Narendra Saini and colleagues<sup>(20)</sup> reported 35.29% excellent, 17.60% good and 29.41% poor results in zone III flexor tendon injuries repaired by modified Kessler core suture technique with locking epitendinous sutures and rehabilitated by modified Kleinert's regimen and Silfverskiöld regimen. This satisfactory outcome is attributed to early repair, a smaller number of tendons to repair and therefore lesser operative time. In addition, only 4 cases were associated with median nerve injury.

Zone II injuries were encountered in 25% of our series, we achieved 16.7% excellent, 41.7% good, 33.3% fair and 8.3% poor results. Four strand cruciate repair also showed a better functional result than in modified Kessler repair. These results were comparable to other studies<sup>3,21</sup> which reveal a lower complication rate and a shorter time of treatment in 6 strands repair technique, but in contrast with Navali and Rouhani<sup>(2)</sup> who were unable to show significant difference in active range of finger motion achieved with 2 strand and 4 strands repair techniques.

#### 4. Conclusion

The 4-strands cruciate technique had better functional outcome and less chance of complications compared to modified Kessler repair.

#### Declaration of competing interest

The author have no financial disclosures or conflicts of interest.

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