Research Article

Four-strands versus six-strands core sutures technique for surgical management of acute zone II flexor tendon injury

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Abstract
This randomized prospective comparative study was conducted on 52 patients (60 fingers) who sustained acute zone 2 flexor tendon injury in the form of complete laceration of isolated FDP tendon or combined FDP and FDS tendons. All patients were operated in the period between March 2017 and January 2020 in Minia Hand and Microsurgery Unit (MHMU) in orthopaedic surgery department. The injured fingers were repaired using either a 4-strand or a 6-strand core suture repair by simple random selection using sealed envelope method. The patients were divided into 2 groups: Group A: Patients were managed by 4-strand; double modified Kessler core suture and Group B: Patients were managed by 6-strand; triple modified Kessler core suture. Post operatively, the patients were instructed to start early controlled active motion from the first day. Then, they were assessed regularly at the 4th, 8th and 12th week of rehabilitation for: Visual analogue scale (VAS), Grip strength and Total active motion (TAM). There was no significant differences in grip strength in both groups measured in comparison with the other normal side at all examination time point but the difference between TAM is significant all through measurement time points between the 2 studied groups. so, the 6-strand repair is superior to the 4-strand repair regarding the TAM and effective PIPJ and DIPJ flexion. It was also found that 6-strand repair gives a better range of extension through different inter-phalangeal joints.
Keywords: Orthopaedic, surgery, fingers

Introduction
Hand injuries have become one of the most significant reasons for patients to seek medical advice on an emergency basis. Sharp injuries resulting in flexor tendon injuries, have always remained a challenge for hand surgeons to get patients back to normal health and save them from prolonged disability and emotional distress. The flexor tendons in the hand and forearm are divided into five zones anatomically, which offer the basic nomenclature for anatomy of the flexor tendons and surgical repairs. Among them, zone 2 is the most important and difficult to manage. It was termed "No man's land" by Dr. Sterling Bunnell in 1948 due to the complications often arising from injury to both the FDS and the FDP tendons with either tendon rerupture but mostly due to adhesions. These complications are well known and may require revision surgery in up to 25% of cases.

Repair of Zone 2 flexor tendon injuries is an evolving topic in hand surgery with a wide range of repair techniques, materials, and post-operative rehabilitation options. All flexor tendon repair approaches and procedures have improved over the past decade, as surgeons try to improve postoperative outcomes. The objectives of optimal repair include sufficient strength, reduced gapping at the repair site, healing promotion, and efficient gliding and excursion of the tendon.

Subsequently, there is currently no consensus on the best intraoperative and postoperative care for these injuries, although the literature supports performing robust suture repair to allow early active motion.

Patients and Methods
This randomized prospective comparative study was conducted on 52 patients (60 fingers) who sustained acute zone 2 flexor tendon injury in the form of complete laceration of isolated FDP tendon or combined FDP and FDS tendons. All patients were operated in the period between March 2017 and January 2020 in Minia Hand

and Microsurgery Unit (MHMU) in orthopaedic surgery department. The institutional review board approval was obtained (ID: 9110727). The injured fingers were repaired using either a 4-strand or a 6-strand core suture repair by simple random selection using sealed envelope method. All patients recruited for this study have signed full informed consents. Patients eligible for this study were recruited after applying the following inclusion and exclusion criteria.

Inclusion Criteria:

1. Zone 2 flexor tendon injuries.
2. Acute (within 24 hours since the onset of injury) clean sharp injury.

Exclusion Criteria:

1. Patients with other associated injuries which may affect rehabilitation.
2. Patients who presented with soft tissue injury, skin loss, tendon loss and/or fracture of phalanges.
3. Patients with history of previous tendon injuries or surgeries.
4. Non-compliant patients to rehabilitation protocols.
5. Psychological and personality disorders.
6. Patients with local vascular compromise.
7. Patients with any systemic disease that could affect healing capacity.
8. Thumb FPL injuries.

All procedures were done under general or local anesthesia based on patient co-operation and surgeon preference. The patient was positioned supine with the arm extended on a side table. The wound was first copiously irrigated and a pneumatic arm tourniquet was set at 50 mm Hg above the systolic blood pressure. Then, disinfection with povidone iodine, draping of the hand and forearm and scrubbing were done. The position of the fingers or hand was determined by levels of cuts in the tendons in relation to their superficial tissues. The assistant would usually hold the hand, so that it could be adjusted during surgery. The surgical approach was actually the wound itself, which was extended by oblique incisions at both ends into Bruner like zigzag incisions. The chief principles for the choice of incision were to avoid crossing flexion creases at right angles to prevent later flexion contracture caused by scar and to protect the underlying neurovascular bundles from being injured.

Flexor tendon injuries in the palm appear to be easier to expose and repair because the lumbricals (which arise from the FDP at this level) are mostly intact, preventing retraction of the FDP tendon's cut ends.

The patients were divided into 2 groups:

Group A:

Patients were managed by 4-strand; double modified Kessler core suture.

Group B:

Patients were managed by 6-strand; triple modified Kessler core suture.

The patients were instructed for initial edema control by elevation of the limb, movement of the shoulder and elbow, and light bandaging of wounds. If needed, a self-adhesive circumferential wrap to the injured digit to decrease swelling was applied at night, if the patient was able to apply it safely. Antibiotics and analgesics were described for the first 7 days.

The patients were instructed to start early controlled active motion from the first day. Sutures were removed after healing of the wound and the median was 12 days. The patients had scheduled visits to MHMU 3 times per week for the whole the first two weeks of the rehabilitation course. Then, the following measures were regularly assessed at the 4^{th}, 8^{th} and 12^{th} week of rehabilitation:

1- Visual analogue scale (VAS).

2- Grip strength. In our study the grip strength was measured using the sphygmomanometer cuff and asking the patient to squeeze the cuff with arm adducted, elbow flexed, forearm supinated and 30° of wrist flexion. Then, recording the pressure obtained from squeezing the cuff and comparing it with the uninjured hand.

Dominant hand

- Good above 80% of uninjured hand
- Bad below 80% of uninjured hand

Non dominant hand

- Good above 60% of uninjured hand
- Bad below 60% of uninjured hand

3- Total active motion (TAM)

Classically measured in total arc of motion in injured finger and was compared to contralateral uninjured finger. Measurements were recorded by manual hand goniometry using a

standard finger goniometer. The findings were analyzed using the Total Active Movement (TAM) score, as defined by the American Society for Surgery of the Hand (ASSH).

The Calculation is

TAM = (DIPJ +PIPJ +MCPJ) Flexion – extension loss

It equals to the sum of flexion range in MCPJ, PIPJ and DIPJ minus extension lag and compared to total active range of motion of contralateral digit in percentage. The normal TAM of the thumb was considered to be 130° while that of the digits to be 260°.

On the basis of this comparison the results are classified as follows.

Excellent: TAM more than 90% of normal side.

Good: TAM more than 75% to 89% of normal side.

Fair: TAM more than 50% to 74% of normal side.

Poor: TAM less than 50% of normal side.

Worse: TAM worse than before surgery.

Range of motion (ROM) was taken at 4, 8, and 12 weeks after surgery using a Goniometer for each of the following joints: MCPJ, PIPJ & DIPJ.

Results

Patients were divided into 2 groups:

Group A: Four-strand repair group (22 patients {30 fingers} with mean age 23.6 ± 7.2 years {range: 4-42}) including 12 males and 10 females.

Group B: Six-strand repair group (30 patients {30 fingers} with mean age 27.8 ± 7.6 years {range: 16-42}) including 17 males and 13 females. Both groups showed statistically comparable demographic data.

At all follow up intervals there was insignificant difference between the 2 groups according to VAS measurements and there was decline in mean values noticed in group A from 5.1 ± 1.6 to 3.2 ± 1.1 then 1.2 ± 1. Regarding group B, these values declined also from 5.3 ± 1.8 to 3.3 ± 1.4 then 1.5 ± 1.2. It was noticed to be the highest at first 4 weeks which was primarily owed to the incision wound which declines with time.

There was no significant differences in grip strength measured in comparison with the other normal side at all examination time point. There was sequential improvements in mean values noticed in group A from 22.4 ± 14.4 to 41.6 ± 16.7 then 64.67 ± 9.52. Regarding group B, these values improved from 20.7 ± 12 to 42.3 ± 16.6 then 70.8 ± 9.4 which was the lowest at the end of week (4) owed to splinting which was weaned after the 5th week (table 7 and 8).

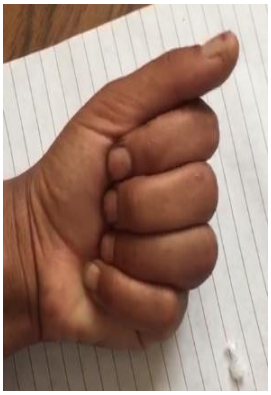
The difference between TAM is significant all through measurement time points between the 2 studied groups and this could be explained by the expected less complications with 6-strand repair as repair site gaping and rupture which occur mostly early at the early stages of rehabilitation. The mean ± SD for group A at 4th week is 45 ± 9.2 and for group B is 53.6 ± 13.6 and at 8^{th} week it is 62.5 ± 9.5 for group A and 74.5 ± 8.2 for group B. at 12^{th} week it is 80 ± 7 for group A and 87.9 ± 4.5 for group B.

Case 1:

Female patient, 18 years old presented with cut wound at zone 2 (subzone C) of left ring finger with complete cut of FDP, FDS tendons and affection of the neurovascular bundle on the radial aspect .

Repair was done for the FDP tendon only using 4-strand core suture technique by poly-propylene (Ethicon) 3/0, partial venting of the A2 and A4 pulleys was performed, the injured digital nerve was repaired by polypropylene (Ethicon) 9/0 and epitendineous sutures were taken.

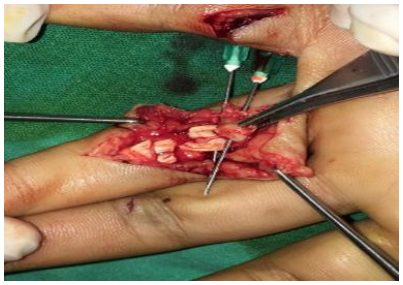




Case 2:

Male patient, 15 years old presented with cut wound at zone 2 (subzone C) of left ring finger with complete cut of FDP and FDS tendons.

Repair was done for both FDP and FDS tendons using 6-strand core suture technique by polypropylene (Ethicon) 3/0, partial venting of the A2 pulley was performed and epitendineous sutures were taken.


Complications

In group A complications were managed as follows:

- Six cases of variable grades of adhesions and were instructed to continue physiotherapy; one case of severe adhesions of FDP function with no progression on physiotherapy and refused tenolysis.
- One case of rupture of the repaired tendon was recorded in a 42 years old male with isolated injury of FDP of little finger, revision surgery was instructed but the patient refused.
- Post-operative radial nerve tourniquet palsy diagnosed with affection of both motor and sensory divisions in a 24 years old female patient with cut FDP and FDS of the index, middle, ring and little fingers of the left hand.

The operation lasted for 2 hours but the tourniquet was deflated after 1 hour and 20 minutes. The patient was followed up for nearly 3 months until complete recovery.

- Twenty eight years old female patient presented with superficial wound infection managed by wound care and proper antibiotics.
- Twenty four years old male patient with injury to the right ring finger presented after 8 days with signs of inflammation and purulent discharge. He was managed by wound care, daily dressing, and proper antibiotics.

• Twenty nine years old male patient with injured volar plate in addition to cut FDP and FDS of middle finger presented at follow up with hyper extension deformity.

In group B complications were managed as follows:

• Four cases of variable degrees of adhesions were managed by close follow up of physiotherapy (3 visits per week). The most severe case which did not improved with physiotherapy was advised for tenolysis but the case refused surgery.

• Twenty eight years old female patient with injury to the left ring presented with wound inflammatory signs managed by wound care and administration of proper antibiotics.

• One case of tendon repair rupture was recorded in a male 39 years old with cut FDP and FDS little finger. Immediate revision of repair was performed using Palmaris tendon graft.

Discussion

Zone 2 was termed "no man's land" by Dr. Sterling Bunnell in 1948 due to the complications often arising from injury to both the FDS and FDP tendons with either tendon rerupture but mostly due to adhesions.

This study compared using of two different techniques (4-strand and 6-strand core suture) for primary flexor tendon repair. The study was conducted on 52 patients (60 fingers) who sustained acute zone 2 flexor tendon injury recruited from the emergency department of Minia university hospital. These patients were mainly young adults and middle-aged individuals, and this helped us greatly in achieving the post-operative program as these age groups are highly motivated and compliant patients.

All patients were treated by primary repair within the first 24 hours. The patients were divided into two groups; the first group of patients underwent 4-strand suture technique repairs, while the second group underwent 6-strand suture technique repairs. Early active mobilization has been used post-operatively in both groups.

In all cases we used polypropylene (Ethicon) in both core (3/0) or (4/0) and epitendineous (6/0) sutures because the ideal suture material should be non-reactive, of small caliber, strong, easy to handle, and able to hold a good knot. So, Polypropylene satisfies all our needs.

Post-operative management following repair of flexor tendon injuries in the hand is the result of the balance between repair protection and prevention of adhesions through early motion.

In this study, age and sex were comparable and there were insignificant statistical differences between both groups (for age: $P = 0.06$ and for sex: $P = 0.169$).

The little finger was the most frequently injured finger in both groups (24 fingers; 40%). In group A, there were 12 little fingers and according to TAM; excellent results were obtained from 6 cases (50%) and good results were obtained from 3 cases (25%). So, 75% of cases obtained excellent and good results. In group B, there were 12 little fingers and according to TAM; excellent results were obtained from 7 cases (58.3%) and good results were obtained from 3 cases (25%). So, 83.3% of cases obtained excellent and good results.

Subzone C (22 fingers; 33%) was the most injured, where repair was technically challenging because this region is limited by the A2 pulley. So, repair of both tendons is difficult and if both were repaired it may lead to crowdedness and triggering under the A2 pulley so repair of the FDS tendon is according to the condition if permit. Subsequently, at both groups, about half of cases were treated by repairing of both tendons and the other half is treated by repairing FDP tendon only. At subzone A and subzone B where the FDS tendon is bifurcated into two slips. It is almost impossible to repair the FDS tendon there and repair was to excise the FDS locally especially in cases with severe peritendineous injuries or when the tendons appear edematous. Treatment of the FDS tendon in zone 2D was straight forward, similar to the FDP tendon, except that the FDS is flatter and four or fewer strands were used.

In the studied groups, it was found that the mean grip strength values at the 4th week, 8th week and 12th week of follow up were comparable and There were an insignificant statistical difference between both groups (at the 4th week: $P = 0.986$, at the 8th week: $P = 0.658$ and at the 12th week: $P = 0.417$).

In the studied groups, the differences between TAM criteria is significant all through measurement points between the two studied groups with a higher mean in group B(in week 4: P = 0.028, in week 8: P = 0.001 and in week 12: P = 0.001).
According to time points, the improvement in both groups was obvious and although the statistical differences between the 2 groups were significant in favor of group B but the clinical differences in the results between the 2 groups were not major and most of cases were well improved.

In group A, 16 digits (53.3%) were found to have excellent results, 8 digits (26.7%) had good results, 4 digits (13.3%) obtained fair results and the results were poor in 2 digits (6.7%). So, good and excellent results were found in 80% of digits (24 digits)

In group B, 20 digits (66.7%) were found to have excellent results, 6 digits (20%) had good results, 2 digits (6.7%) obtained fair results and the results were poor in 2 digits (6.7%). So, good and excellent results were obtained in 86.7 % of digits (26 digits)

On comparing the two studied groups regarding the mean angle of effective PIPJ flexion after 4 weeks, 8 weeks and 12 weeks follow up, we found that there was a significant statistical difference between both groups with a higher mean in group B (after 4 weeks: P = 0.002, after 8 weeks: P = 0.001 and after 12 weeks P = 0.002).

On comparing the two studied groups regarding the mean angle of effective DIPJ flexion after 4 weeks follow up, we found that there was insignificant statistical differences between both groups (p = 0.435). While after 8 and 12 weeks there was significant statistical difference between both groups with a higher mean in group B (after 8 weeks: P = 0.006 and after 12 weeks: P = 0.004).

As a result, we found that there was a statistically significant difference between four and 6-strand repairs as regards the angle of effective PIPJ flexion in favor of 6-strand repairs. The mean angle of PIPJ flexion was comparable at both groups but according to PIPJ mean angle of extension (extension lag), it was higher at group A than group B and that is why there were statistically significant difference as regard to angle of effective PIPJ flexion in favor of six strand repair.

There was statistically significant difference between 4 and 6-strand repairs as regard to angle of effective DIPJ flexion in favor of 6-strand repairs. The mean angle of DIPJ flexion was comparable at both groups but according to DIPJ mean angle of extension (extension lag), it was higher at group A than group B, that was why there were statistically significant difference in the angle of effective DIPJ flexion in favor of 6-strand repairs.

It could be explained as 6-strand repair gave sufficient strength to the tendon repair which allowed secure motion particularly in extension from the first day. So, it allowed early physiotherapy and rehabilitation that affect the outcome later on so this early motion and help in completing the extension of PIPJ and DIPJ so decreasing angle of extension compared with 4-strand repairs.

Although the significant statistical differences between both groups in effective PIPJ and DIPJ flexion with higher mean in favor of group B but we found that the final clinical differences between both groups after completing physiotherapy were not much as the mean of effective PIPJ flexion for group A was 57.9 ± 6.2 while for group B was 64.3 ± 7.3 and the mean of effective DIPJ flexion was 83±9.4 for group A while for group B it was 90.6 ± 9.

Conclusion

In our study, we found that the 6-strand repair is superior to the 4-strand repair regarding the TAM and effective PIPJ and DIPJ flexion.
It was also found that 6-strand repair gives a better range of extension through different inter-phalangeal joints.
It was found that using 3|0 polypropylene for the core suture followed by 6|0 polypropylene for epitendineous suture was ideal for the repair and decreases the repair site bulk.
As regard grip strength, PIPJ and DIPJ angle of flexion there is no statistical differences between four and 6-strand repair.

Recommendations

In the light of the results and conclusions of the current study, the followings are recommended: There were differences between 4 and 6-strand repair as regard TAM and effective PIPJ and DIPJ flexion in favor of 6-strand repair but these differences were not so much so the 6-strand repair of flexor tendons zone two injury is the first choice and to be applied whenever possible and if the tendon caliber permits although 4-strand repair also still working with good comparable results. So both methods of repair have good comparative results on the function of flexor tendons.

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