

Ultras ono graphic Assessment of 2-Strand Versus 4-Strand Core Suture in Flexor Tendon Repair: A Comparative Study

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Abstract

Background: There are many techniques of flexor tendon repair, which comprise of a core suture of different configurations with or without an epitendinous running stitch. Several studies have compared these methods with different results. Ultrasonography is being used more in the management of tendon injuries, however few studies have used it to compare repair techniques.

Aim of Study: The study aimed to use ultrasonography (US) to compare 2-strand and 4-strand core sutures in flexor tendon repair, in addition to functional outcome.

Patients and Methods: This was a randomized prospective comparative study of 40 patients with flexor tendon injuries. They were assigned to 2 groups - Group A had a 4-strand cruciate core suture, while Group B received a 2-strand modified Kessler repair. Patients started an early controlled active mobilization protocol and were assessed by ultrasonography and clinical examination.

Results: A total of 64 tendons were repaired in 50 fingers, equally divided among both groups where their demographics were comparable. Ultrasonographic assessment showed less tendon gap measurements with 4-strand repair, and adhesions were not significantly different. Most patients had good range of motion, and this was not related to adhesion formation. There was no significant difference between both groups in terms of complications.

Conclusion: Ultrasonography is a useful method to compare different types of tendon repair. Four-strand core sutures had less gap formation, with no significant difference in adhesions or complication rates, compared to 2-strand repairs.

Key Words: Flexor tendon - Repair - Core suture – Ultrasound.

Introduction

FLEXOR tendon injuries are one of the commonest forms of hand injuries, and have long term sequelae in terms of function and loss of work [1]. Outcome of treatment relies on a strong repair that would permit early rehabilitation to allow for proper intrinsic tendon healing and to prevent adhesions

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and joint stiffness, aiming for restoration of the range of motion (ROM) of the finger [2]. Many techniques have been described, and mainly involve a core and a peripheral running suture. While the 2-strand core suture was the most popular method used for repair, recently there has been a shift to multi-strand core sutures [3]. Many studies have compared the results of the different techniques, but with no consensus. The aim of this study was to compare the commonly performed techniques of flexor tendon repair in our unit using ultrasonographic (US) assessment and functional outcome.

Patients and Methods

This is a prospective comparative randomized study performed at Kasr Al-Ainy plastic surgery department, in which forty patients who presented with flexor tendon injuries in zones II or III were recruited over a period from January 2017 to February 2018. Exclusion criteria included degloved injuries, crushed tendons and segment loss, concomitant nerve or skeletal injury, and soft tissue loss that required complex coverage. All patients were assessed clinically, and radiographs were done as required to exclude fractures. Wounds were irrigated, and patients were commenced on intravenous antibiotic and received tetanus prophylaxis when indicated. Using alternate allocation, patients were put into one of 2 groups: Group A were repaired by a 4-strand core suture, and Group B were repaired by a 2-strand core suture.

Surgical techniques:

All patients were operated upon under general or regional anesthesia, using a pneumatic tourniquet, magnification, and good lighting. Local wound exploration was done, and wounds extended as needed. Once the digital tunnel was identified, attempts were done to retrieve the tendon ends by flexing the distal joints and milking the palm to

find the proximal end. Palm incisions were done if the proximal end was not identified in the wound. When both ends were retrieved, tendon edges were refreshed to about 1-2mm and a core suture was placed using a 4/0 round needle monofilament polypropylene suture material. Group A tendons received a 4-strand cruciate type repair, while a 2-strand modified Kessler repair was performed in Group B (Fig. 1). The core suture in both groups was followed by running epitendinous stitching using a 6/0 polypropylene suture. After hemostasis and wound closure, all patients were placed in a dorsal blocking splint. Patients were referred to physiotherapy the next day for an early controlled active mobilization program and were followed-up for 6-8 weeks before assessment was done.

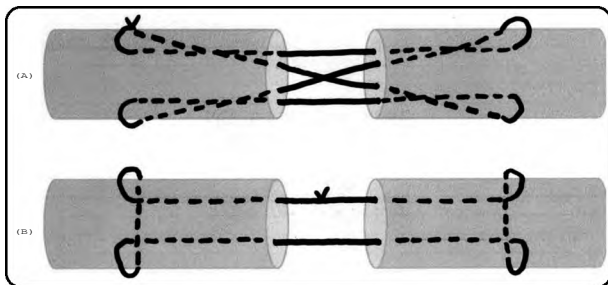


Fig. (1): Schematic image of types of core sutures used in both groups. (A) 4-strand cruciate repair applied to Group A, (B) 2-strand modified Kessler repair applied to Group B patients.

Clinical assessment:

Evaluation of range of motion (ROM) was done using finger-to-palm method, where the distance between the finger pulp and the distal palmar crease was measured in full flexion (Table 1). Complications were documented to include infection, wound dehiscence, contractures, and tendon rupture.

Table (1): Finger-to-palm distance method classification of ROM.

Finger to palm Distance (cm)	Extension Deficit (°)	ROM
0-1	0-15	Good
1-1.5	16-30	
1.5-3	31-50	Fair
>3	>50	Poor

Ultrasonographic assessment:

Ultrasonography (US) was done using GE logiq p5 premium BT1 1 (GE Medical Systems, Milwaukee, WI, USA) machine with musculoskeletal GE 11 linear probe (5-13MHz). The gap between tendon ends that appeared as a linear shadow at the repair sites were measured in centimeters both at rest (GOR), and at load (GOL). Adhesions were

assessed and classified as no adhesions, mild, moderate, and severe adhesions according to the thickness measured (Table 2).

Table (2): Ultrasonographic classification of adhesions according to thickness.

Grade of Adhesions	Adhesion thickness (cm)
No	≤0.1
Mild	0.11-0.24
Moderate	0.25-0.49
Severe	≥0.5

Statistical analysis:

Data was presented as mean, standard deviation (SD), median and range, or frequencies (number of cases) and percentages when indicated. Comparison of numerical variables between the study groups was done using Mann Whitney U test for independent samples. For comparing categorical data, Chi-square (χ^2) test or Exact test was performed. *p*-values less than 0.05 was considered statistically significant. Spearman rank correlation equation was used for correlation between variables. Statistical calculations were done using IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows.

Results

Forty patients were recruited during the study period, where a total of 50 fingers were involved with a total of 64 flexor tendon injuries in zones II and III. Patients were equally assigned to either group A or group B according to technique of tendon repair.

Demographic data and tendon injury characteristics: (Table 3)

Regarding sex distribution there was a male predominance in both groups, where 80.0% of all patients were male with 75% in Group A and 85% in Group B. The overall ages of the patients ranged from 15 to 60 years, with mean ages of 24.9 and 23.5 years for Group A and Group B respectively. Handedness was almost equally distributed between the right and left hands with a slight right-hand predominance forming 52.5% of all injuries. All patients were injured with sharp objects, with no loss of segment or crushed tendons. Considering the number of injured tendons amongst both groups, there were 23 cases with single tendon injury, 13 cases with two tendons, 3 cases with three tendons, and a single case with six tendons injured. As for finger affection, the most affected finger overall was the index finger in 14 cases, followed by the

ring in 13 cases, the little finger in 10 cases, and the least affected was the middle finger in 6 cases. The thumb was involved in 7 cases within the study group.

Table (3): Summary of demographics and characteristics of injuries in both groups.

	Group A	Group B
<i>Sex:</i>		
Male	15	17
Female	5	3
<i>Age (years):</i>		
Mean	24.9	23.5
Range	15-40	19-60
<i>Zone:</i>		
II	12	14
III	8	6
<i>Tendon:</i>		
FDS	9	6
FDP	17	15
FPL	1	6
Total	27	27
<i>Finger:</i>		
Thumb	1	6
Index	10	4
Middle	4	2
Ring	5	8
Little	5	5
Total	25	25

Zones of injury were comparable between both groups where Group A had 12 injuries in zone II and 8 injuries in zone III, compared to 14 injuries in zone II and 6 in zone III in Group B patients. This included injury of the flexor digitorum superficialis (FDS) in 9 fingers in Group A and 6 in Group B, while the flexor digitorum profundus (FDP) was injured in 17 fingers in Group A and 15 fingers in Group B. There was one flexor pollicis longus (FPL) injury in Group A and 6 in Group B. Six fingers in each group had more than one tendon injury.

Clinical outcomes:

ROM was graded as good, fair or poor; where most patients in Group A (n=13) assessed as having good ROM compared to 7 patients in Group B. The rest of the patients in Group A had fair ROM, while in Group B 10 patients had fair ROM and 3 patients were assessed as poor. As for complications, Group B exhibited 2 cases of failure of repair, and both groups had 2 cases of infection and one case of joint contracture and delayed healing each.

Ultrasonographic findings:

Gap formation was assessed at rest (GOR) and on load (GOL), with Group A repairs showing narrower gaps when compared to Group B (Fig. 2). There were also 6 cases with gaps of 3mm or more in Group B compared to only one case in Group A. This difference was statistically significant (Table 4).

Table (4): Post-operative tendon gapping as assessed by ultrasonography.

	Group A	Group B	p-value
Mean GOR (cm)	0.093	0.144	0.001
Mean GOL (cm)	0.152	0.236	0.00012

Adhesion formation was graded according to thickness and compared between both groups, with 15 patients (37.5%) showing some grade of adhesions (Fig. 3). Group B patients showed more moderate to severe adhesions in contrast to Group A, however this was not found to be significant (Table 5).

Table (5): Grade of adhesions among both groups.

Grade of Adhesions	Group A	Group B	p-value
No	13	12	0.217
Mild	4	1	
Moderate	1	5	
Severe	2	2	

The latter results were correlated with the ROM in both groups (Tables 6,7). Collectively, 25 cases had no adhesion formation (62.5%) where 16 of them regained good ROM (11 in Group A, 5 in Group B) and 9 regained fair ROM (2 in Group A, 7 in Group B). For the 5 cases with mild adhesions (12.5%), 2 of them regained good ROM (both in group A) and 3 regained fair ROM (2 in Group A, 1 in Group B). Six cases showed moderate adhesions (15%), for which 2 regained a good ROM (both in Group B), 2 with fair ROM (one in each group), and 2 with poor ROM (both in Group B). As for the four cases with severe adhesions (10%), 3 showed fair ROM (2 in group A, 1 in group B), and one case from Group B had poor ROM. Considering the relations between the level of adhesion and ROM, there was no significant effect of the grade of adhesion on the quality of flexion and ROM.

Table (6): Correlation between adhesions and ROM in Group A.

	ROM			Total	p-value
	Poor	Fair	Good		
<i>Adhesions:</i>					
No	0	2	11	13	0.06
Mild	0	2	2	4	
Moderate	0	1	0	1	
Severe	0	2	0	2	
Total	0	7	13	20	

Table (7): Correlation between adhesions and ROM in Group B.

	ROM			Total	p-value
	Poor	Fair	Good		
<i>Adhesions:</i>					
No	0	7	5	12	0.077
Mild	0	1	0	1	
Moderate	2	1	2	5	
Severe	1	1	0	2	
Total	3	10	7	20	

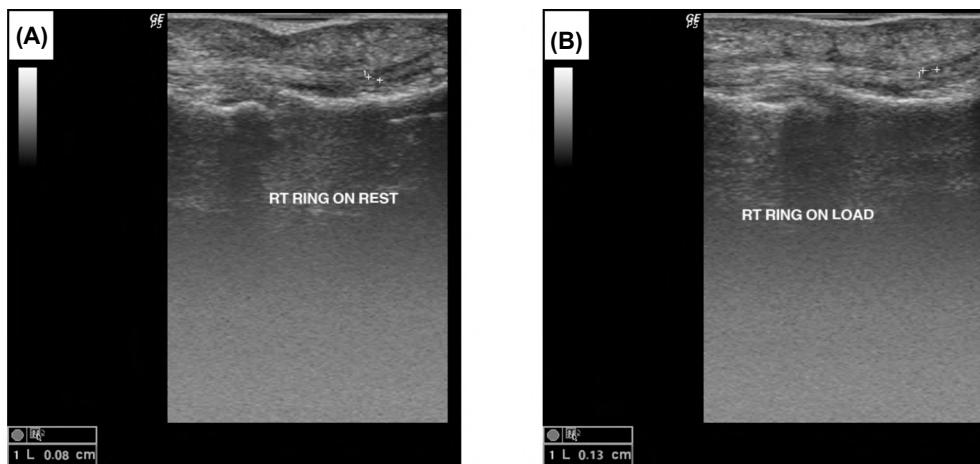


Fig. (2): Ultrasound images showing tendon gap measurements after righting finger FDP tendon repair using 4-strand cruciate core suture: (A) Gap on rest = 0.8mm. (B) Gap on load = 1.3mm.



Fig. (3): Ultrasound image of severe adhesions after repair using modified Kessler repair in Zone II.

Discussion

Flexor tendon injuries are one of the commonest forms of hand trauma that present to the hand surgeon and many advances have been achieved in the understanding of tendon healing, tendon repair techniques, and rehabilitation programs [4]. In general, a robust repair is needed to allow for early active hand therapy in order to prevent adhe-

sions and restore the range of motion. Many repair techniques have been described regarding suture configuration, and there has been a shift towards a multi-strand core suture with or without an epitendinous repair. Although many studies have compared different core sutures, there is still no consensus about the superiority of any of them [5].

Ultrasonography is an affordable and available imaging modality that is being used more in hand surgery centers as a diagnostic and therapeutic tool. Its value in assessment of tendon repairs has been reported in several studies [6,7]. However, it has not been used to assess different types of repair. The aim of this study was to use ultrasonography to assess two commonly used core suture configurations in our unit, and to correlate the findings with the functional outcome.

This study included 40 patients presenting with a total of 64 flexor tendon injuries in zones II and III. The majority of patients were male with a mean age of 24 years, with the index finger most commonly affected. Patients were randomly assigned to one of 2 groups: Group A received a 4-strand cruciate core suture, while a 2-strand modified Kessler repair was used in Group B. All patients

were referred to hand therapy in the form of early controlled active mobilization and were assessed at 6-8 weeks postoperatively both clinically and by ultrasonography.

Post-operative gap between repaired tendon ends is predictive of adhesion formation and rerupture rates as suggested by biomechanical studies, with measurements of over 3mm denoting a weak repair [8]. We assessed this by US, and our results showed that gapping on rest and on load was wider in Group B patients that were repaired by the 2-strand modified Kessler core suture, and this was statistically significant. More patients in Group B also showed gaps over 3mm on load, however these were not within the only 2 cases that had a failed repair in the same group.

The studies that have previously used US to measure flexor tendon gaps were mostly done in cadavers. Only one study had evaluated tendon gapping in living subjects by US, and similarly concluded that strong multi-strand core sutures may result in no or less gapping [9]. However, they had used a 6-strand core repair with no epitendinous suture, and had not compared their results with other core suture configurations. The studies that used US to assess tendon repair gapping in cadavers aimed to evaluate US as a tool for post-operative evaluation rather than to compare different repairs. The authors concluded that although US had poor sensitivity to confirm intact repairs it had a better specificity to diagnose tendon failure, and that US overestimated actual gap measurements [10]. These sonographic results regarding tendon gaps confirmed data from studies done on animal models where, similar to our results, the 4-strand repair showed gap resistance and less gap formation compared to 2-strand repair techniques [11,12].

Other than gap formation, our study used US to compare the grade of adhesions between both methods of repair, and we found that most patients had no-to-mild adhesions irrespective of the type of repair. While more patients from Group B showed more moderate-to-severe grades of adhesions, there was no statistically significant difference between both groups in this respect. This was in agreement with a study that had also compared 2 and 4-strand repairs, showing that there was no significant difference in terms of adhesions, and concluded that multi-strand core sutures did not increase adhesion formation [13]. On the contrary, another study demonstrated that 2-strand techniques were less prone to adhesions, but this difference was not significant [12]. The latter 2 studies, how-

ever, were in animal models to allow for histological analysis.

Clinical examination showed that the majority of patients in Group A (65%) who underwent a 4-strand repair had good ROM compared to only 35% in Group B who received a 2-strand core suture, but this difference did not reach significance. Other studies have reported the same clinical results when comparing the same techniques and, in agreement to our findings, some reports did not find the difference to be significant [14-16]. In our study we correlated these clinical results with the ultrasonographic adhesion grades, and found no significant effect of US-detected adhesions on the ROM. There were patients within both groups with severe and moderate adhesions who had regained good ROM, while on the other hand there were patients with mild adhesions who demonstrated poor ROM. This supports the conclusions of previous studies that US should be better performed on cases with suspected failed repair [10].

In a study that compared the complications between 2 and 4-strand flexor tendon repairs, the authors found that there was no significant difference in terms of rupture rates and infection [17], while other studies demonstrated lower complication rates using multi-strand repairs [18,19]. Our results showed similar complication rates for both groups, although group B had 2 cases of tendon failure. These cases had a poor ROM and US showed moderate to severe adhesions, which can emphasize the value of US in conjunction with clinical examination in similar complicated cases, where earlier decisions can be made regarding revisional surgery or adjustment of rehabilitation protocols.

To the best of our knowledge, this is the first study to use ultrasonography to compare different core sutures in living subjects. However, this work was not without limitations, the most important being the sample size and follow-up period where both need be increased to deduce more reliable results. Being operator-dependent, US might also need to be done by more than one sonographer to avoid bias. We have also excluded nerve and skeletal injuries from our study that might affect US assessment and can confound the functional outcome.

Conclusion:

In conclusion, 4-strand core sutures lead to less gap formation compared to 2-strand techniques of flexor tendon repair when assessed by ultrasonography. This may decrease the risk of rupture with

active mobilization programs, however it was not accompanied by a significant advantage in terms of decreasing adhesion formation or improving range of motion. Ultrasonography has been proven to be a useful tool to compare different repair techniques, and its use is also recommended in complicated cases to guide management.

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استخدام الموجات فوق الصوتية لتقييم الطريقة ثنائية الجديلة ورباعية الجديلة لإصلاح الاوتار القابضة باليد : دراسة مقارنة

هناك العديد من التقنيات لإصلاح الاوتار القابضة باليد والتي تتكون من خياطة جوهريّة ذات أشكال مختلفة مع أو بدون غرزة خارجية متسلسلة.

قارنت العديد من الدراسات هذه الأساليب مع الوصول إلى نتائج مختلفة يتم استخدام الموجات فوق الصوتية في مناظرة وعلاج إصابات الاوتار ومع ذلك فقد استخدمتها دراسات قليلة لمقارنة تقنيات الإصلاح المختلفة.

هدفت هذه الدراسة إلى استخدام الموجات فوق الصوتية لمقارنة الغرز الجوهريّة ثنائية الجديلة (المكون من خيطين) ورباعية الجديلة (المكونة من ٤ خيوط) في إصلاح الاوتار القابضة بالإضافة إلى مقارنة النتائج الوظيفية وكانت هذه دراسة مقارنة عشوائية لـ ٤٠ مريض يعانون من إصابات في الاوتار القابضة وتم وضعهم بمجموعتين.

المجموعة أ استخدم فيها ٤ خيوط بطريقة صليبية بينما تلقت المجموعة ب إصلاح بتقنية كيسلر المعدلة ثنائية الخيوط بدأ المرضى بروتوكول العلاج الطبيعي مبكراً وتم تقييمهم عن طريق التصوير بالموجات فوق الصوتية والفحص السريري تم الإصلاح في ٦٤ وتراً في ٥٠ أصبغاً مقسمة بالتساوي بين المجموعتين حيث كانت التركيبة السكانية قابلة للمقارنة.

أظهر التقييم بالموجات فوق الصوتية قياسات فجوة أقل بين أطراف الاوتار مع الإصلاح باستخدام الغرز ذات أربع خيوط ولم تكن الالتصاقات مختلفة بشكل كبير بين التقنيتين كان لدى معظم المرضى نطاق جيد من الحركة ولم يكن هذا مرتبطاً بنسبة حدوث الالتصاق كما أنه لم يكن هناك فرق كبير بين المجموعتين من حيث المضاعفات.

خلصت هذه الدراسة إلى أن التصوير بالموجات فوق الصوتية طريقة مفيدة لمقارنة أنواع مختلفة من إصلاح الاوتار فكان استخدام الغرزة الجوهريّة ثنائية الجديلة مع عدم وجود فرق كبير في معدلات الالتصاقات أو المضاعفات.