COMPARATIVE STUDY OF FLEXOR TENDON REPAIR BY MODIFIED KESSLER'S TECHNIQUE WITH OR WITHOUT USING VENOUS GRAFT AS A TENDON SHEATH SUBSTITUTE IN ZONE II

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Abstract

Background: Hands are frequently exposed to injuries during daily working hours which might affect its function. Flexor tendon injuries of the hand result in loss of function. The main goal of surgery is to restore function, and avoid the occurrence of postoperative adhesions. However, a better understanding of the process of tendon healing, and continuous evolution of operative technique helps in improving the result. The use of venous graft as a tendon sheath substitute following tendon repair, reduces the adhesion formation, improves tendon nourishment, decreases the need for intensive physiotherapy, restores the function, and improves the results. Despite this remarkable progress, flexor tendon lesions still continues to present difficulty.

Objectives: To observe the effectiveness of using vein graft in tendon sheath reconstruction with the aim of decreasing adhesions and comparing it to the conventional method of tendon repair.

Patients and Methods: Forty patients who were injured recently, had flexor tendon injuries of the hand involving zone II. They were divided into test and control groups (20 patients each). Modified Kessler technique for primary repair of acute flexor tendons injuries were used in both groups added by the cephalic vein as a tendon sheath substitute in the test group.

Results: The evaluation of the results is based on TAM (Total Active Motion) score of the ASSH (American Society for Surgery of the Hand). The final results were 75% excellent, 25% good, with no fair or poor results concerning the test group, while in the control group, there was no excellent results; thus, 55% good, 45% fair, and the results obtained were not poor.

Conclusion: Repair of the flexor tendon injuries using modified Kessler

technique using a venous graft as a tendon sheath substitute and early active movement are recommended to provide effective results as a replacement for the conventional methods.

Keywords: Flexor tendon repair, tendon graft, tendon injury.

Introduction

The flexor tendon system of the hand consists of the flexor muscles of the forearm, the tendinous extensions, and the specialized digital flexor sheaths. These components work together to produce a smooth and efficient flexion of the individual digits of the hand. However, injury on the flexor tendon system can lead to significant morbidity for patients (Li et al., 2008, Nimbarte et al., 2008).

The muscles that flex the digits include the flexor digitorum profundus (FDP), flexor digitorum superficialis (FDS), and the flexor pollicis longus (FPL) (Moore, 1992). The anatomic relationships of the flexor tendons are usually discussed in terms of zones. Thus, the five (5) flexor tendon zones are modifications of Verdan's original work (Verdan,1960); and it is (Figure.1) applied only to the index through the small fingers

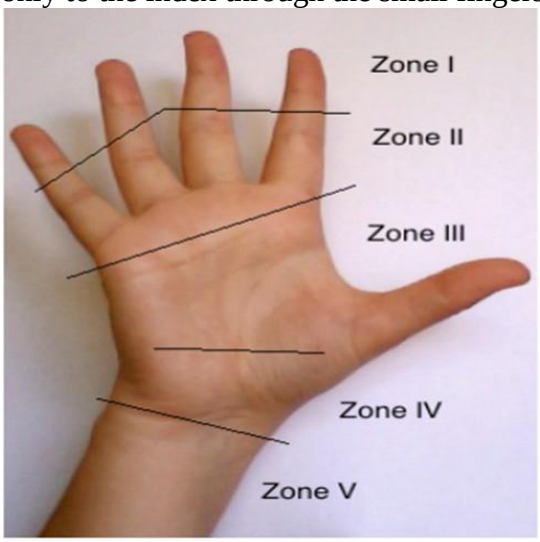


Figure (1): Verdan classification of the flexor system (Verdan, 1960)

The pulley system consists of the palmar aponeurosis (PA) pulley, 5 annular pulleys, and 3 cruciform pulleys. This system supplies a mechanical advantage by maintaining the flexor tendons close to the joint's axis of motion. However, in doing so, the pulleys prevent bowstringing, which makes up interphalangeal and metacarpophalangeal (MCP) joint motion (Figure 2).

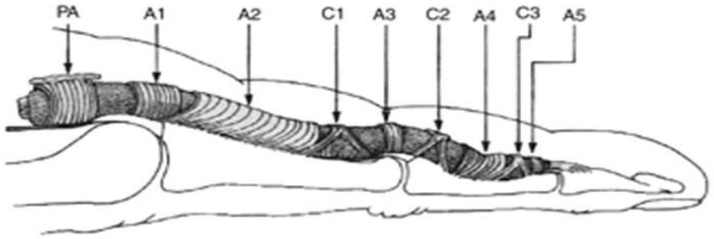


Figure (2): The arrangement of pulleys in the fibrous tendon sheath. Note that the A2 and A4 were from bones, while the A1, A3, and A5 were from volar plates. (Soma, 2006)

Furthermore, the synovial sheath offers a smooth gliding bed and provides synovial nutrition to the tendons. Mechanically, the pulleys serve to strengthen the sheath and hold the flexor tendons close to the phalanges and their joints (Stewart et al., 2007).

Flexor tendon injuries are often common, as the tendons lies close to the skin. Thus, they are usually the result of either laceration such as from knives or glass, or from crush injuries. Also occasionally, these tendons may rupture from where they are joined at the bone during contact sports such as football, rugby, and wrestling. Tendons can be injured through open wounds caused by sharp cuts or machine injuries, closed ruptures after fractures, bone problems, or spontaneously without any history of injury or any clear etiology. In addition, severe forms of tendon injury can become a part of compound injuries due to major trauma to the extremities. Consequently, surgically repaired tendons may disrupt during functional exercise (Mason, 1940)

Flexor tendon repair was first described by Kirchmayr in 1917, when he published a method of 'locking' suture for tendon repair (Kleinert, 1995). Age, gender, mechanism and nature of injury, time elapsed, occupation and dominant hand, are all important factors that will affect the plans and decisions made during the repair period. Therefore, the mechanism of injury is vitally important to understand that the level of contamination (clean knife versus oily scrap yard machine) will indicate preoperative and postoperative care (Verdan, 1977).

Two complications that can prevent active flexion of the finger may occur; one is the breakdown of the suture, while the other is adhesions in the digital canal around the tendon repair (Klein et al., 2002; Starck et al., 1977).

Zone II must be carefully treated as there is a close relationship between the FDS and the FDP, which can cause adhesion formation and failed repair. It is therefore recommended that both the FDS and FDP should be repaired in zone II injuries rather than just the flexor digitorum profundus alone as was once thought about (Grobbeler and Hudson, 1994)

In addition, autogenous saphenous vein graft has been used for the prevention of the adhesion of tendons (Moosavi et al., 2005; Wael et al., 2009; and Emad et al., 2012).

Mobilization following flexor tendon repair is essential for healing and repair. However, it has been said that the aim of rehabilitation after tendon repair is to achieve function and gliding, and to avoid the rupture of the tendon (Kleinert and Weiland, 1979). Furthermore, it has been shown experimentally that early motion stimulates tendon healing and decrease adhesions (Kleinert et al., 1973).

Also, the use of autogenous vein graft as a replacement of tendon sheath has many advantages. The advantages is that they are cheap; being autogenous; carries less risk of infection; does not affect tendon healing like other materials, so it is used to treat postoperative tendon adhesion and s e r v e s as prophylactic procedure in cases of lost tendon sheath in fresh cases; and it improves tendon nourishment (Kleinert and Verdan, 1983).

Table (1) TAM Evaluation System of ASSH (Strickland, 1980)

Score	%
Excellent	Normal
Good	> 75
Fair	50-75
Poor	>50
Worse	< pre-operative

TAM=total active flexion- total extension deficit (MCP, PIP, DIP)

%= TAM of injured finger/ TAM of contralateral finger

Table (2) Strickland Evaluation (Strickland, 1980)

Score	Original Strickland %	adjusted Strickland %
Excellent	85-100	75-100
Good	70-84	50-74
Fair	50-69	24-49
Poor	>50	0-24

$$\text{Strickland} = \frac{\text{active flexion} - \text{extension of deficit (DIP+PIP)}}{175^\circ} \times 100\%$$

Patients and Methods

A prospective randomized clinical trial was planned with 40 patients suffering from flexor tendon injury. The patients were admitted from

January 1st to June 1st 2014 in the Emergency Surgical Teaching Hospital of Sulaimani. All patients were informed about the study and had signed the relevant forms.

In addition, all patients had acute injuries on the hand in flexor zone II. They had features of flexor tendon injury with tendon sheath and pulley injury in which the repair was expected to be surrounded with adhesion during healing due to tendon sheath
Laceration, and further injury during exposure of tendon ends. However, they were operated on the same day of admission.

Inclusion Criteria

1. Flexor tendon injury in zone II.
2. Injuries in the medial four digits.
3. Single digital involvement.
4. Injuries during the first 24 hours.

Exclusion Criteria

1. Concomitant fractures, nerve injury, vascular injury, injured extensor mechanism, heavy skin laceration, and skin loss.
2. Previously injured hands or deformed hands.
3. Highly contaminated injuries.
4. Thumb injuries.

Thus, plain radiograph of the affected hand was done for all patients to exclude concomitant fractures and foreign bodies.

Wound irrigation was done using physiologic saline solution, and wound dressing was also carried out. Antibiotics (Ampiclox vial 1000mg) were administered through intravenous route to all patients (without history of allergy to penicillin group), and tetanus immunization was given to patients with an uncertain immunization status.

Surgical Technique

Forty patients were randomly divided into 2 groups equally. They include:

Control Group (20 patients underwent flexor tendon repair by the classical method using modified Kessler's suturing without using vein graft as a tendon sheath)

Test group (20 patients underwent flexor tendon repair using modified Kessler's repair using autogenous vein graft as a tendon sheath substitute)

All patients were operated under general anesthesia .The arm was prepared using Betadine solution for painting. Also, an arm tourniquet was used to get a bloodless field using the cuff pressure of 100 mmHg above

the systolic pressure after the arm has been exsangunated with a sterilized non-elastic disposable bandage.

The initial wound was examined and a plan for extension was drawn to complete the zigzag (Brunner incision) in a way that allows maximum visualization of the injured site. The skin and subcutaneous fat were raised off the tendon sheath as a single thick layer. The laceration of the sheath was identified, and a limited debridement of the hemorrhagic ends of the sheath was performed yielding to the exposure of the tendons after the reflection of the sheath flaps within the window between A2 and A4 annular pulleys.

Consequently, both ends of the injured tendons were brought together to the injured zone. The distal tendon was usually brought through distal interphalangeal joint passive flexion, while the proximal end was brought by the help of a pediatric feeding tube through a small incision in the palm proximal to the A1 pulley holding the tendons by a single stitch, and then, traction is applied to the tube till the tendons were delivered to the injury site. Also, it could be done simply by grasping the endotenon gently with a non-toothed tissue forceps if it is visible after milking the tendon ends in a proximal to distal massaging manner of the digit. Blind grasping of the tendon through the paratenon was avoided. The tendon position was then maintained by the placement of a fine (25-gauge) needle through the tendon and adjacent soft tissues.

Flexor tendon repair was performed using modified two strand Kessler method core suture with a round needle 3.0 polypropylene monofilament suture material followed by continuous epitendinouse suture using 6.0 polypropylene. For cases with combined flexor digitorum profundus and flexor digitorum superficialis tendon injury, only one slip of the flexor digitorum superficialis tendon sutured and the other one was removed to allow more space for tendon gliding.

The above procedures were applied to the first half (20 cases control group), while at the other half (20 cases test group), the same procedure was repeated with harvesting and placing the cephalic vein graft in the same wrist as follows:

1. Cephalic vein of the same wrist was identified prior to the application of the arm tourniquet and marked with a skin marker. Then after doing 3cm skin curved incision over the dorsum of the wrist, the identification of both cephalic vein and superficial branch of the radial nerve was made and for protecting the later from accidental injury. Ligation of both ends of the vein was done, then 1.5 to 2 centimeters from the vein were harvested, and the graft was put in a physiological saline solution.
2. The vein graft was dilated using a hemostat for dilatation. Then, a

segment of the vein through which the tendon had been passed prior to the repair, or a vein patch if the diameter was too small to pass over the tendon, was used as a tendon sheath substitute. A 6.0 polypropylene monofilament suture was used for anastamosing the proximal and distal ends of the sheath defect and the interposed segment of the autogenous vein or vein patch. The vein patch was wrapped around the tendon in a way that the smooth intimal layer faced the paratenon. The vein graft segment is considered as a replacement of the tendon sheath in which the tendon is gliding.

In addition, the wound was irrigated with physiological saline solution; tourniquet removed; haemostasis achieved; and the skin was closed with a single full thickness layer using polypropylene 4.0 suture materials.

Furthermore, postoperative dorsal slab was applied from elbow to fingertips wrist 40^0 flexion, metacarpo-phalangeal joints 90^0, and interphalangeal joints 180^0 for six weeks. The exercises consisted of 2 phases: the first three (3) weeks protective passive motion, and the second three (3) weeks assisted active motion.

In the last visit (6 months), an assessment of the finger movement was done using the total active movement (TAM scoring system) applied to all patients in either of the groups (Table 3).

After calculation of the sum of active flexion ranges in MCP, PIP, DIP minus the extension deficit (collectively stated 260 degrees by American Society for Surgery of Hand (ASSH)), the percentage of total active motion (TAM score) was calculated in the affected digit of every patient by dividing the recorded result with that of the contralateral non-injured digit.

In taking the measurement of TAM in each digit, standard goniometer was used.

All data analysis was done using the SPSS version16 software program. Statistical analysis was done using independent T.test to compare Means. However, *p.value* is regarded as significant if it is less than (0.005).

Table (3): TAM score system

TAM score	%
Excellent	Normal 100%
Good	75-99%
Fair	50-74%
Poor	<50%
Worse	<pre-operative

TAM=total active flexion – total extension deficit
(MCP, PIP, DIP)
%=TAM of the injured finger / TAM of the contralateral finger

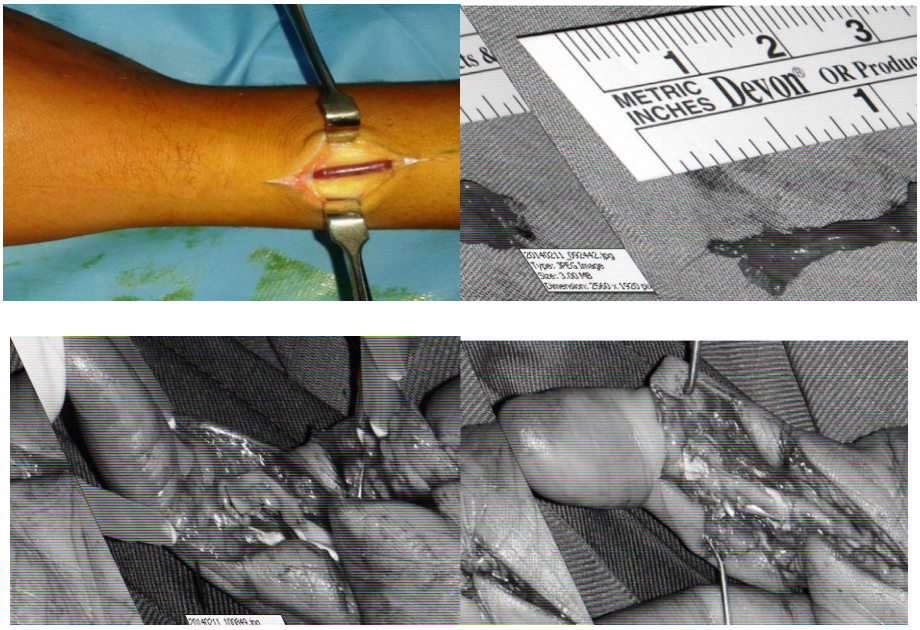


Figure (3): Cephalic vein exposed through a small incision, 2cm harvested and wrapped around the repair site of FDP tendon after repair and tendon sheath closed.

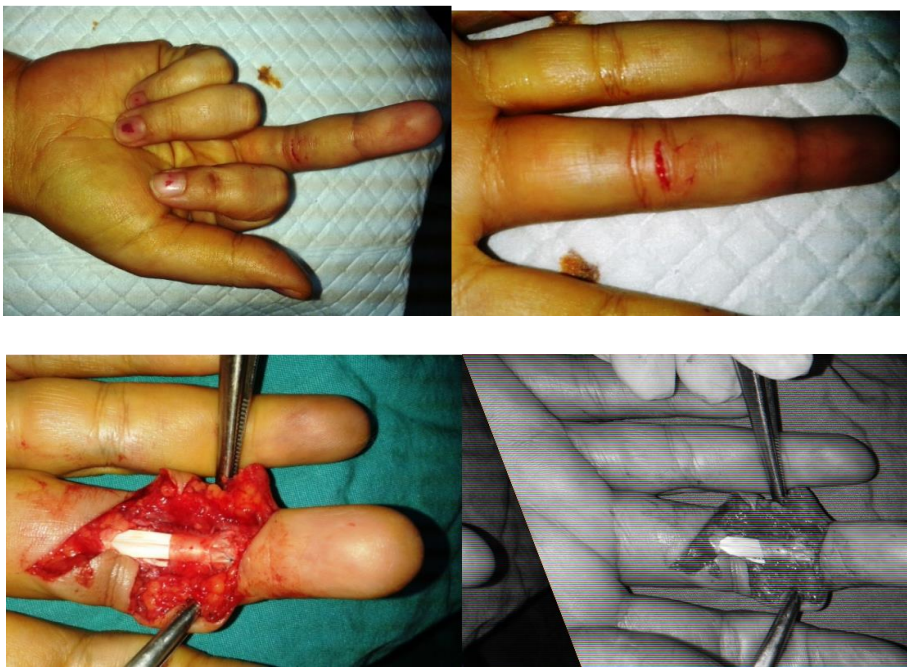


Figure (4): Right middle finger injury with lacerated FDP alone, tendon repair done without vein graft, and tendon sheath left opened.

Results

Forty patients with acute flexor tendon injury in zone II were included in the study, and they completed the final follow up period of 6 months. However, no patient escaped or was excluded from the study. The ages were ranged from 14 to 46 years with a mean age of 25.9 years. They were 25 (62.5%) males and 15 (37.5%) females.

Regarding occupational status, 37.5% of the patients did not need fine movement to perform their work. 10 were farmers, 3 housewives, and 2 were drivers. The others 62.5%, did depend on the fine hand movements; thus, 15 were students, 5 were computer operators, 4 were accountants and 1 was a violist. The right hand was the dominant hand in 35 patients (87.5%) and was more commonly injured in 22 cases (55%); the left hand was injured in 18 cases (45%) and was the dominant hand only in 5 cases (13.5%).

The causative agent was a glass in 18 patients (45%), knife in 16 (40%) patients, and other agents in 6 (15%) patients correlating with the type of the wound.

Time elapsed since the injury for the surgery ranged from 3 to 24 hours with the mean time of 14.45 hours. The injured digits were 10 index (25%), 10 middle (25%), 10 ring (25%), and 10 little (25%) finger.

The size of the wound was one centimeter in 5 (12.5%) of the patients, two centimeters in 22 (55%), three centimeters in 11 (27.5%), and four centimeters in only 2 (5%) of the patients. The frequency of flexor digitorum profundus injuries alone were in 19 patients (47.5%), but were seen in 21 patients (52.5%) when combined with flexor digitorum superficialis.

Complications

The reported complications were superficial infections in 2 patients (5%) in the form of cellulites. This was earlier during the second week after surgery, which disappeared with 5 days course of oral antibiotics (amoxicillin + clavulanic acid) of 625 milligrams three times in a day. Four patients (10%) developed adhesions for which they underwent surgery (tenolysis) after three months from the initial tendon repair. Thus, all of them were from the control group (Table 4).

Table (4): Cross table of complications and tenolysis using venous graft

Tenolysis		Complications		Total
		Infection	No other complication	
no tenolysis used	Vein graft used	1	19	20
	Vein graft not used	1	15	16
	Total	2	34	36
tenolysis done	Vein graft used	-	0	0
	Vein graft not used	-	4	4
	Total			40

After 6 months from the initial surgery of tendon repair in both control and test groups, evaluation was done by:

TAM=total active flexion – total extension deficit
(MCP, PIP, DIP)
% =TAM of the injured finger / TAM of the contralateral finger

From the test group, 15(75%) patients were excellent, 5(25%) patients were good with no fair, poor or worse results; whereas the control group showed no (0%) excellent results, 11 (55%) good, 9(45%) fair, and no poor or worse results. The mean for both groups were 87.82 % with a maximum of 100% and a minimum of 65% score (Figure 5, 6, and 7).

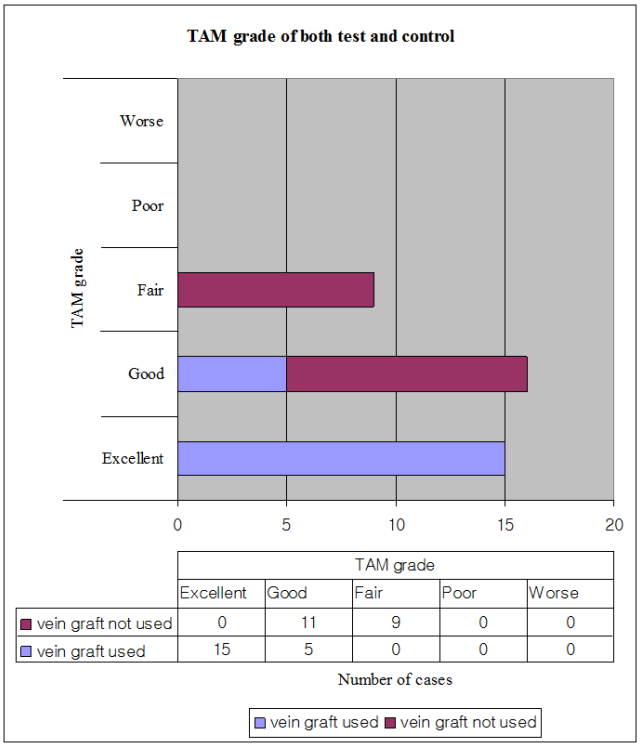
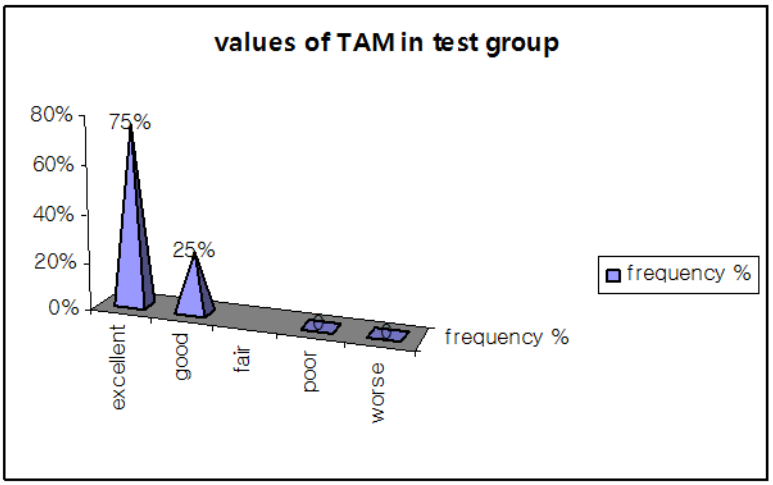


Figure (5): Results of both control and test groups using TAM system after 6 months



Figure(6): Frequency of TAM evaluation among test group

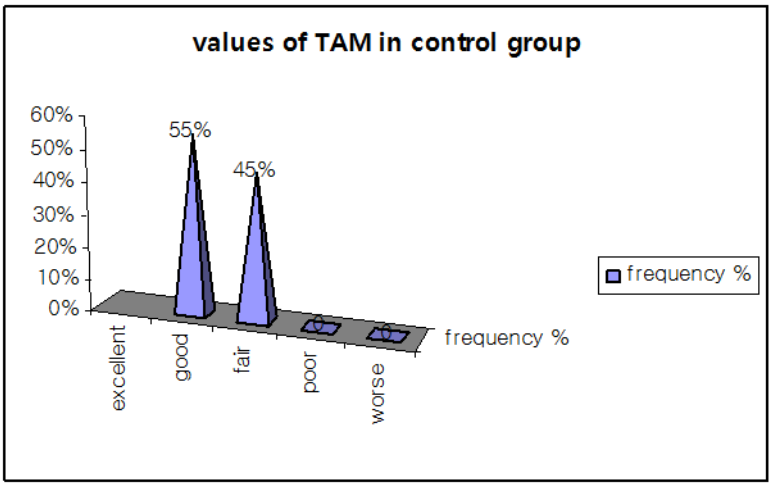


Figure (7): Frequency of TAM evaluation among control group

Statistical analysis was done to evaluate the significant differences in the range of active flexion in the affected digit between both the test group and control group using independent sample T.test to compare the means of both groups. Consequently, the result showed a significant difference between the test group and the control group (p.value=<0.001) (Fig.8).

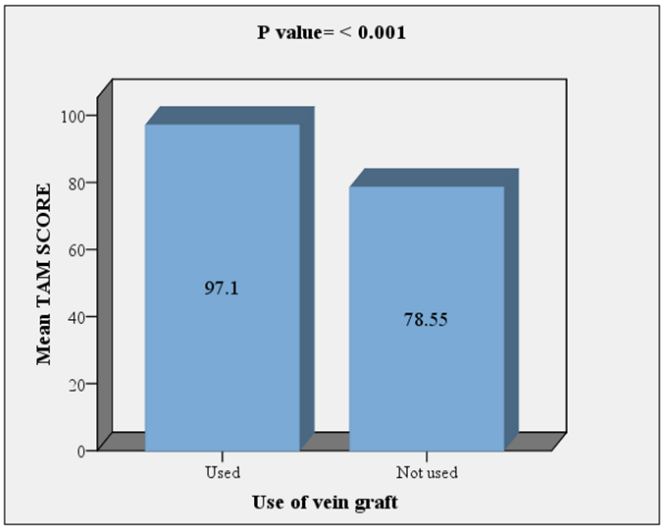


Figure (8): The differences in the TAM score of both test and control

Discussion:

This study is significantly different from previous studies on the same subject in that the results of tendon injuries in a single digit are evaluated only in zone II. Therefore, it takes only acute tendon injury in the first 24 hours without concomitant fractures, neurovascular, extensor injuries, or skin loss. This gives the study much specificity of the effect of tendon sheath substitution by vein graft versus non-vein grafting.

During the past, most surgeons used to remove a portion of the flexor tendon sheath around the repaired site in the digits for a flexor tendon repair in zone II injuries (Hernandez et al., 1974; Ketchum, 1977). They believed this would allow the development of some motion of the repaired tendon without the intervention of the sheath and pulley system. As already mentioned, the concepts of tendon nutrition and healing have changed, and emphasis is now placed on the role of nutrients diffusion from the synovial fluid for the nourishment of flexor tendons.

Theoretically and experimentally, since the synovial sheath and fluid are maintained, nutrition of the tendons is improved and there are fewer tendencies for adhesion formation (Mc Dougall, 1960; Colville, 1973; Lindsay and Mackin, 1975; Hunter, 1979). Furthermore, any un-repaired window or laceration in the sheath, leave an edge against which a tendon suture line can catch, and produce posttraumatic triggering and possibly attenuation and rupture. The free edges of an un-repaired sheath scars down, and adhesions might be formed resulting to contracture. For this reason, a segment of vein for repairing is used (Strauch, 1985)

However, the predominance of male population in this study is similar to most of other studies (Proano and Partride, 2002).The ages of the patients involved ranged from 14-46 years, and the average is 25.9 years. Though some studies considers age as an unfavorable factor, others however had wider ranges of age involved and scored more or less the same outcome of this current study; for instance, Alonet et al. (1993), 15-66 years; and Pribaz et al. (1989) 2-58 years.

Nowadays, it has been established that the primary treatment of acute tendon injury is the best method of treatment. With the growing awareness of people seeking medical attention, patients tend to present immediately to the emergency unit (Verdan, 1964; Green and Niebauer, 1994).

In this study, patients who were presented in the first few hours after injury and surgery done within 24 hours (mean time =14.45 hours ranging 3-24 hours) were included. This decreases the patient's stay in the hospital and manages the wound earlier, but at the same time, needs the availability of the expert personnel and surgical theater. Most of the previous studies on flexor tendon repair had signified the difficulty in surgery and the unwanted outcomes in zone II, because of the close relation between FDS and FDP within the flexor sheath and the narrow digital canal in addition to the critical nature of the blood supply (Alnot and Dupark, 1974; Early and Milward, 1982; Strickland, 1989; Alnot et al., 1993).

The results of this study is related to that of similar studies (Alonet et al., 1982 ; Pribaz et al., 1989; Earley et al.,1993) , as 75% (46 out of 61 tendons) of our patients had excellent results, while the previous authors had 80% out of 77 tendons. In addition, 85% out of 59 tendons, and 87% out of 137 tendons respectively had excellent results. On the other hand, Greekmore, Bellinghawsin, and Gault had poor results which were only 12% out of 44 tendons and 36% out of 116 digits, respectively. Hunge et al. (2005) reported 80% excellent results, which is quite near from our results. Consequently, our results show patients whose tendon sheaths were repaired and substituted with vein graft. Thus, they had significantly ($p < 0.001$) better function of their related digits compared to others without vein graft.

Regarding measuring the range of motion which has never been tested for reliability, the Goniometric assessment of a single joint ROM in one finger has been proven to be reliable. However, this was according to summating two or three joints which are likely to be less reliable. Despite that, we used the summation of the three joints (MCP, PIP, and DIP) in the affected digit, because it is still the recommended system by the ASSH. Another possible explanation was given by HUME et al. (1990). Hence, their study showed that in normal daily life activities, only 39% of the possible range of motion of the finger was required. Hardly any patient was

this far limited in his movements, implying that he would not have many difficulties in normal life. Staying on this point , in our series with using vein graft , 100% of patients reported excellent and good results which is more than 75% (between 75- 100%) of the range of motion in the digits. Thus, this gives satisfactory results.

However, post-operative complications include peritendinous adhesions which was prevented from the start by gentle handling of the tendon ends, keeping the paratenon intact, avoiding much dissection around the tendon to keep its blood supply, good haemostasis to prevent hematoma formation, and also the fine 6/0 polypropyline repair layer after taking the core suture to make the tendon suture line smooth from outside. Menderes et al. (2004) studied 30 rabbits, with Seprafilm which was used for the prevention of peritendinous adhesions following flexor tendon repair. Seprafilm Bioresorbable Membrane (Genzyme Corporation, Cambridge, MA) contains sodium hyaluronate and carboxymethyl cellulose. Thus, they concluded that in rabbit, the peri-tendinous adhesions following flexor tendon repairs could be lowered with Seprafilm and hyaluronic acid.

Small et al. (1989) concluded on the benefit of early mobilization following flexor tendon repair in zone II in their study; hence, this also confirmed our result. Moran et al. (2000) studied the effect of a single intra operative application of 5-Flouro Uracil at concentrations of 25mg/mL. However, this appears to be an effective mechanism for reducing postoperative flexor tendon adhesions.

Muhittin et al. (2008) suggested that Suramine (a known inhibitor of transforming growth factor β) decreases adhesions after flexor tendon repair. At the same time, it may also decrease the tendon strength as dose-dependent. They also suggested that future studies should be performed with a variety of doses to determine the appropriate dosage for clinical application.

But in the current study, the use of autogenous vein graft as a substitute for the destroyed tendon sheath is evaluated. This is followed by a post-operative program of physiotherapy and the results were encouraging, giving an excellent and good post-operative range of movement in 100% of the cases after 6 months. Furthermore, to confirm the decrease in the adhesion rate looking at the results, a statistically significant value ($p<0.001$) of the total need for future tenolysis (20% needs tenolysis in control group versus 0% in test group) can be seen. Other methods mentioned above which are used to prevent post-operative adhesions are either expensive, or affects healing besides preventing adhesions formation. Some of the synthetic materials may decrease blood supply reaching the area of repair which is not present when using the vein graft because blood reaches by diffusion. Thus, the use of autogenous vein graft as a

replacement of tendon sheath has many advantages like; it is not expensive, being autogenous, it is to a great degree aseptic, it does not affect the tendon healing like other materials, and it was used and recommended by Massovi et al., 2005 and Emad et al., 2012.

Conclusion

The repair of the flexor tendon injuries using a venous graft as a tendon sheath substitute, and early active movement is recommended to provide effective results as a replacement for the conventional methods of repair of flexor tendon injuries by modified Kessler's technique.

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