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Assessment of repair of flexor tendon in zone II, with modified kessler technique to know the functional outcomes

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Abstract
The management of tendon injuries has not only seen advances in primary care, repair technique, suture technique, understanding of biomechanics and postoperative evaluation protocol, but also a drastic change in mobilization protocols ranging from strict immobilization to early/delayed active mobilization. Hence the present study was planned to evaluate the early repair of Flexor Tendon in Zone ll, with Modified Kessler Technique have more functional Outcomes.
A prospective randomized clinical trial was planned with 30 patients suffering from flexor tendon injury, in Zone II. The patients were admitted from Nov 2016 to Oct 2018 in the Department of Plastic Surgery, Pulse Emergency Hospital, Patna, Bihar. All the patients were informed consents. The aim and the objective of the present study were conveyed to them. Approval of the institutional ethical committee was taken prior to conduct of this study
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.
The present study concludes that primary or delayed primary repair of sharply cut flexor tendons with a modified Kessler core suture and locking epitendinous circumferential suture increases the overall strength, allowing active mobilization, which causes cyclic tension loading, leading to prevention of adhesions and good tendon healing. There needs to be improved awareness of the evidence, and we would suggest that departmental guidelines should be drawn up or updated based on current evidence in order to encourage best practice.

Keywords: flexor tendon, zone II, modified kessler technique, hand injury

Introduction
Hand injuries have become one of the commonest reasons for patients to visit emergency departments of hospitals. Sharp injuries leading to flexor tendon tears have always remained a challenge for doctors to bring the patients back to normal condition and saving them from prolonged disability and emotional suffering.
The primary goal of the flexor tendon repair is to perform a repair, which is strong and can withstand early active rehabilitation programs. It has been established that a healing tendon can be strengthened by the application of tension forces that lead to a more rapid recovery of the
tensile force, fewer adhesions, improved excursion, and better nutrition [1, 2, 3]. Clinical and experimental studies have shown that to minimize failure rates related to complications occurring during active rehabilitation, like gap formation or rupture, it is crucial that primary repair is performed using a reliable and strong suturing technique [4,5,6,]. Many suture techniques were developed by investigators to improve the mechanical properties, particularly depending on the fact that number of the suture strands crossing the repair strongly influences the strength of the repair [7, 8, 9]. However, most current repair methods employ the technique described by Kessler or one of its many variations, which have reported to be associated with high rupture rates [10], and because of the complexity and technical demands, multi-strand suture methods, designed to strengthen the tendon repair, are not in widespread use. The four-strand core suture techniques are easy to perform with adequate strength to allow active mobilization [7, 8, 9]. The locking configuration of the core suture loop may influence tensile strength of the repair [11, 12]. Repairs usually rupture at suture knots, and a single external knot is superior to a knot within the repair site [1, 7, 8, 13]. The purpose of this study is to evaluate the outcome of properties of two strand core suture techniques in Early repair of Flexor tendon in Zone II and its functional outcomes.

Relevant Anatomy
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 [14, 15]. The muscles that flex the digits include the flexor digitorum profundus (FDP), flexor digitorum superficialis (FDS), and the flexor pollicis longus (FPL) [16]. 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 [17];

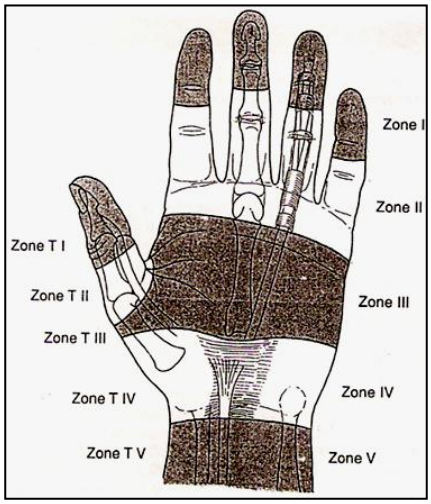

Fig 1: Verdan classification of the flexor system (17)

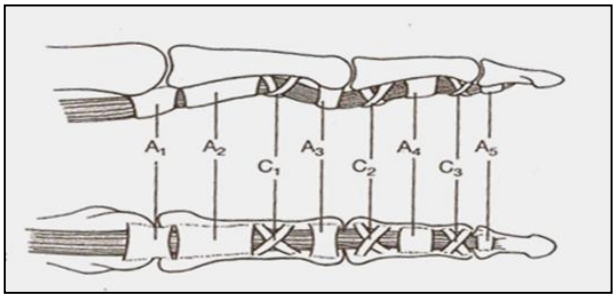

Fig 2: The arrangement of pulleys in the fibrous tendon sheath. Note that the A2 and A4 were from bones, while the A1, A3, and A5 were from volar plates. [18]

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 inter phalangeal and metatarsophalangeal (MCP) joint motion.

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 [19]. 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 [20] Flexor tendon repair was first described by Kirchmayr in 1917, when he published a method of 'locking' suture for tendon repair [21]. 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 [22]. 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 [23,24]. 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 [25] In addition, autogenous saphenous vein graft has been used for the prevention of the adhesion of tendons [26,27,28]. 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 [29]. Furthermore, it has been shown experimentally that early motion stimulates tendon healing and decrease adhesions [30]. 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 serves as prophylactic procedure in cases of lost tendon sheath in fresh cases; and it improves tendon nourishment [31].

Table 1: TAM evaluation System of ASSH (32)

	Result (%)
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 [32]

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

Strickland Adjusted System: $\frac{\text{Active Flexion-extension deficit (PIP+ DIP)}}{175}$ = % of Normal. x100

The improved understanding of splinting techniques has promoted these mobilization protocols. It has been proven that postoperative immobilization leads to increased disability period, weak tensile strength, decreased final functional capacity, stiffness, and deformity. Further early postoperative mobilization leads to improved tendon healing, increased tensile strength, and decreased adhesion formation, early return of function, and less stiffness and deformity as compared to the immobilization protocol. However, as any other procedure it has its own demerits in the form of rupture of repaired tendons. Hence the present study was planned to evaluate the early repair of Flexor Tendon in Zone ll, with Modified Kessler Technique have more functional Outcomes.

Patients and Methods

A prospective randomized clinical trial was planned with 30 patients suffering from flexor tendon injury, in Zone II. The patients were admitted from Nov 2016 to Oct 2018 in the Department of Plastic Surgery, Pulse Emergency Hospital, Patna, Bihar. All the patients were informed consents. The aim and the objective of the present study were conveyed to them. Approval of the institutional ethical committee was taken prior to conduct of this study

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. 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.

Surgical Technique

We repaired both flexor digitorum profundus and flexor digitorum superficialis tendons if both were injured. Core suture done with 4-0 polyporpylene using modified Kessler suture technique and the sutures are taken 7.5mm to 10mm from cut end of the tendon on either side. Epitendinous suture done with 6-0 prolene continuous sutures. We preserved A2 and A4 pulleys and if more exposure was needed upto 50% venting was done for access and to ensure smooth gliding of the sutured tendons. If the cut end of tendons (proximal end) lies close to the wound, tendons retrieved by flexing the wrist and fingers while milking the forearm in a proximal to distal direction. If the proximal tendon ends could not be retrieved by the above method, a transverse skin crease incision in the distal palmar crease proximal to A1 pulley was made and tendons retrieved. Then a suction catheter / Scalp vein set tube was inserted from the wound into the proximal incision and tendons were anchored to the tube and retrieved into the wound. By transfixing the proximal tendon end with a 22-guage needle, the retraction of the tendon was prevented and also facilitating tension-free repair.

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

Table 3: Strickland Evaluation

Score	Adjusted Strickland %	No. Of Cases	Percentage
Excellent	75-100	22	73.33
Good	50-74	6	22.00
Fair	24-49	2	6.66
Poor	0-24	0	-

$$\text{Stricklnd Adjusted System} \quad \frac{\text{Active Flexion-extension deficit (PIP+ DIP)}}{175 = \%\ \text{of Normal.}} \times 100$$

Results

Thirty 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 12 to 46 years with a mean age of 24.6 years. They were 22 (73.3%) males and 8 (26.6%) females. The right hand was the dominant hand in 25 patients (83.3%) and was more commonly injured in 18 cases (60%); the left hand was injured in 12 cases (40%) and was the dominant hand only

in 5 cases (16.6%). The causative agent was a glass in 12patients (40%), knife in 8 (26.6%) patients, and other agents in 10 (33.33%) patients correlating with the type of the wound. Time elapsed since the injury for the surgery ranged from 1day to one weak with the mean time of 3 day. The frequency of flexor digitorum superficialis injuries alone were in 11 patients (36.6%), but were seen in 19 patients (63.3%) when combined with flexor digitorum superficialis.

The reported complications were superficial infections in 1 patients (3.33%). After 6 months from the initial surgery of tendon repair evaluation was done by: Strickland adjusted scoring system
(Table 3). In this study 22(73.33%) patients having excellent result, 6 (20.00%) patients were good, 2 (6.66%) patients with fair results,and poor or worse results in no any cases (Table 3) (Fig.3, Fig. 4, Fig. 5, Fig.6, Fig.7, Fig.8, Fig.9, Fig.10, Fig.11).

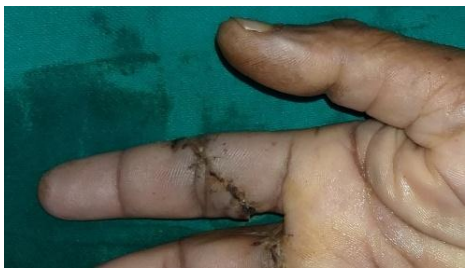

Fig 3(a): Glass cut Injury to Index finger at Verdan's Zone II. (5day old injury)

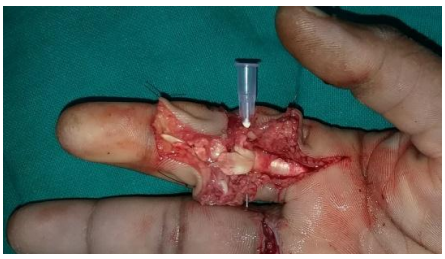

Fig 3(b): wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

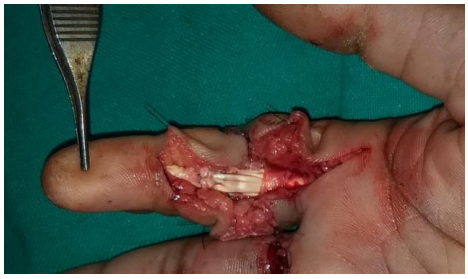

Fig 3(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique

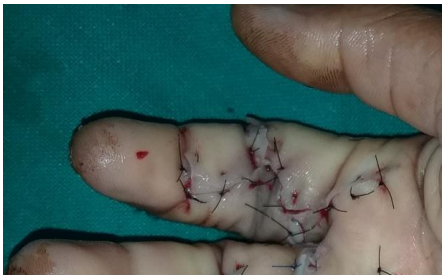

Fig 3(d): Closure of skin(Post-Operative)

Fig 3: Glass cut Injury to Index finger at Verdan's Zone II.

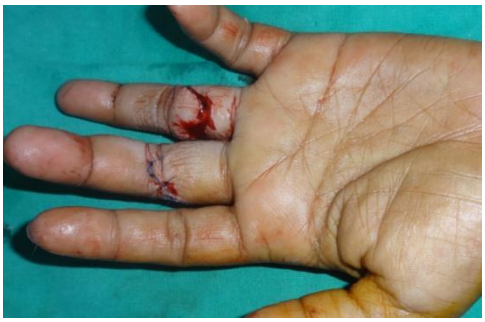

Fig 4(a): Glass cut Injury to Ring finger at Verdan's Zone II. (5hour old injury)

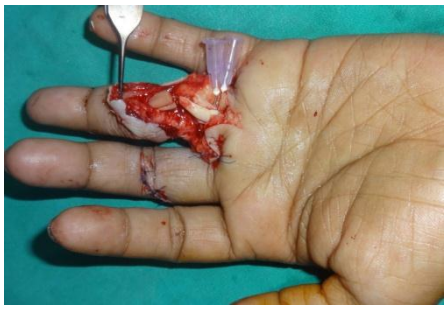

Fig 4(b): wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

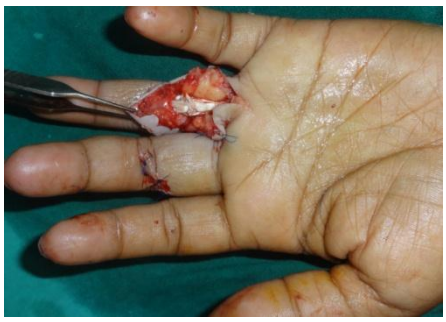

Fig 4(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique

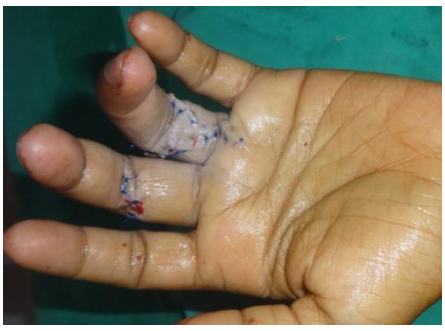

Fig 4(d): Closure of skin(Post Operative)

Fig 4: Glass cut Injury to Ring finger at Verdan's Zone II.

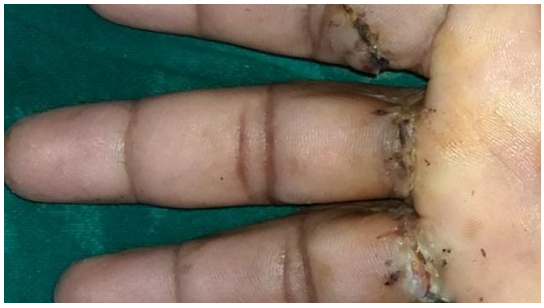

Fig 5(a): Glass cut Injury to Middle finger at Verdan's Zone II. (5day old injury)

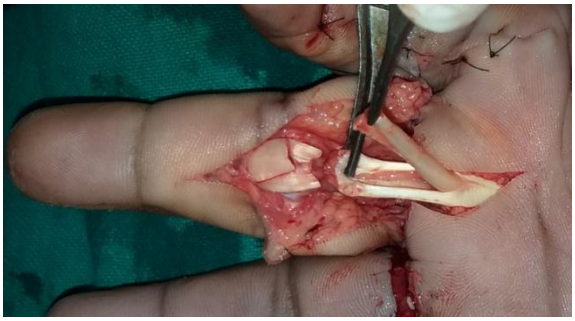

Fig 5(b): wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

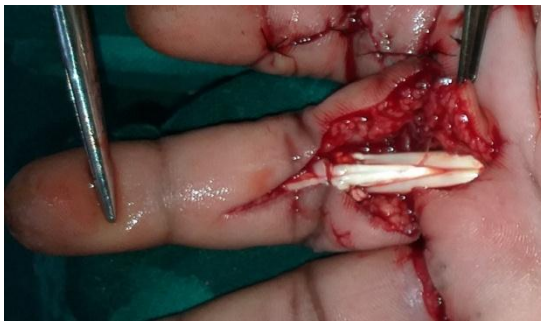

Fig 5(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique

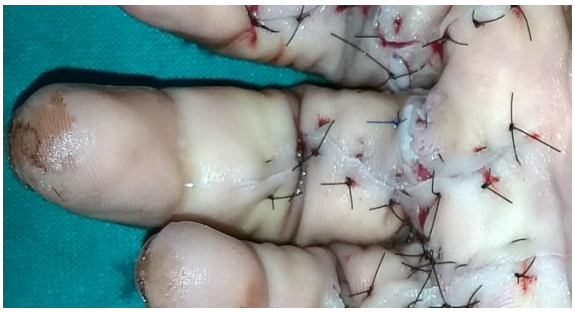

Fig 5(d): Closure of skin(Post Operative)

Fig 5: Glass cut Injury to Middle finger at Verdan's Zone II.

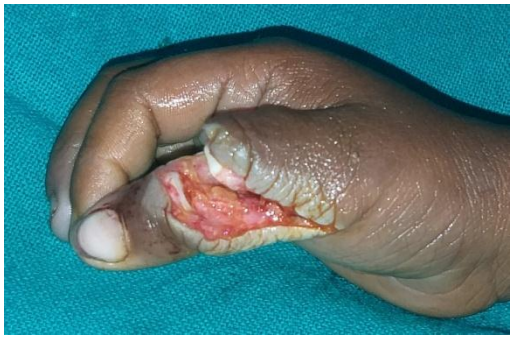

Fig 6(a): Glass cut Injury to Thumb at Verdan's Zone II. (3day old injury)

Fig 6(b): Severed FDP and FDS tendon retrieved

Fig 6(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique.

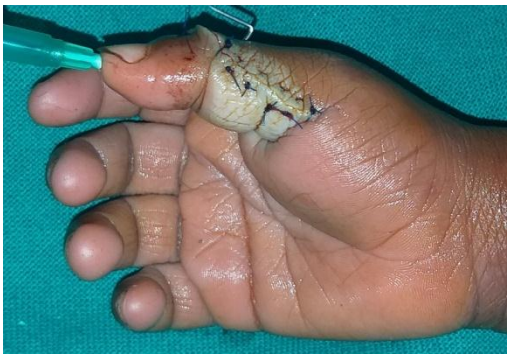

Fig 6(d): Closure of skin(Post Operative)

Fig 6: Glass cut Injury to Thumb finger at Verdan's Zone II.

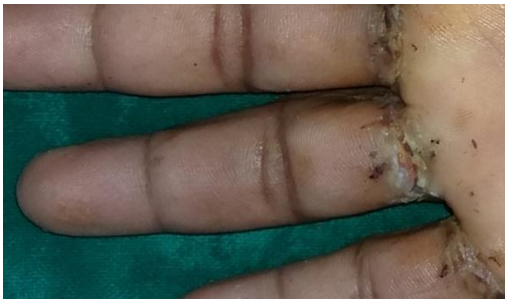

Fig 7(a): Glass cut Injury to Middle finger at Verdan's Zone II. (5day old injury)

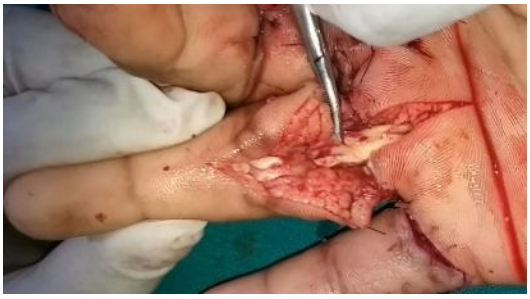

Fig 7(b): wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

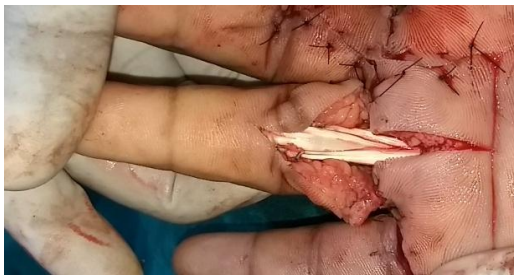

Fig 7(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique

Fig 7(d): Closure of skin(Post Operative)

Fig 7: Glass cut Injury to Middle finger at Verdan's Zone II.

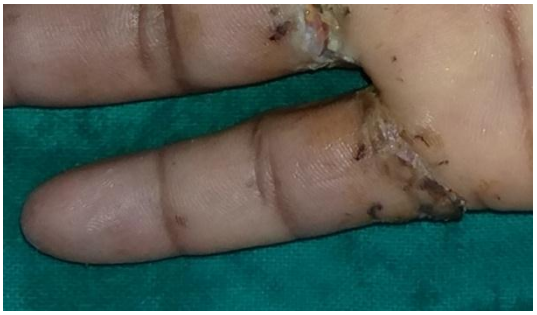

Fig 8(a): Glass cut Injury to Little finger at Verdan's Zone II. (5day old injury)

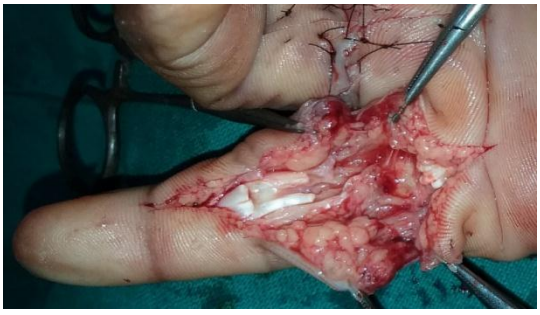

Fig 8(b): wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

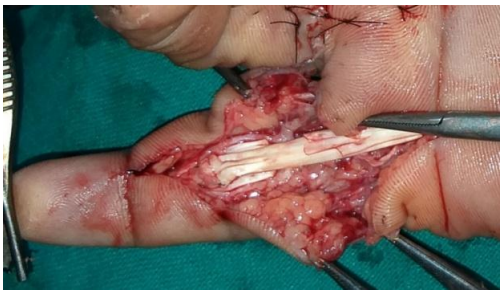

Fig 8(c): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique

Fig 8(d): Closure of skin(Pot Operative)

Fig 8: Glass cut Injury to Little finger at Verdan's Zone II.

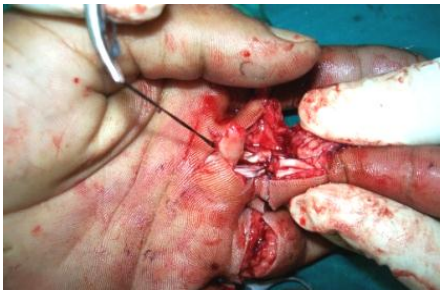

Fig 9(a): Glass cut Injury to ring and middle finger at Verdan's Zone II. (6 hours old injury). Wound explored by zig-zag (Brunner)Skin Incision and Severed FDP and FDS tendon retrieved.

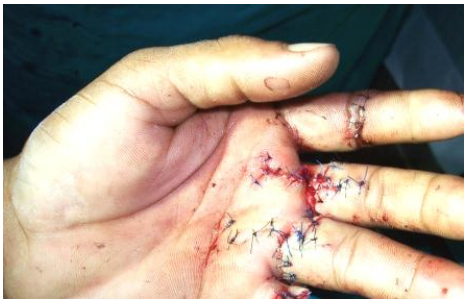

Fig 9(b): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique. Skin Closure done. (Post Operative)

Fig 9: Glass cut Injury to ring and middle finger at Verdan's Zone II.

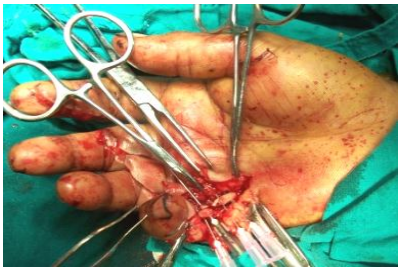

Fig 10(a): Glass cut Injury to Little finger at Verdan's Zone II (3 hour old injury) wound exploredand Severed FDP and FDS tendon retrieved.

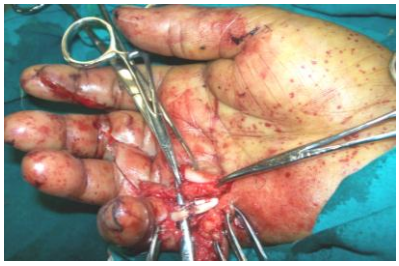

Fig 10(b): Repair of FDP and FDS tendon by Modified Double Stranded Kessler's Technique.

Fig 10: Glass cut Injury to Little finger at Verdan's Zone II.

Fig 11(a): Glass cut Injury to Index finger at Verdan's Zone II. (5 hours old injury). Wound explored by extending Skin Incision and Severed FDS tendon retrieved.

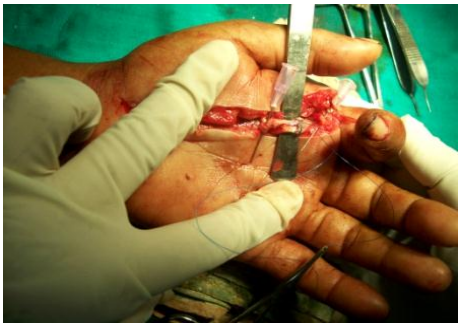

Fig 11(b): Repair of FDS tendon by Modified Double Stranded Kessler's Technique.

Fig 11: Glass cut Injury to ring and Index finger at Verdan's Zone II.

Discussion

Flexor tendon injuries are among the most common injuries of hand, occurring commonly in young males of the working class. The present study showed the data of the 30 cases as discussed below. Flexor tendon injuries are a difficult, serious and frustrating problem for every hand surgeon. Injuries in zone II remain the most difficult in treatment and have the less favorable results. Even after meticulous surgical repair, full motion is not consistently achieved. Nevertheless patients achieved functional motion and good usage of the hand.

Early postoperative active functional exercise can not only effectively reduce the formation of local adhesions and edema but also facilitate sliding function of the tendon, thereby promoting endogenous tendon healing [33, 34]. The choice of tendon repair technique plays an important role in tendon healing and postoperative functional exercise. The ideal repair should be easy to perform; provide sufficient strength for healing (over 30 N) [35], which can ensure minimal interference with tendon vascularity; and involve secure suture knots and smooth junction of tendon ends.

Results after a flexor tendon injury repair are inversely proportional to the delay in the repair of the tendon [36]. The added benefits of a primary/delayed primary repair are decreased rehabilitation time, adhesion formation, and rupture rate, and increased healing rate with adequate tensile strength. In this case series all cases were repaired within 7 days.

The technique of surgical repair for zone two flexor tendon injuries has been debated extensively through the years but adhesion formation, suture rupture, and suture locking on the pulley edge remain possible consequences of a poor

repair [36]. Although increasing the repair strength through increasing the number of strands crossing the repair site to allow active postoperative mobilization without increasing the risk of rupture is logical, it can compromise tendon gliding function. Furthermore, increased numbers of strands increase the tendon bulk and surface irregularity which has mechanical implications on gliding function [37].

There are many different options for the repair technique, but it is now clear that a two-strand repair is biomechanically inferior to a repair with 4 or more strands. Despite this we found that a two strand Kessler repair remains the most popular choice, being the preferred technique in most of respondents. These findings are similar to those of an earlier survey [38]. The two-strand Kessler core with a simple peripheral suture remains the most popular flexor tendon suture technique and that most surgeons favour sheath closure. [39] Although this study was published many years back but the trend continues even today. The double modified Kessler and cruciate repairs (Adelaide technique) [40] are being utilized more commonly than before. Single knotted core suture techniques (e.g., Cruciate) have been shown to be biomechanically superior to double-knotted techniques (e.g., Double Kessler, modified Becker, Tsuge) [41]. 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 [42, 43].

In this study, patients who were presented in the first day after injury to one week of injury were included. 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 [44, 45, 46, 47]. The results of this study is related to that of similar studies [45, 47, 48]. as 73.33% (22 out of 30) of our patients had excellent results. 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. 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 difficulties in normal life. 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. 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 [49].

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

The present study concludes that primary primary and delayed primary repair of sharply cut flexor tendons with a modified double stranded Kessler core suture and locking epitendinous circumferential suture increases the overall strength, allowing active mobilization, which causes cyclic tension loading, leading to prevention of adhesions and good tendon healing. There needs to be improved awareness of the evidence, and we would suggest that departmental guidelines should be drawn up or updated based on current evidence in order to encourage best practice.

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