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Biomechanical assessment of suture techniques used for tendon repair

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Objective: The aim of this study was to assess different tendon suture techniques from the perspectives of both tensile strength and early active mobilization.

Methods: In this study, we implemented repairs on 40 flexor digitorum profundus (FDP) tendons, acquired from fresh frozen cadavers. The tendons were divided into 5 groups of 8 tendons each. We applied the 2-strand modified Kessler suture technique in the first group, the 4-strand Strickland suture technique in the second group, the 4-strand modified Kessler (without epitenon suture) suture technique in the third group, and the 4-strand modified Kessler (with epitenon sutures) suture technique in the fourth group. The remaining 8 intact tendons were set aside as the control group. The strength of the different tendon suture techniques were measured using the Instron® device.

Results: The average tolerance strength of the first group was determined as 39.89±9.65 Newtons (N), the average tolerance strength of the second group was 39.64±9.14 N, the average tolerance strength of the third group was 50.29±11.24 N, the average tolerance strength of the fourth group was 54.47±6.83 N, and the average tolerance strength of the control group was 119±17.59 N. The tensile strength of the fourth group was significantly higher ($p<0.05$) than the first group, and the tensile strength of the third group was also significantly higher ($p<0.05$) than the first group. No significant difference was observed between the tensile strengths of the second and first groups ($p>0.05$).

Conclusion: According to our findings, the tensile strength of 4-strand sutures, with or without epitenon sutures, are significantly higher than the tensile strength of 2-strand sutures. All suture techniques applied had sufficient tensile strength to promote early mobilization.

Key words: Adhesion; biomechanics; cadaver; controlled active movement; suture technique; tendon.

Regaining function following zone 2 flexor tendon repair continues to be a problem in hand surgery. Some authors have suggested the use of tendon grafts in the repair of tendon injuries, although following further research, primary repair has become the recommended treatment method.[1,2] However, complications, such as tendon rupture, adhesion, and movement limitation have been reported following primary repair. Long-term immobilization after tendon repair may result in adhesions which can impair the functional outcomes. Thus, some authors advocate the promotion of early mobilization after tendon repairs.[3,4] Studies have shown that early movement increases the repair strength of the tendon, causes less adhesion and better functional results.[3-8] As strong suture strength is necessary for early active

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mobilization, newer studies have been focused on modifications in suture techniques, or on the development of new, stronger tendon suture techniques to minimize the risk of re-rupture.[9-14]

The aim of this cadaver study was to assess different tendon suture techniques from the perspectives of both tensile strength and early active mobilization by measuring the breaking off strength.

Materials and methods

For this study, we used the index, middle and ring fingers of 14 hands from adult cadavers (5 male, 2 female; mean age: 74 years; range: 68-84 years) of 4 to 6 weeks, which were frozen at -20 degrees. The study was conducted at the Institute II of Anatomy of the University of Cologne, Germany. Forty flexor digitorum profundus (FDP) tendons isolated through an incision, made on the palmar sides of the metacarpophalangeal joint, were separated into 5 groups of 8 tendons. We applied a 2-strand modified Kessler suture technique in the first group (Fig. 1), a 4-strand Strickland suture technique in the second group (Fig. 2), a 4-strand modified Kessler (without peripheral suture) technique in the third group, and a 4-strand modified Kessler (with peripheral suture) suture technique in the fourth group (Fig. 3). The remaining 8 intact FDP tendons were set aside as the control group. All knots were tied by the same surgeon. 4/0 Ethibond® (Ethicon, Johnson and Johnson Medical Ltd., Edinburgh, Scotland) polyester sutures were used for the tendons and 6/0 Prolene® (Ethicon, Johnson and Johnson Medical Ltd., Edinburgh, Scotland) polypropylene sutures for the epitenon.

Tendon strength was measured with the Instron® device (Instron Corp., Norwood, MA, USA) (Figs. 4a and b). All measurements were made by the same person. After the installation of sutures, each group of tendons was dissected from the distal phalanx insertion to the muscle tendon junction and kept in gauze dressing soaked in saline solution. Tendons were assessed with the Instron® device immediately following the transection. The strength test was conducted based on the principle of distending the proximal and distal ends of the tendons with the clamps of the Instron® device with a pulling speed of 20 mm/min. Measurements were simultaneously recorded in the computer through a special program. Statistical analysis was made using the SPSS 10.0 program according to the two-strand Mann-Whitney U test.

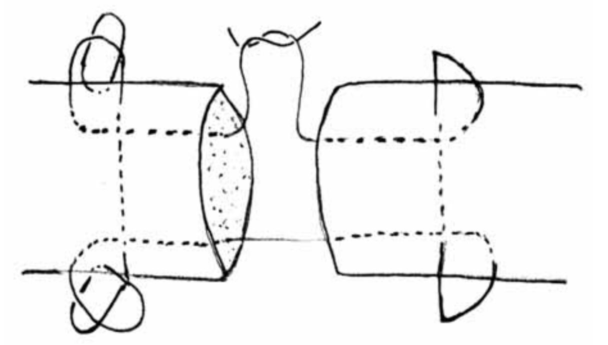

Fig. 1. Modified Kessler technique locked at the proximal end.

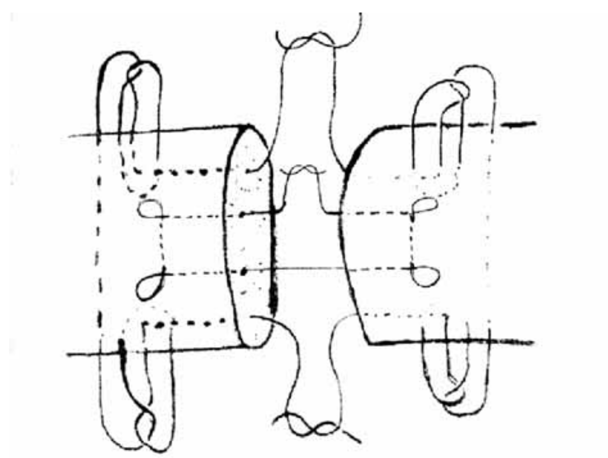

Fig. 2. The Strickland technique.

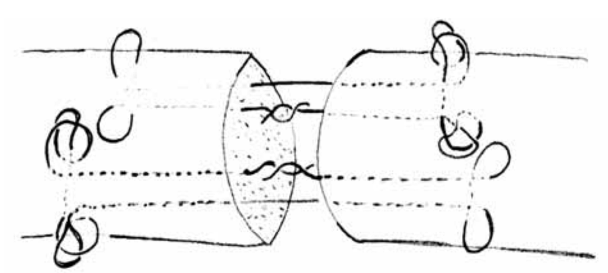

Fig. 3. Four-strand modified Kessler technique.

Results

Average tensile strengths of the tendons were: 39.89±9.65 Newton (N) for the 2-strand modified Kessler technique; 39.64±9.14 N for the 4-strand Strickland technique; 50.29±11.24 N for the 4-strand modified Kessler technique without epitenon sutures; 54.47±6.83 N for the 4-strand Kessler technique with epitenon sutures; and 119±17.59 N for tendons left intact (Fig. 5). While no statistically significant fer-

Fig 4. **(a)** The Instron® device and **(b)** the tendon strength measuring. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

ences were observed between the 2-strand modified Kessler and the 4-strand Strickland techniques, the 2-strand modified Kessler technique had significant differences with the 4-strand modified Kessler with epitenon suture group (U=34; p>0.05) and the 4-strand modified Kessler without epitenon suture (U=49; p<0.05) group. Results with a difference of 10 N were assessed as statistically significant.

A significant difference was detected among all suture techniques when compared to the intact tendons in the control group (U=64, p<0.05). No suture technique could match the strength of an intact tendon.

Discussion

Several animal studies, such as those of Gelberman et al.[3] on dogs and Hitchcock et al.[4] on chickens, have shown that early active mobilization following tendon repair improves tendon tensile strength and sliding function. In Hitchcock et al.'s study, profundus tendon cuts on the central toes of chickens were repaired. Some chickens were left immobile by placing their toes in plaster casts, and others were allowed to move actively in splints. Chickens were killed at 0, 5, 15, 20, 30, 40th days following repair and assessed for edema and adhesion. The study proved that in tendons which were permitted active movement starting from 5 days following repair, tensile strength was significantly higher and adhesion ratio was significantly lower than in those left immobile. As a result, the use of active movement protocols became more frequent.[5-8,10]

In a study by Strickland et al.[8] of patients undergoing zone 2 flexor tendon repair, one group of patients was immobilized in splints for a period of 3.5 weeks, and another group was allowed passive movements at intervals within the first 5 postoperative days. A statistically significant difference in range of motion was observed in the group with passive movement compared to the group of immobilized tendons.

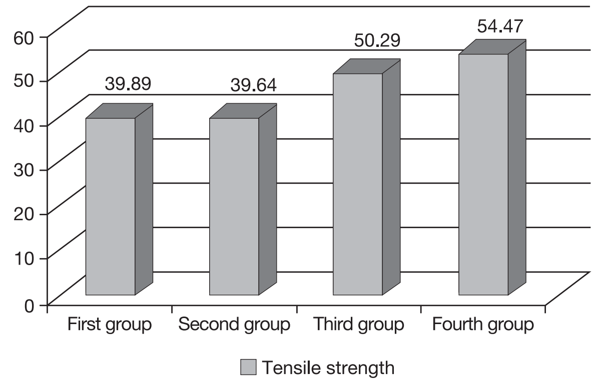

Fig. 5. Average tensile strength values of four study groups (Newton).

However, the high probability of repair failure during early motion protocols necessitated further studies on stronger suture techniques. According to a study conducted by Schuind et al.,[15] the average load on the FDP in the 2nd finger produced by active distal interphalangeal joint flexion is approximately 18.6 N, and the interphalangeal flexion on the flexor pollicis longus in the thumb is 17.6 N. In the tip pinch movement, however, a much greater load (81.3 N) is applied on the flexor tendon. For this reason, the authors suggest that allowing active movement tendon repair strength should be higher than these values.

In a cadaver study by Thurman et al.,[12] 2-strand, 4-strand and 6-strand suture techniques were assessed biomechanically. Average tensile strength following the 2-strand suture technique was 33.9 N (modified Kessler), 43 N for the 4-strand technique (Strickland), and 78.7 N for the 6-strand technique (Savage). Tensile strength of the 6-strand technique was significantly higher than that of the 2-strand and 4-strand suture techniques. The study showed that the 2-strand suture technique could not resist the repetitive loading, while the 4-strand and 6-strand suture techniques were resistant.

In another study performed by Barrie et al.,[9] the 2, 4 and 6-strand suture techniques were compared and the tension needed for repair failure following the 6-strand suture technique was found to be significantly higher. Additionally, the 4-strand suture technique was significantly stronger than the 2-strand technique.

In a biomechanical study on 24 dogs, Winters et al.[11] applied Savage, Tajima, Kessler, and 8-strand suture techniques and measured their strengths. The authors determined that the failure strength of tendons sutured with the 8-strand technique was significantly higher at the 3rd and 6th postoperative week than the other techniques and that tendons repaired with this technique could resist higher strengths during earlier stages of rehabilitation.

It was shown that, while tendon strength increased parallel to the number of sutures, the ratio of complications also increase in techniques with more than 4 strands.[14] Wagner et al.[14] proved that although the tensile strength of the 6-strand Savage technique was higher than other techniques used in their study, the technique caused damage at the ends of tendons. Furthermore, it was also stated that the tendons became thicker as the number of strands increased, making it difficult for the tendon to slide inside the sheath and that this might lead again to ruptures. In the study carried out by Barrie et al., it was stated that the 4-strand suture technique was optimal in terms of technical ease, failure strength and impingement within the tendon sheath.[9]

We also found that the tensile strength of the 4-strand modified Kessler technique with or without epitenon sutures was significantly higher than the 2-strand modified Kessler technique. It can, therefore, be suggested that a higher number of strands result in an increased tensile strength. We did find significant differences between tensile strengths of Strickland and modified Kessler techniques. It is believed that, although both are 4-strand techniques, the difference in strength is based on the number of gripping sutures; 4-gripping sutures in the Strickland technique and 8 in the double-modified Kessler. For this reason, classification according to the number of gripping sutures, as well as the number of strands passing through the tendon, would be more accurate. A study by Hotokezaka et al. in which the tensile strength of 2-strand locked sutures was found to be significantly higher than 2-strand unlocked sutures also supports this idea.[16]

In conclusion, all 4 tendon suture techniques applied in this study have been found appropriate to promote early active mobilization. For tensile strength, the number of gripping sutures is as important as the number of strands, and tensile strengths of 4-strand sutures with or without epitenon sutures are significantly higher than the tensile strengths of 2-strand sutures.

Conflicts of Interest: No conflicts declared.

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