Journal of Visualized Experiments

Using Q Suture to Enhance Resistance to Gap Formation and Tensile Strength of Repaired Flexor Tendons

--Manuscript Draft--

Article Type:	Invited Methods Article - JoVE Produced Video
Manuscript Number:	JoVE61445R2
Full Title:	Using Q Suture to Enhance Resistance to Gap Formation and Tensile Strength of Repaired Flexor Tendons
Section/Category:	JoVE Medicine
Keywords:	tendon repair; peripheral sutures; 2-mm gap formation; ultimate strength; cyclic loading; surgical time
Corresponding Author:	Ya Fang Wu, M.D. Affiliated Hospital of Nantong University Nantong, China CHINA
Corresponding Author's Institution:	Affiliated Hospital of Nantong University
Corresponding Author E-Mail:	applefang002@126.com
Order of Authors:	Wei Feng Mao
	Ya Fang Wu, M.D.
Additional Information:	
Question	**Response**
Please indicate whether this article will be Standard Access or Open Access.	Standard Access (US$2,400)
Please indicate the **city, state/province, and country** where this article will be **filmed**. Please do not use abbreviations.	Nantong, Jiangsu, China

TITLE:

Using Q Suture to Enhance Resistance to Gap Formation and Tensile Strength of Repaired Flexor Tendons

AUTHORS AND AFFILIATIONS:

Wei Feng Mao[1], Ya Fang Wu[2]

[1]Department of Anatomy, Medical School, Nantong University, Nantong, Jiangsu, China

[2]Department of Hand surgery, Affiliated Hospital of Nantong University, Nantong, Jiangsu, China

Corresponding Author:

Ya Fang Wu (applefang002@126.com)

Co-Authors:

Wei Feng Mao (maoweifeng@ntu.edu.cn)

KEYWORDS:

tendon repair, peripheral sutures, 2-mm gap formation, ultimate strength, cyclic loading, surgical time

SUMMARY:

Here, we present a “Q” suture technique that can be performed in tendon repair and its effects on the gap formation and tensile strength of the repaired tendons. Q suture is shown to be efficient in enhancing the tensile resistance and tendon repair strength.

ABSTRACT:

Peripheral epitendinous sutures are believed to enhance core suture strength in tendon repair and decrease the risk of gapping between tendon ends. Here Q suture, an alternative to peripheral sutures, is presented for the use in tendon repair. Its effects on gap formation and tensile strength of the repaired tendons were compared with conventional running peripheral sutures. Three 2-strand sutures and three 4-strand sutures were used in repairing porcine tendons. The time required for performing 2Q and running sutures were recorded. The repaired tendons were subjected to a cyclic loading test, and the cycle number, during which a 2-mm gap was formed, was determined. After the cyclic loading, the gap size at the tendon ends and the ultimate strength of the repaired tendons were measured. Augmentation with the Q sutures reduced the number of tendons showing 2-mm gaps at tendon ends during cyclic loading. 2-strand sutures significantly increased the ultimate strength of the repaired tendons and 4-strand sutures decreased the gap distance at the repair site of tendons. The time required for performing 2Q sutures was significantly less than that for running sutures. Therefore, we conclude that the Q suture is efficient in enhancing the tensile resistance and tendon repair strength and can be an alternative to conventional peripheral sutures.

INTRODUCTION:

Gap formation at tendon repair site affects tendon repair strength and gliding resistance substantially. The consequences of gapping between tendon ends may ultimately impede tendon healing in vivo[1]. It has been reported that the presence of a gap larger than 2 mm at the repair site lead to a significant increase in the gliding resistance of repaired intrasynovial tendon in cadaveric hands[2]. A study in a canine model has shown that a gap size larger than 3 mm would impair the tendon healing strength and stiffness[3]. Therefore, improving resistance and decreasing the risk of gapping between tendon ends are critical for tendon repair.

Addition of peripheral sutures has been shown to reduce the gapping at the tendon repair site thereby improving gliding function of the repaired tendons[4-6]. During the last few decades, a number of peripheral sutures have been developed, including the interlocking cross-stitch (IXS), interlocking horizontal mattress (IHM), and cross-linked Silfverskiöld and Lembert, et al[7-10]. These peripheral sutures have proven to be superior to running peripheral sutures with respect to gapping resistance in tendon repair. However, many of these sutures are complex in structure and difficult to perform, thereby limiting their widespread applications. An ideal suture for tendon repair should aim to prevent gap formation while avoiding the addition of bulk to the repair site after tendon repair. Currently, running peripheral suture remains a popular technique due to its simplicity.

In a recent study, a technique, alternative to peripheral suture, named Q suture, because its shape is similar to the letter “Q”, is presented[11]. Here, we compared this suturing technique with running peripheral suture to check for the differences in gapping resistance and the tensile strength of repaired tendons. The results showed that Q suture was more efficient in enhancing the gapping resistance and ultimate strength of the repaired tendons in the cyclic loading test. Therefore, this article aims to provide a detailed description of how to perform Q suture technique and the biomechanical settings for testing the effects of Q suture on the properties of the repaired tendons.

PROTOCOL:

All experimental procedures described were approved by the Administration Committee of Experimental Animals of the Nantong University. Thirty porcine tendons were repaired with three 2-strand repairs: 2-strand core suture, 2-strand core suture plus 2Q, and 2-strand core suture plus running peripheral sutures. The other 30 porcine tendons were repaired with three 4-strand repairs: 4-strand core suture, 4-strand core suture plus 2Q, and 4-strand core suture plus running peripheral sutures.

1 Preparation of porcine tendons

1.1 Purchase fresh adult pig hind-leg trotters from a slaughtering house. Remove the skin and subcutaneous tissues to expose the pulley and tendon sheath (**Figure 1A**).

NOTE: The pulley and tendon sheath are dense in texture, which form an obvious fibro-osseous tunnel for the gliding tendons. The subcutaneous tissues are relatively loose in texture and very easy to be removed.

1.2 Incise the pulley and tendon sheath longitudinally along the central line to expose the flexor tendons (**Figure 1B**).

1.3 Dissect the flexor digitorum superficialis (FDS) tendon to expose the branches of the FDP tendons (**Figure 1C**).

1.4 Harvest the FDP tendons by cutting proximally at about 5 cm to the bifurcation of the FDP tendon and distally at the tendon insertion to the distal phalanx. (**Figure 1D**).

1.5 Wash the tendon samples with clean water and remove the paratenon using surgical scissors.

1.6 Cut the tendon along the midline from the end that was proximal to the bifurcation (**Figure 1E**).

1.7 Cut the FDP tendon transversely into 2 stumps at the level that structurally corresponds to the middle part of human zone 2 flexor tendons. The resulting 2 tendon stumps are ready to be repaired (**Figure 1F**).

2 Tendon repair

2.1 Mark the anterior surface of one of the tendon stumps with 2 points that are 10 mm from the cut tendon end, with each point locating one-fourth of the way from the left (point 1) and the right (point 2), respectively, in the medial-lateral direction (**Figure 2A**).

2.2 Mark each of the left (point 3) and right (point 4) lateral surfaces of the tendon with one point that is 8 mm from the cut tendon end and locate in the middle in the anterior-posterior direction. (**Figure 2A**). Determine all lengths with a Vernier caliper (rated accuracy of 0.02 mm).

2.3 Repair the tendon with 4-0 core sutures. Insert the needle into the cut surface of one tendon stump from the point that is in the middle in the anterior-posterior direction and one-fourth of the way from the left in the medial-lateral direction (**Figure 2B**). Pass the needle longitudinally through the tendon and withdraw the needle on the anterior surface of the tendon, exiting from point 1 (**Figure 2B**).

2.4 Re-insert the needle obliquely from point 3 and pass it transversely toward point 4, creating a small loop at the lateral surface of the tendon (**Figure 2C**). Pull out the suture and re-insert the needle obliquely from point 2 and pass it longitudinally toward the cut end (**Figure 2D,E**).

2.5 Insert the needle into the cut end of the other tendon stump and repair it with the same construct, forming a symmetrical repair (**Figure 2F**).

2.6 Tighten the suture with 10% shortening of the tendon segment within the core suture. Tie the tendon ends together with 3 to 4 knots and complete the 2-strand core suture (**Figure 2G**).

2.7 Repeat the operation once to complete the 4-strand core suture. Do not cut off the first core suture when performing the second core suture.

2.8 Insert the same needle into the tendon anterior surface 2 mm away from the joined tendon end and pass through the full thickness of the tendon stump (**Figure 3A**).

2.9 Withdraw the needle on the posterior surface of the tendon and re-insert the needle into the posterior surface of the tendon 2 mm away from the other side of the joined tendon end (**Figure 3B**).

2.10 Pull out the suture from the anterior surface of the tendon and tie 3 knots to complete 1 Q suture (**Figure 3C**). Repeat the procedure to complete the second Q suture (**Figure 3D**).

2.11 In the 2-strand and 4-strand core suture plus running group, add a running epitendinous suture of 9 to 10 stitches to the tendon ends using 6-0 suture. Keep a similar purchase of 1.5 mm and depth of 1 mm (**Figure 3E,F,G**).

2.12 Keep the repaired tendon moist by wet gauzes before biomechanical testing.

3 Software setting

3.1 Open the testing software and go to the **Home** screen. Click **Method** to create a test method. Click **New** to open the **Create a New Test Method** dialog box. Select the test type **Tension-TestProfile Method** and click **Create**. Click **Save As** to name and save the test method file.

3.2 Open the **Control-Pre-Test** screen in the **Method** tab by clicking **Control | Pre-Test** in the navigation bar. Click **Preload**. Set the control mode as extension, the rate as 25 mm/min, the channel as load, and the value as 0.5 N. Enable **Auto balance**. Add the **Available Channels** of Tensile strain and Load to the **Selected Channels**.

3.3 Open the **Control-Test** screen in the **Method** tab and click **Edit Profile of the cyclic loading**. Insert 4 blocks.

3.4.1 In the first block, set the **Mode** as Tensile extension, **Shape** as Triangle, **Maximum load** as 8 N in the 2-strand repairs and 15 N in the 4-strand repairs, **Minimum load** as 0 N, **Rate** as 25 mm/min, and **Cycle** as 10.

3.4.2 In the second block, set the **Mode** as Tensile extension, **Shape** as Absolute Ramp, **Rate** as 25 mm/min, and **Endpoint** as 15 N.

3.4.3 In the third block, set the **Mode** as Tensile extension, **Shape** as Hold, **Criteria** as Duration, and **Duration** as 8 s.

3.4.4 In the fourth block, set the **Mode** as Tensile extension, **Shape** as Absolute Ramp, **Rate** as 25 mm/min, and **Endpoint** as 100 N.

3.5 Open the **Control-End of Test** screen in the **Method** tab. Set **Criteria 1** as Rate of Load, and **Sensitivity** as 40%.

3.6 Open the **Calculation-Setup** screen in the **Method** tab. Select **% of Break** and add to the **selected calculations**. Apply to the **4. Absolute Ramp.**

3.7 Open the **Results 1-Columns** screen in the **Method** tab. Select **Maximum Load** and add to the **selected results**. Click **Save and Close**.

4 Biomechanical test

4.1 Turn on the testing machine and the computer that runs the software (**Figure 4A**). Open the testing software and go to the **Home** screen (**Figure 4A**). Set the initial distance between the upper and lower clamps of the testing machine to 5 cm (**Figure 4B**).

4.2 Wrap the tendon with dry gauzes 2–3 cm away from the cut end. Mount the tendon segments wrapped with gauzes into the upper and lower clamps and keep the tendon vertical as much as possible (**Figure 4C**).

4.3 Click **Test** on the **Home** screen. Choose the test method file saved in step 3.8 above. Click **Next.**

4.4 Enter a name and choose a location for the sample data file. Click **Next**. The **Test** tab displays. Open **Load Cell Setup** dialog and click **Calibrate** to remove load from load cell.

4.5 Click **Balance Load** and **Reset Gauge Length.** Click **Start** to run a test for each specimen in the sample. Record the number of tendon when a 2-mm gap is formed between the 2 ends during the cyclic loading.

4.6 Measure the gap distance between tendon ends during a pause of 8 s at the maximum load of the 10th cycle (**Figure 4D**).

4.7 Pull the tendon upwards until the repair ruptures and record the ultimate breaking strength (**Figure 4E**).

4.8 Click **Finish Sample** and save the results.

5 Statistical Analysis

5.1 Present data as mean and standard deviation (SD).

5.2 Analyze data on gap distance and ultimate strength of tendons repaired by different methods using a one-way analysis of variance (ANOVA).

5.3 Perform multiple comparisons using LSD tests. Set the level of significance at $P < 0.05$.

REPRESENTATIVE RESULTS:

Table 1 shows that addition of Q suture reduced the number of tendons with 2-mm gapping during cyclic loading in both 2-strand and 4-strand repairs. All tendons repaired with 2-strand and 4-strand core sutures formed a 2-mm gap, whereas none of the tendons repaired with 2-strand plus 2Q and only half of those repaired with 4-strand plus 2Q had a 2-mm gapping after 10 cycles. More tendons repaired with 2-strand plus running or 4-strand plus running sutures showed a 2-mm gap than those augmented with Q sutures.

Table 1 also shows that with 2-strand repairs, addition of the Q suture and running sutures both reduced the gap distance between tendon ends after cyclic loading, but only Q suture addition significantly increased the ultimate strength of the repaired tendons. The addition of the Q suture also minimized the gap distance with 4-strand repairs, albeit the ultimate strength of the repaired tendons was not affected. The average time required for performing 2Q sutures was significantly shorter than that for a running suture.

FIGURE LEGENDS

Figure 1: Preparation of porcine tendons for tendon repair. (**A**) Skin and subcutaneous tissues were removed. (**B**) Pulley and tendon sheath were incised. (**C**) Flexor digitorum superficialis (FDS) tendon was dissected. (**D**) Flexor digitorum profundus (FDP) tendons were harvested. (**E**) Tendon was cut along the midline. (**F**) FDP tendon was cut transversely into 2 stumps.

Figure 2: 2-strand core suture in tendon repair. (**A**) Surface of tendon stump was marked with point 1, 2, 3, and 4. (**B-E**) Core suture in one tendon stump was completed. (**F**) The entire core suture was completed. (**G**) Suture was tightened, and knots were tied.

Figure 3: Q and running peripheral sutures in tendon repair. (**A-D**) 2Q sutures were added. (**E-G**) Running peripheral sutures were added. (**H**) Tendons repaired with 4-strand core suture plus 2Q and 4-strand core suture plus running sutures.

Figure 4: Biomechanical test of repaired tendons. (**A**) Testing machine and computer that

runs the software. (**B**) Distance between the upper and lower clamps was set to 5 cm. (**C**) Tendon segments were mounted into the clamps. (**D**) Gap distance between tendon ends was measured after cyclic loading. (**E**) Tendon was pulled upwards until the repair ruptures.

Table 1: Number of tendons with 2-mm gap formation during cyclic loading, gap size at the repair site after cyclic loading, ultimate strength of the repaired tendons, and surgical time for 2Q and running sutures.

DISCUSSION:

The results of the current study showed that Q suture not only reduced the gapping and improves tensile strength of the repaired tendons but was also timesaving and labor-saving. Nonetheless, some key points regarding tendon repair in the current study should be noted.

First, we tried to select tendon samples that were similar in shape and size because we were not sure whether tendon size would have a notable impact on tensile strength after repair. In addition, tendon samples can be preserved at -20 °C if they cannot be repaired and tested in time. It has been shown that freezing tendons does not significantly alter the repair strength of tendons and is considered an acceptable method for preserving tendons[12]. However, repeated freeze–thaw cycles should be avoided. Once thawed, tendon specimens should be kept moist; otherwise, the properties of tendon tissue will change drastically.

Second, the core suture purchase of tendon repair in the current study was set as 10 mm. Core suture purchase is defined as the exit and entry distance of the core suture from the cut ends of the tendon. Previous studies reported that lengthening of the suture purchase effectively increased the repair strength of tendon. The optimal length is considered to be between 0.7 and 1.0 cm[13,14]. A purchase length of less than 0.7 cm results in a significantly weaker repair, while further increasing the length of purchase to more than 1.0 cm does not improve the strength of tendon repair. The underlying mechanisms involved may include a greater tendon–suture interaction, a more secure grip power of sutures on the tendon surface, and increased stiffness to counteract tensile forces by the increased length of the suture purchase[15,16].

Third, the core sutures should be tightened to a certain degree before tying knots because addition of a slight tension to the core suture has been shown to be beneficial in reducing the risk of gapping in tendon repair[17,18]. Wu and Tang reported that 10% of tendon shortening by tensioning of core suture markedly increased the gap formation forces without obvious increase in tendon bulkiness[19]. Slight tensioning of the core suture might help equalize the load on the core suture strands, which prevented gap formation in the repaired tendons. Further shortening of the tendon segment by 20% through tensioning increased the gapping resistance by a small amount. However, the further increase led to a bulge in the repair site of the tendon, which might increase sliding friction in vivo thereby increasing the gliding impairment.

Fourth, previous studies have demonstrated that the tensile strength of repaired tendon was significantly affected by the depth and purchase of peripheral sutures. Peripheral suture with a depth of 1 mm and purchase of 1.5 mm were considered optimal for strengthening the core suture without adding too much bulk at the tendon ends[20]. The Q suture differs from conventional peripheral sutures in that it passes through the full thickness of the tendon substance. We set the purchase of Q suture to 2 mm and found it could hold the tendon stumps tightly without obvious bulk.

Lastly, the maximum loads were set at 8 N for the 2-strand repairs and 15 N for the 4-strand repairs in the cyclic loading test. These forces were predetermined in a preliminary experiment, which showed that these forces could lead to differences in gap formation at the repair site in different groups during cyclic loading. Gapping at the repair site would not occur if the loading force decreased, while all tendons would show immediate gapping if loading force increased. Therefore, the maximum loading forces had been carefully determined based on the preliminary experiment to avoid immediate gapping or absence of gapping at the repair site when the tendons were subjected to a cyclic loading test.

A limitation of the current study is that only 1 type of core suture was used. Future studies should employ additional core suture techniques to evaluate the effects of Q suture. In addition, we did not study the gliding resistance of the repaired tendon ex vivo and the effects of Q suture on tendon healing in vivo, which also warrants further investigations.

Base on the present study, the Q suture shows superior performance in resisting gapping in tendon repair when compared with running peripheral sutures. This suture is also very easy to perform, as well as timesaving and could be an alternative to conventional peripheral sutures.

ACKNOWLEDGEMENTS:

The authors acknowledge support from Graduate Research Innovation Project of Jiangsu Province (YKC16061).

DISCLOSURES:

The authors have nothing to disclose.

REFERENCES:

1 Linnanmaki, L. et al. Gap Formation During Cyclic Testing of Flexor Tendon Repair. *Journal of Hand Surgery - American volume.* **43** (6), 570 (2018).

2 Zhao, C. et al. Effect of gap size on gliding resistance after flexor tendon repair. *Journal of Bone and Joint Surgery - American volume.* **86** (11), 2482-2488 (2004).

3 Gelberman, R. H., Boyer, M. I., Brodt, M. D., Winters, S. C., Silva, M. J. The effect of gap formation at the repair site on the strength and excursion of intrasynovial flexor tendons. An experimental study on the early stages of tendon-healing in dogs. *Journal of Bone and Joint Surgery - American volume.* **81** (7), 975-982 (1999).

4 Sull, A., Inceoglu, S., Wongworawat, M. D. Does Barbed Suture Repair Negate the Benefit of Peripheral Repair in Porcine Flexor Tendon? *Hand (New York, N.Y.).* **11** (4), 479-483

(2016).

5 Merrell, G. A. et al. The effect of increased peripheral suture purchase on the strength of flexor tendon repairs. *Journal of Hand Surgery - American volume.* **28** (3), 464-468 (2003).

6 Rawson, S., Cartmell, S., Wong, J. Suture techniques for tendon repair; a comparative review. *Muscles, Ligaments, and Tendons Journal.* **3** (3), 220-228 (2013).

7 Dona, E., Turner, A. W., Gianoutsos, M. P., Walsh, W. R. Biomechanical properties of four circumferential flexor tendon suture techniques. *Journal of Hand Surgery - American volume.* **28** (5), 824-831 (2003).

8 Mishra, V., Kuiper, J. H., Kelly, C. P. Influence of core suture material and peripheral repair technique on the strength of Kessler flexor tendon repair. *Journal of Hand Surgery - British and European Volume* **28** (4), 357-362 (2003).

9 Moriya, T., Zhao, C., An, K. N., Amadio, P. C. The effect of epitendinous suture technique on gliding resistance during cyclic motion after flexor tendon repair: a cadaveric study. *Journal of Hand Surgery - American volume.* **35** (4), 552-558 (2010).

10 Takeuchi, N. et al. Strength enhancement of the interlocking mechanism in cross-stitch peripheral sutures for flexor tendon repair: biomechanical comparisons by cyclic loading. *Journal of Hand Surgery - European volume.* **35** (1), 46-50 (2010).

11 Mao, W. F., Wu, Y. F. Effects of a Q Suture Technique on Resistance to Gap Formation and Tensile Strength of Repaired Tendons: An Ex Vivo Mechanical Study. *Journal of Hand Surgery - American volume.* **45** (3), 258 (2020).

12 Hirpara, K. M., Sullivan, P. J., O'Sullivan, M. E. The effects of freezing on the tensile properties of repaired porcine flexor tendon. *Journal of Hand Surgery - American volume.* **33** (3), 353-358 (2008).

13 Tang, J. B., Zhang, Y., Cao, Y., Xie, R. G. Core suture purchase affects strength of tendon repairs. *Journal of Hand Surgery - American volume.* **30** (6), 1262-1266 (2005).

14 Cao, Y., Zhu, B., Xie, R. G., Tang, J. B. Influence of core suture purchase length on strength of four-strand tendon repairs. *Journal of Hand Surgery - American volume.* **31** (1), 107-112 (2006).

15 Kim, J. B., de Wit, T., Hovius, S. E., McGrouther, D. A., Walbeehm, E. T. What is the significance of tendon suture purchase? *Journal of Hand Surgery - European volume.* **34** (4), 497-502 (2009).

16 Lee, S. K. et al. The effects of core suture purchase on the biomechanical characteristics of a multistrand locking flexor tendon repair: a cadaveric study. *Journal of Hand Surgery - American volume.* **35** (7), 1165-1171 (2010).

17 Vanhees, M. et al. The effect of suture preloading on the force to failure and gap formation after flexor tendon repair. *Journal of Hand Surgery - American volume.* **38** (1), 56-61 (2013).

18 Smith, G. H., Huntley, J. S., Anakwe, R. E., Wallace, R. J., McEachan, J. E. Tensioning of Prolene reduces creep under cyclical load: relevance to a simple pre-operative manoeuvre. *Journal of Hand Surgery - European volume.* **37** (9), 823-825 (2012).

19 Wu, Y. F., Tang, J. B. Effects of tension across the tendon repair site on tendon gap and ultimate strength. *Journal of Hand Surgery - American volume.* **37** (5), 906-912 (2012).

20 Wu, Y. F., Tang, J. B. How much does a Pennington lock add to strength of a tendon repair? *Journal of Hand Surgery - European volume.* **36** (6), 476-484 (2011).

Figure 1

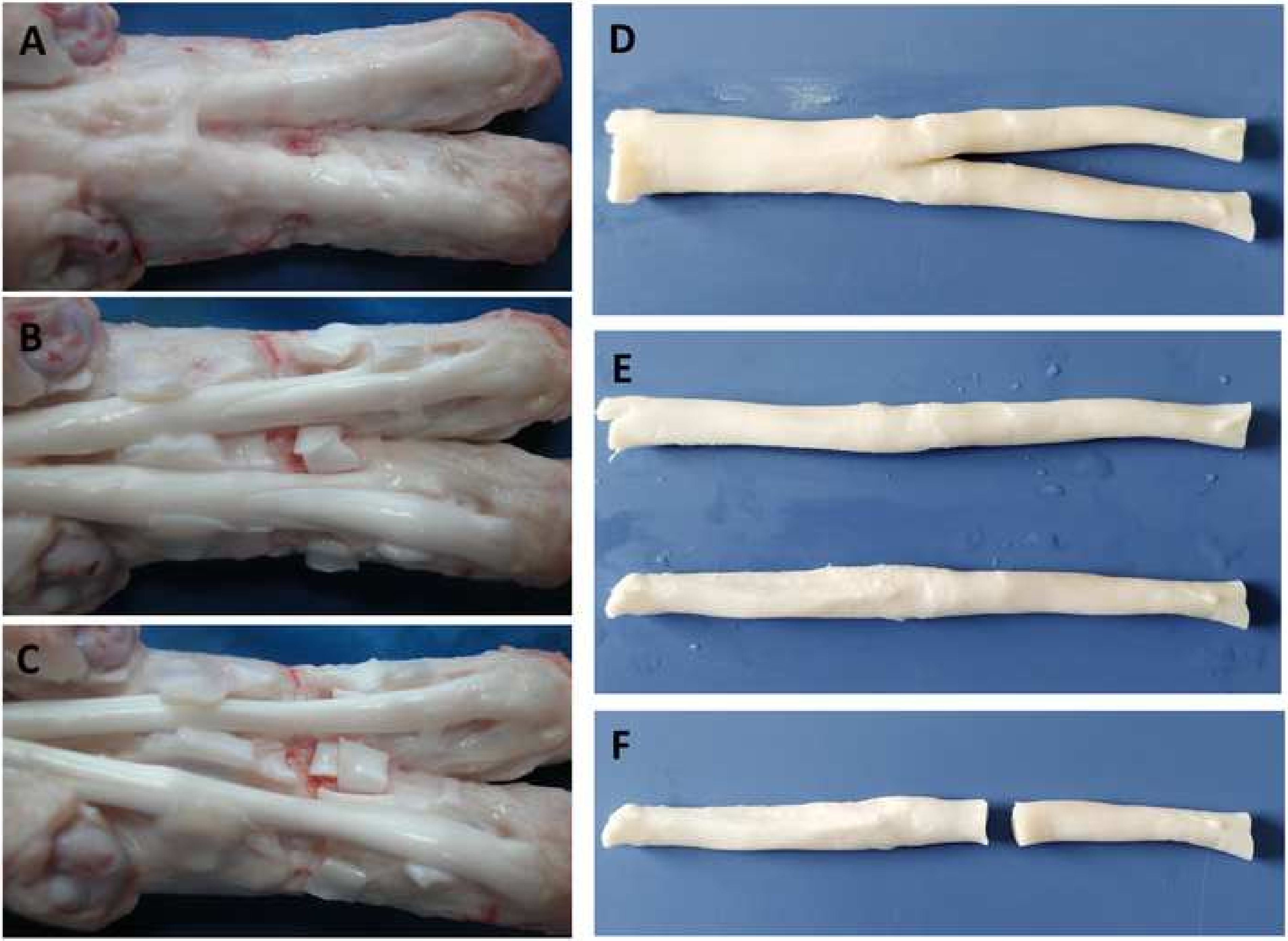


Figure 2

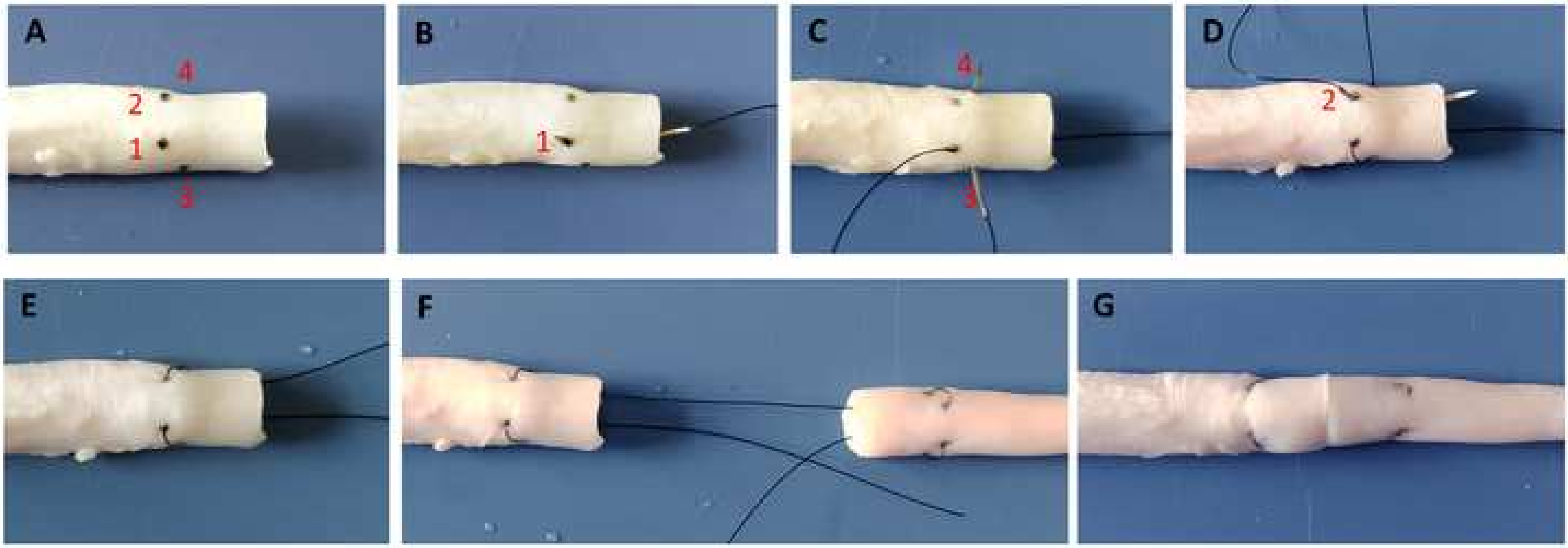


Figure 3

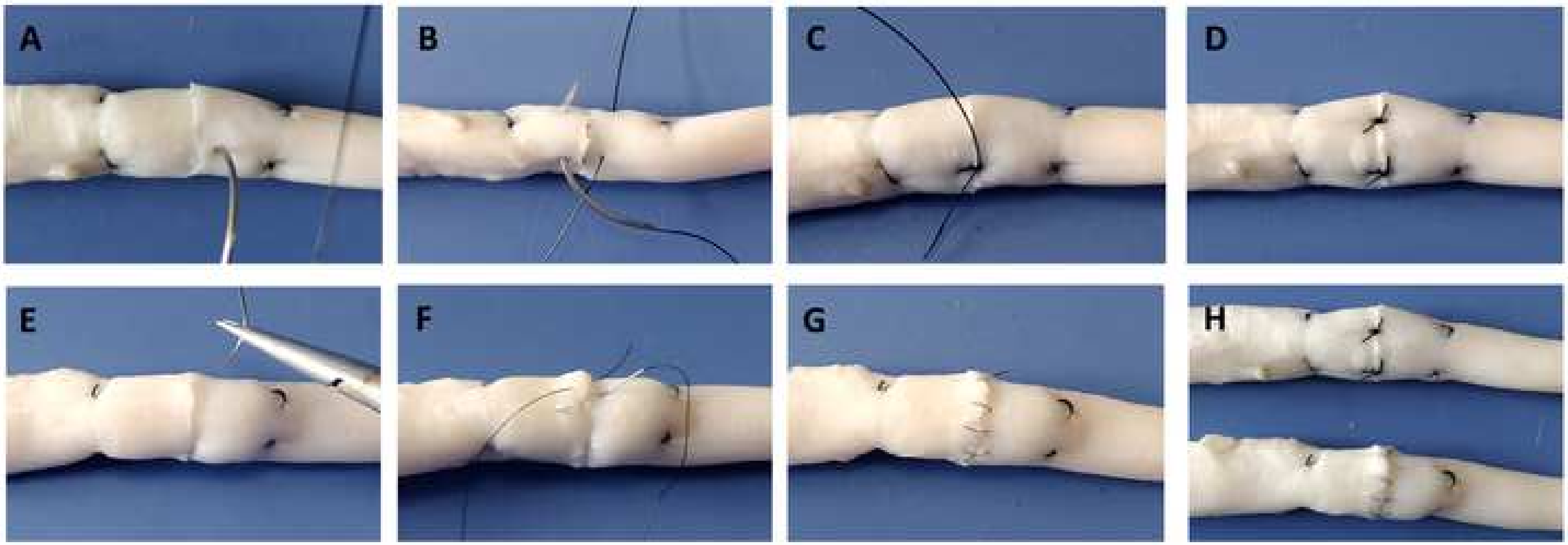
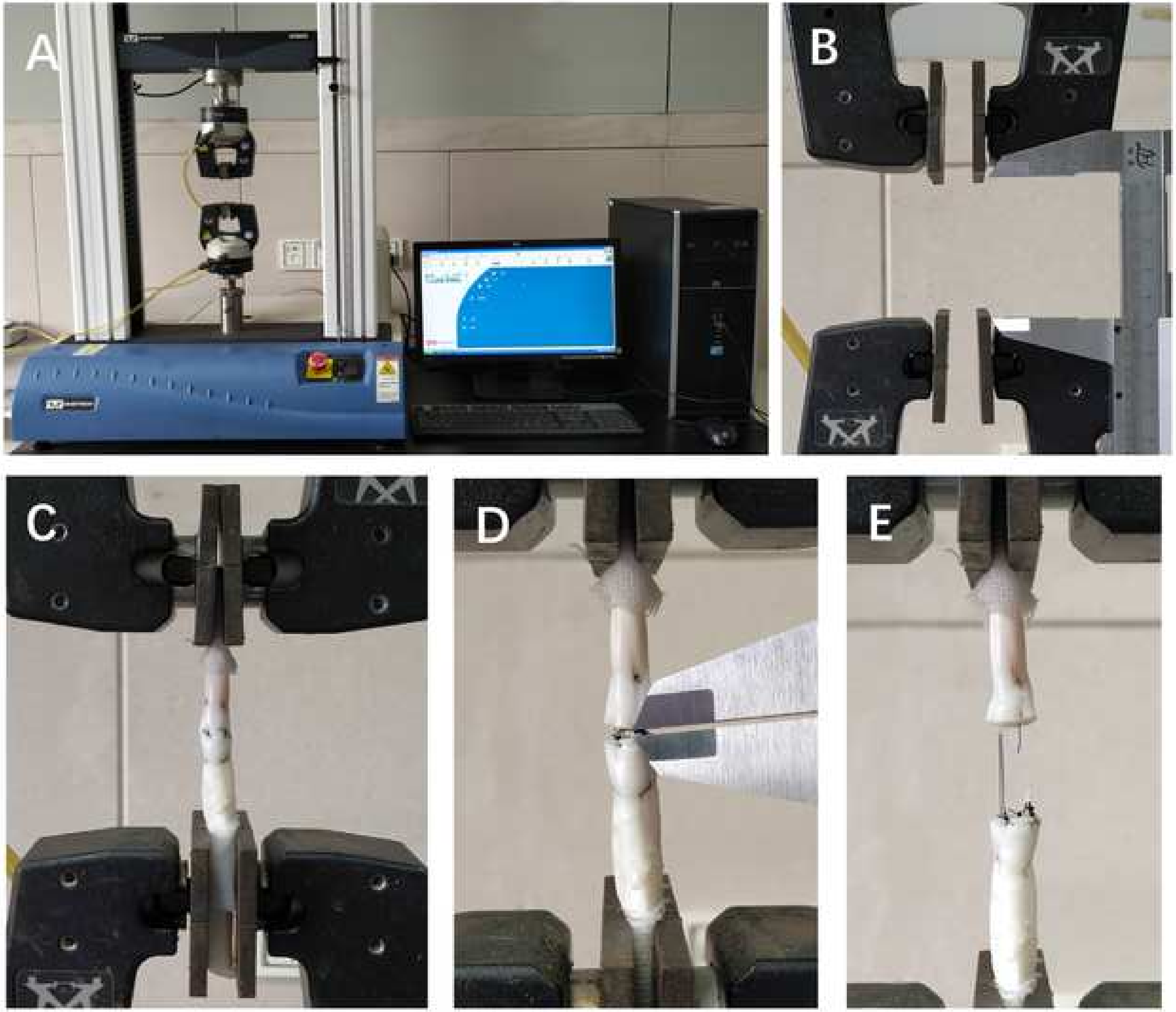


Figure 4 Click here to access/download;Figure;Figure 4.psd



Click here to access/download
Video or Animated Figure
JoVE61445R1_screenfile2.mp4

Click here to access/download
Video or Animated Figure
JoVE61445R1_screenfile1.mp4

Table 1 Number of tendons with 2-mm gap formation during cyclic loading, gap size at the repair site after cyclic loading, ultim

	Number of Tendons with 2-ı	Gap Size (mm)	Ultimate Strength (N)	Surgical Time (min
2-strand core suture	10	8.7 + 1.1	21.7 + 1.4	
2-strand core suture plus 2Q	0	1.1 + 0.4*	25.7 + 4.1*	1.8 + 0.2*
2-strand core suture plus running	2	0.8 + 0.2*	22.9 + 1.5	3.2 + 0.2
4-strand core suture	10	8.2 + 1.1	32.8 + 4.3	
4-strand core suture plus 2Q	5	1.8 + 0.8*	32.4 + 3.3	
4-strand core suture plus running	9	6.5 + 2.8*#	33.8 + 5.5	

The data of 2-strand core suture and 4-strand core suture are analyzed separately. *Significant different from those data without an aster

ate strength of the repaired tendons, and surgical time for 2Q and running sutures.
)

isk in the same column. #Significantly different from 4-strand core suture plus 2Q data in the same column.

Name of Material/ Equipment	Company	Catalog Number
4-0 suture	Ethicon, Somerville, NJ	Ethilon 1667
6-0 suture	Ethicon, Somerville, NJ	Ethilon 689
biomechanical testing machine	Instron Corp, Norwood, MA	Instron 3365
biomechanical testing software	Instron Corp, Norwood, MA	Bluehill 2

Comments/Description

Editorial comments:

1. The editor has formatted the manuscript to match the journal's style. Please retain and use the attached version for revision.
   Response: Many thanks.
2. Please address all the specific comments marked in the manuscript.
   Response: Finished.
3. Once done please ensure that the highlight is no more than 2.75 pages including headings and spacings.
   Response: Finished.

Reviewers' comments:

Reviewer #1:

Major Concerns:

1. This novel Q suture could be as an additional suture to core suture. Stating Q peripheral suture would be inappropriate as the suture involves in piercing tendon anteroposteriorly (through the tendon). Peripheral suture doesn't involve in suturing through the tendon, it is placed at epitendinous. the Q suture, in my opinion, could not be categorized into peripheral suture.
   Response: We totally agree with you that the Q suture should not be categorized into peripheral suture. We have made the relevant revisions in the Abstract section.
2. IF this journal is to be accepted, I would suggest that the aim of this study is to evaluate alternative Q suture to peripheral suture in flexor tendon repair, instead of Q suture technique as new peripheral suture.
   Response: Revised as suggested.

Reviewer #2:

Manuscript Summary:

by adding "flexor tendons" make the concern is more clearly.

Response: Many thanks.

Major Concerns:

The Authors need to explain, why they were placing the suture only at anterior site, not contra laterally?

Response: The medial-lateral diameter of tendon is larger than anterior-posterior diameter. Therefore, placing the Q suture at anterior site is easier to perform and could accomplish a better end-to-end apposition of injured tendon.

Minor Concerns:

The author need to present a picture of the Q suture as it is a new technique in flexor tendon repair

Response: In **a previous study, we have presented the illustration of Q suture. (*Mao, W. F. & Wu, Y. F. Effects of a Q Suture Technique on Resistance to Gap Formation and Tensile Strength of Repaired Tendons: An Ex Vivo Mechanical Study. Journal of Hand Surgery - American volume. 45 (3), 258 e251-258 e257, (2020)*).**

Here, we drew a schematic of the stitching steps of Q suture for your convenience.