Journal of Orthopaedics, Trauma and Rehabilitation 15 (2011) 62–64

Contents lists available at ScienceDirect

Journal of Orthopaedics, Trauma and Rehabilitation

Journal homepages: www.e-jotr.com & www.ejotr.org

Original Article

In vitro Biomechanical Study of Pulvertaft Tendon Weaving Technique
在生物體外對Pulvertaft魚口式肌腱編織縫合法之生物力學的研究

Yuen Chi-Pan[a,*], Yen Chi-Hung[a], Leung Hon-Bong[b], Tse Wing-Lim[c], Ho Pak-Cheong[c], Hung Leung-Kim[c]

[a] *Department of Orthopaedics and Traumatology, Kwong Wah Hospital, Kowloon, Hong Kong*
[b] *Department of Orthopaedics and Traumatology, Queen Mary Hospital, The University of Hong Kong, Hong Kong*
[c] *Department of Orthopaedics and Traumatology, Prince of Wales Hospital, The Chinese University of Hong Kong, Hong Kong*

ARTICLE INFO

Article history:
Accepted March 2011

Keywords:
pulvertaft technique
tendon injuries
tendon repair

ABSTRACT

Background/Purposes: The outcome of tendon repair depends on the strength, which allows early active mobilization to achieve better function without rupture. The aims of this study are to assess quantitatively the biomechanical properties and relationship between the number of tendon weaving and suture method using Pulvertaft technique.
Results: We found that the load to failure was increased with increasing number of weaves and sutures. From 1-weave to 4-weave single suture samples, the peak load to failure was 9.5 N, 19.7 N, 37.5 N, and 42.6 N, respectively. Based on previous studies, wrist and finger tendons should withstand 1–8 N on passive mobilization.
Conclusion: On active mobilization, finger tendon repair need to provide 34 N for immediate mobilization. Therefore, irrespective of number of sutures, both 3- and 4-weave repairs could allow early mobilization biomechanically.

中 文 摘 要

臨床肌腱修復的成果，其中一個決定性的因素在於已修復肌腱的強度是否足以應付術後的早期活動與康復。本文以生物力學的角度去研究Pulvertaft魚口式編織方法之魚口數目和縫合的數目以及肌腱強度之間的關係，目的為臨床手功能康復提供數據。拉伸實驗的結果顯示， 肌腱的最大失效載荷會因為魚口數目和縫合數目的增加而有所增加。由1至4個魚口單縫合的最大失效載荷分別為9.5N, 19.7N, 37.5N 和 42.6N。基於以往的研究，肌腱需要抵擋1至8N的載荷以應付保護性的肌腱活動。而主動性的肌腱活動更需要高達34N的載荷。所以在生物力學的層面，不論縫合的數目，3至4個魚口的肌腱縫合便足以應付術後的主動性肌腱活動。

Introduction

Since 1948, Pulvertaft tendon weaving has been one of the popular methods used in tendon transfer.[1] Tendon transfer outcome depends on the strength of repair, which allows early active mobilization, and thence better range of motion without risk of rupture.[2] In addition, the reported strength of repair ranges from 105 N to 159.7 N, which are related to the size of tendon, size of suture, number of weaves, and number of sutures in each weave.[3,4] As there is no biomechanical study addressing the above issues, the aims of this study are to assess quantitatively the biomechanical properties of Pulvertaft tendon weaving technique, in particular load to failure, energy absorbed before failure and mode of failure, and the relationship between the number of tendon weaving and that of suture.

* Corresponding author. *E-mail:* simoncpyuen@gmail.com.

Materials and Methods

Pigs' trotter extensor tendons were harvested in view of their availability and constant caliber. Choice of tendon was confined to diameter of 2.5 mm (2.2–2.7). The Student's t test was used to compare data between the groups, and 95% confidence interval of the difference between groups was determined. A p value of 0.05 was considered statistically significant. There was no statistically significant difference in diameter of tendon ($p = 0.87$). Each tendon specimen was cut and repaired by 3-O Ethilon (Ethicon, Inc., Somerville, NJ, USA) using Pulvertaft technique. The weaves were made perpendicular to one another. The specimens were divided to one, two, and three weaves (Figure 1). For each weaving method, three suturing methods were performed: single, double, or triple strands sutures (Figure 2), which means that one, two, or three suture knots were tied to the same weave, respectively. Ten repairs were done for each of the above types, amounting to a total of a 120

doi:10.1016/j.jotr.2011.04.005

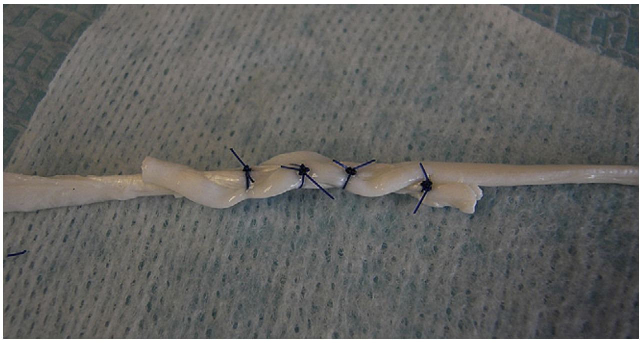

Figure 1. Each tendon specimen was cut and repaired by 3-O Ethilon using Pulvertaft technique. The weaves were made perpendicular to one another. This sample was a 4-weave, single suture repair.

repairs. All repairs were tested to failure in tension using a Hounsfield screw-driven tensile testing machine (Figure 3). The software used in the tensile testing machine was QMat 5.42 S-Series.

Results

Peak load to failure

In 1-weave sample, the peak load to failure was 9.5 N, 12.8 N, and 18.0 N for one suture, two sutures, and three sutures, respectively. In 2-weave sample, the peak load to failure was 19.7 N, 26.7 N, and 42.3 N for one suture, two sutures, and three sutures, respectively. In 3-weave sample, the peak load to failure was 37.5 N, 51.3 N, and 76.0 N for one suture, two sutures, and three sutures, respectively. Lastly, in 4-weave sample, the peak load to failure was 42.6 N, 76.3 N, and 66.0 N for one suture, two sutures, and three-sutures, respectively (Table 1 and Figure 4).

Energy absorbed before failure

In 1-weave sample, the energy absorbed before failure was 30.8 Nmm, 46.8 Nmm, and 93.2 Nmm for one suture, two sutures, and three sutures, respectively. In 2-weave sample, the energy absorbed before failure was 80.8 Nmm, 84.5 Nmm, and 208.9 Nmm for one suture, two sutures, and three sutures, respectively. In 3-weave sample, the energy absorbed before failure was 119.2 Nmm, 448.8 Nmm, and 547.4 Nmm for one suture, two sutures, and three sutures, respectively. Lastly, in 4-weave sample, the energy absorbed before failure was 264.5 Nmm, 671.5 Nmm, and 533.8 Nmm for one suture, two sutures, and three sutures, respectively (Table 1 and Figure 4).

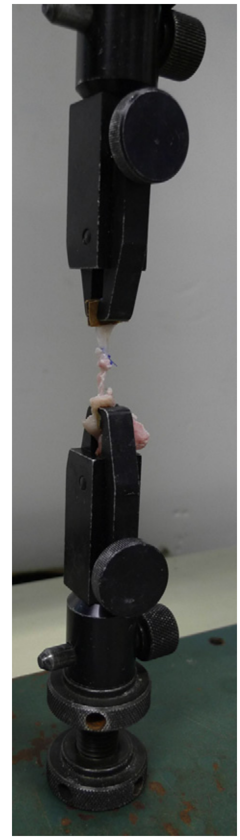

Figure 3. All repairs were tested to failure in tension using a Hounsfield screw-driven tensile testing machine. Each tendon sample was stabilized to the machinery at both ends by clamps and sand paper.

Mode of failure

All tendon repairs failed in the repair region by sutures cutting through tendon, which was compatible with results by Brown et al.[1]

Discussions

Based on previous studies, wrist and finger tendons could withstand 1–8 N on passive mobilization. On active mobilization, finger tendon repair need to provide 34 N for immediate mobilization.[3,5,6] Our data shed light on the clinical implication of Pulvertaft technique. Irrespective of number of sutures, both 3- and

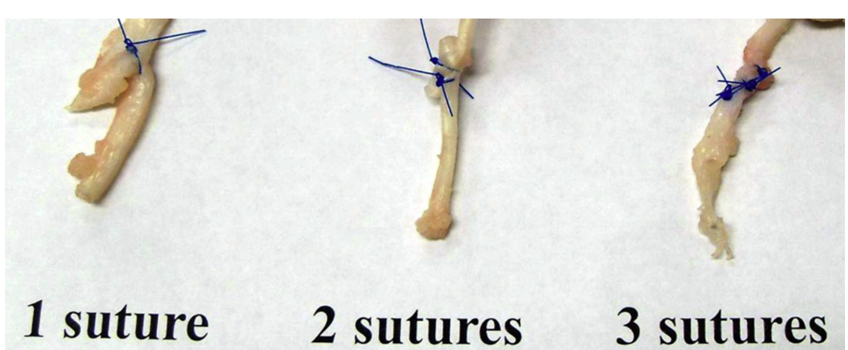

Figure 2. For each weaving method, three suturing methods were performed; they were single, double, or triple strands sutures.

Table 1
Data of mean load to failure and energy absorbed before failure

Number of weave	Number of suture	Mean load to failure/N	Mean energy before failure/Nmm
1	1	9.5 (9.2–9.7)	30.8 (30.2–31.5)
1	2	12.8 (12.5–13.1)	46.8 (46.3–47.8)
1	3	18.0 (17.5–18.4)	93.2 (92.7–93.6)
2	1	19.7 (19.6–20.1)	80.8 (80.1–82.2)
2	2	26.7 (26.4–27.3)	84.5 (83.8–85.4)
2	3	42.3 (42.0–43.4)	208.9 (208.5–209.7)
3	1	37.5 (37.1–38.2)	119.2 (118.5–120.0)
3	2	51.3 (50.8–52.1)	448.8 (448.1–449.9)
3	3	76.0 (75.3–76.8)	547.4 (546.7–548.3)
4	1	42.6 (42.2–43.8)	264.5 (263.0–265.9)
4	2	76.3 (75.7–76.8)	671.5 (670.9–672.2)
4	3	66.0 (65.4–66.6)	533.8 (533.0–534.8)

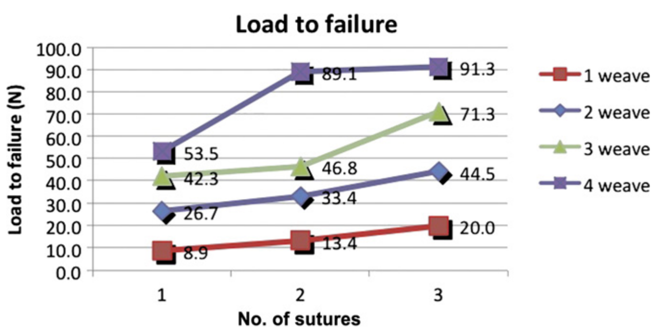

Figure 4. Data of mean load to failure and energy absorbed before failure.

4-weave repairs could allow early and safe active mobilization and yet it was clinically practicable.

However, we cannot conclude that the data gathered in the study is completely applicable in human *in vivo*. First, only a single constant force was loaded to challenge the tendon repair; but in real clinical situation, repetitive stress was applied. Therefore, controlled mobilization exercise is usually used in the initial phase of tendon transfer rehabilitation program. Second, the tendons were dead and harvested from pigs. The alignment and structure of collagen fibers, the inflammatory response and cellular reaction to the suture materials, and tendon repair zone are not the same as in human. Third, the healing time of the tendon is around 6–8 weeks in human and the change of biomechanical property of the tendons and suture in the healing period have not been accountable in this study.

In the event of short tendon lengthen that precluded 3-weave repairs, a 2-weave repair was also safe enough to allow active mobilization provided that three sutures were made for each weave. The studies clearly showed that 1-weave repair and double suture for 2-weave repair were unacceptable to allow active mobilization. The decrease in peak load to failure observed in triple sutures in 4-weave repairs was because of too many sutures causing catastrophic damage to tendon itself. It implied that Pulvertaft repair would not work as good in putting as many sutures as feasible. In conclusion, if there is adequate tendon length for transfer, even single strand suture with three and four weaves in Pulvertaft technique provides tendon repair of adequate strength biomechanically to allow safe immediate mobilization. When there is limitation of tendon length, one may consider applying triple strands sutures for each weave to improve the strength of the tendon suture.

However, the repetitive stress, microarchitecture of human collagen fibers, and the *in vivo* inflammatory response were not addressed in this study.

Acknowledgements

This study is awarded research grant from Hong Kong Orthopaedic Association (HKOA). This is to acknowledge the technical support from the clinical research team, Department of Orthopaedics and Traumatology, Prince of Wales Hospital. The authors thank Ms Kian Chong for collecting and entering data and Dr WM Lee for editing the manuscript.

References

1. Brown SH, Hentzen ER, Kwan A, et al. Mechanical strength of the side-to-side versus Pulvertaft weave tendon repair. *J Hand Surg Am* 2010;**35**:540–5. Epub 11 March 2010.
2. Bidic SM, Varshney A, Ruff MD, Orenstein HH. Biomechanical comparison of Llasso, Pulvertaft weave, and side-by-side tendon repairs. *Plast Reconstr Surg* 2009;**124**:567–71.
3. Rath S, Schreuders TA, Selles RW. Early postoperative active mobilisation versus immobilisation following tibialis posterior tendon transfer for foot-drop correction in patients with Hansen's disease. *J Plast Reconstr Aesthet Surg* 2010;**63**:554–60. Epub 20 February 2009.
4. De Smet L, Schollen W, Degreef I. In vitro biomechanical study to compare the double-loop technique with the Pulvertaft weave for tendon anastomosis. *Scand J Plast Reconstr Surg Hand Surg* 2008;**42**:305–7.
5. Kulikov YI, Dodd S, Gheduzzi S, et al. An in vitro biomechanical study comparing the spiral linking technique against the pulvertaft weave for tendon repair. *J Hand Surg Eur Vol* 2007;**32**:377–81. Epub 23 April 2007.
6. Pulvertaft RG. Repair of tendon injuries in the hand. *Ann R Coll Surg Engl* 1948;**3**:3–14.