BIOMECHANICAL ANALYSIS OF 4-STRAND FLEXOR TENDON REPAIRS

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INTRODUCTION

Our laboratory has characterized load sharing of the combination suture repair of lacerated digital flexor tendons with the development of a "spring model," which can accurately predict the mechanical behavior of the multi-strand repair.[4,8]

We have previously reported that the mean failure load of tendons repaired with a deep peripheral suture was almost 80% greater than that of tendons repaired with the traditional peripheral suture.[4] Further, our spring model suggested hat additional improvements in repair strength could be obtained by increasing the stiffness of the core suture, in order to balance the increased forces carried by the peripheral suture.

In this report, we postulate and prove that the strength and stiffness of human flexor tendon repairs can be improved through refinements of the core suture in a standard surgical repair.

METHODS

We isolated 60 FDP tendons from fresh frozen human hands over a length of 12 cm starting distally at the chiasm of Camper. Each tendon was divided transversely into two sections, each 6 cm long. We severed both the distal and proximal sections and subsequently repaired them using the double-modified Kessler core suture (DKCS) technique under a microscope.

Each tendon was fixed with cyanoacrylate adhesive on a special sandpaper frame, which was mounted on custom-made clamps with transverse ridges, designed to overcome the problem of slippage during mechanical testing. The tendons were distracted longitudinally on a testing machine at the rate of 0.33mm/s to failure. Tendon loads and grip displacements were continuously recorded.

A. Four types of suture materials were tested on 12 FDPs each: 4.0 monofilament nylon (Dermalon),4.0 braided polyester (Ticron), 4.0 monofilament polyester (Tsuge), and 3.0 braided polyester (Ticron).
B. Placement of sutures with one needle pass of a double-stranded suture or two needle passes of a single-stranded suture was performed and compared. Within each group, 50% had 4 core strands placed with a single needle pass of a specially fabricated suture that contained 2 strands of suture attached to a single needle. In the other 50%, the 4 strands were placed with 2 passes of a standard needle attached to a single suture strand. In each case, 2 knots were tied, 1 for each complete strand.
C. Core suture plus peripheral suture repairs were compared to core suture repairs without a peripheral suture.

12 FDPs were repaired with 3.0 braided polyester suture using a 4-strand double-modified Kessler core suture technique with an additional peripheral 6.0 Proline suture. The results were compared to the 4-strand core suture without a peripheral suture and also to a 2-strand core suture with a peripheral suture.[8]

The failure load was recorded as the peak load of the repair. The stiffness of the repair was calculated at the slope of the most linear part of the load-deflection curve and is report in units of Newtons per millimeter. Statistical analysis of number of needle and suture material was performed by ANOVA. A value of $p<0.05$ was considered to be significant.

RESULTS

Experiment A: Variation of suture materials and suture caliber

Materials	*Peak Load (N)*	*Stiffness (N/mm)*
4.0 Ticron	29.5 ±8.7	4.6±1.5
4.0 Tsuge	25.9±8.1	3.8±1.7
4.0 Dermalon	28.3±5.7	5.0±1.6
3.0 Ticron	46.8±11.4*	9.6±3.3*
		Mean±S.D.

*3.0 Ticron values are greater than those of other sutures, P<0.005.

Experiment B: Placement of sutures with one needle pass (double-strand) or two needle passes of a single strand

No. of Needle	*Peak Load (N)*	*Stiffness (N/mm)*
4.0 Ticron		
1 Needle	25.8±7.2*	4.7±1.1**
2 Needles	30.9±10.1	4.4±1.9
4.0 Tsuge		
1 Needle	23.3±9.2*	3.4±1.1**
2 Needles	28.5±6.7	4.4±2.1
4.0 Dermalon		
1 Needle	27.0±7.9*	4.7±1.9**
2 Needles	29.6±2.4	5.2±1.5
		Mean±S.D.

* No significant difference between 1 or 2 needles, p=0.1520
**No significant difference between 1 or 2 needles, p=0.6066

Experiment C: Core suture plus deep peripheral suture (DPS) compared to core suture alone

Materials	*Peak Load (N)*	*Stiffness (N/mm)*
3.0 Ticron+DPS	78.2±12.6*	17.9±5.1**
3.0 Ticron alone	46.8±11.4	9.6±3.3
4.0 Dermalon+DPS	43.0±8.3	13.2±3.8
		Mean±S.D.
	*p<0.0001	**p<0.005

*3.0 Ticron + DPS values are significantly different than that of the other groups.

DISCUSSION

In this study, a peak load of 78.2±12.6N was obtained by using the method of the DKCS combined with the DPS. This load is two times stronger than the Savage method[7] and significantly greater than *in vivo* tendon forces reported by Schuind for active digital flexion, with 3.5 kgf during active unrestricted finger motion, and 12.0 kgf during tip pinch.[2] Furthermore, there was no significant difference between placement of sutures with one needle pass (double strand) or two needle passes of a single strand suture in terms of stiffness and strength.

We conclude that our new technique (the double-modified Kessler core suture using 1 needle, coupled with a deep peripheral suture) gives sufficient strength to allow early active motion rehabilitation without tendon rupture. Clinically, it is as simple to use as the standard suture repair techniques. The biological effects of these changes in suture materials, caliber and placement still remain to be evaluated in an animal tendon model.

REFERENCES (some references not footnoted)

1. Becker H, et al. J Hand Surg 1979;4A:454-460. 2. Schuind S, et al. J Hand Surg 1992;17A:291-298. Chow JA, et al. J Bone Joint Surg 1988;70B:591-595. 4. Diao E,. et al. J Hand Surg 1996;21A:234-239. 5. Kleinert H, et al. Orthop Clin North Am 1973;4:865-876. 6. Soejima O et al. J Hand Surg 1995;20A:801-807. 7. Wagner FW, et al. J Hand Surg 1994;19A:979-983. 8. Lotz JC, et al. JORS 1998 *in press.*