SCIENTIFIC ARTICLE

The Effect of Asymmetric Core Suture Purchase on Gap Resistance of Tendon Repair in Linear Cyclic Loading

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Purpose To evaluate the biomechanical properties of an asymmetric core suture for tendon repair.

Methods Sixty porcine flexor tendons were repaired with 3 different 4-strand sutures using different core suture purchases: 2 sets of identical purchases of 10 mm, 2 sets of asymmetric purchases (8 mm proximal/distal stump and 12 mm distal/proximal stump), and 2 sets of identical purchases of 12 mm. The tendons were subjected to the cyclic loading for 20 cycles. The number of tendons with gaps at each cycle, elongation of gap area between tendon ends and tendon segment, gap formation forces, and ultimate strengths were recorded.

Results Tendons repaired with the asymmetric core suture purchases had the smallest gaps during cyclic loading. The elongation of gaps and tendon segments were significantly smaller than those with symmetric suture purchase of 10 or 12 mm. The asymmetric core suture repair had significant higher gap resistance forces than the symmetric suture repair at the final loading cycle.

Conclusions A 4-strand core suture repair with asymmetric purchases on the tendon stumps generated greater gapping resistance than that with an equal length of suture purchase.

Clinical relevance The asymmetric core suture purchase may be a practical measure to improve gapping resistance and fatigue strength when the suture purchase meets essential length requirements. *(J Hand Surg Am. 2014;39(5):910–918. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Elongation, gap area, gap formation force, suture purchase, tendon repair.

Additional material is available online.

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FUNCTIONAL RECOVERY AFTER DIGITAL flexor tendon repair relies on a strong repair and a smooth gliding bed. A surgical repair should be strong, with the capability to resist gapping.[1–3] Investigators have tried to understand factors that affect the biomechanical properties of repair method, including the number of suture strands,[4–6] material properties of sutures,[7–9] suture configurations,[10,11] purchase of core suture,[12–15] and suture tension.[17]

The core suture purchase influences resistance to gap formation and the ultimate strength of repairs in either obliquely or transversely lacerated tendons.[12,13,18,19] Flexor tendons in zone II repaired with the cross-locked cruciate–interlocking horizontal mattress method at a

10-mm suture purchase had a low increase in work of flexion, high failure strength, and high resistance to gapping compared with those at 3, 5, or 7 mm purchase.[15] An optimal length of core suture purchase between 7 and 10 mm was recommended, and the increased length of purchase from 0.7 to 1.2 cm did not increase the strength of the repair.[12,13]

We asked whether a small change in placement of the conventional core suture could improve the repair strength when lengths of purchase of all core sutures had already met the essential requirements, as determined in previous studies.[12–15] Usually, the length of purchase in a core suture repair is identical in both tendon stumps (ie, symmetric core suture repair). The closer the tendon substance was to the cut end, the less the grasping power of the transverse element of the core suture was acted upon, which may increase the risk of gapping between the tendon ends. The purposes of this investigation were to test the biomechanical properties of a 4-strand asymmetric core suture and to compare it with 2 symmetric core sutures. We hypothesized that the asymmetric core sutures would have better gapping resistance than the conventional ones during cyclic loading of the tendon.

MATERIALS AND METHODS

We used 60 fresh adult porcine flexor tendons because their structure is similar to that of human flexor tendons and their diameter approximates that of the adult human middle finger.[20–22] After exposure through an incision in the flexor sheath, the flexor digitorum profundus tendons were cut transversely at the level of the metatarsophalangeal joint. This level corresponds to the middle part of human zone II flexor tendons structurally, and the mean width of the flexor digitorum profundus tendon at this level is 6.4 ± 0.5 mm.

Operative techniques

We used 60 tendons. Six were for a pilot study and 54 were for 3 experimental groups of 18 each: 4-strand modified Kessler with core suture purchase of 10 mm on both tendon stumps, 4-strand asymmetric modified Kessler, and 4-strand modified Kessler with core suture purchase of 12 mm on both tendon stumps (Fig. 1). The 4-strand core sutures were 4 individual passes of a needle with a single suture, and we did not deliberately make grasping or locking anchors on the 4 corners of the Kessler suture.

In the asymmetric core suture group, 2 sets of separate but asymmetric 2-strand Kessler sutures passed through the tendon stumps. For the first set, the purchase of the core suture was 12 mm in one tendon end and 8 mm in the other. The second set, as the mirror symmetry of the first one, maintained the same length of purchase but was inverse to the first set. All the repairs were tensioned by 10% shortening of the tendon segment encompassed with the core suture strands.[16] The lengths were determined with the aid of an electronic digital vernier calipers (with a rated accuracy of 0.02 mm), and the points at which the suture limbs emerged from the tendon were marked on the surface.

The core sutures were 4-0 suture (Ethilon 1667; Ethicon, Somerville, NJ). After completion of the core suture, a simple running epitendinous suture of 9 to 10 stitches was added to each of the tendon with 6–0 suture (Ethilon 689) with a similar purchase (about 2 mm) and depth (about 1 mm). The same surgeon repaired all the tendons.

Biomechanical testing

We tested the tendons, which we kept moist with wet gauze, immediately after completing surgical repairs in batches of 4 to 6. We mounted the tendons into pneumatic upper and lower clamps in a tensile testing machine (Instron 3365; Instron, Norwood, MA). The force transducer was connected to the upper clamp that attaches to the transverse crossbar of the machine, and the force was recorded with a software program (Bluehill 2; Instron). The initial distance between the upper and lower clamps was set to 5 cm, and a preload of 1.0 N was exerted on all tendons (Fig. 2). Two video cameras were placed perpendicular to the laceration site to record the changes at the repair site from the front and side separately. A ruler was placed in the video field to provide a reference length. We used the software to simultaneously start the control program of the tensile testing machine, the software recording the process of load–displacement curve, and the cameras. Therefore, the gap formation and the pulling force were precisely synchronized according to the recording time.

We first used 6 tendons with Kessler suture (10 mm) in a preliminary test of load to failure to determine the initial gap formation force. These 6 tendons were pulled continuously at a speed of 25 mm/min after setting the baseline load. The force at which separation of tendon stumps occurred was recorded as the initial gap formation force, which was identified in the image of video. To reduce randomness because the contact surfaces of the 2 tendon ends did not always separate evenly, we standardized the initial gap to when half of the contact areas separated from each other. In this