Original Article With Video Illustration

Evaluation of 3 Needleless Grasping Suture Techniques for Soft-Tissue Graft Fixation: A Porcine Biomechanical Study

Chih-Kai Hong, M.D., Ming-Long Yeh, Ph.D., I-Ming Jou, M.D., Ph.D., Cheng-Li Lin, M.D., Chih-Hsun Chang, M.D., and Wei-Ren Su, M.D., M.Sc.

Purpose: The purpose of this study was to evaluate the tendon graft holding strength of 3 needleless grasping suture techniques, namely the modified Prusik knot, Wittstein suture loop, and modified rolling hitch. **Methods:** Thirty fresh-frozen porcine flexor profundus tendons were used and randomly divided into 3 groups of 10 specimens. The experimental procedure was designed to assess elongation of the suture-tendon construct across 3 different needleless tendon-grasping techniques. All suture configurations were completed with a multistranded nonabsorbable suture. Each tendon was pre-tensioned to 100 N for 3 cycles, cyclically loaded to 200 N for 200 cycles, and then finally loaded to failure. Elongation, load to failure, and mode of failure for each suture-tendon construct were measured. **Results:** During cyclic loading, there were no significant differences in elongation for any of the tested suture-tendon constructs (modified rolling hitch, 21.2% ± 9.6%; modified Prusik knot, 21.4% ± 9.9%; and Wittstein suture loop, 26.2% ± 4.5%). Similarly, the failure load and cross-sectional area were not significantly different across all tested suture groups. **Conclusions:** The modified Prusik knot, Wittstein suture loop, and modified rolling-hitch techniques had equal elongation after cyclic loading, as well as load to failure, in this in vitro biomechanical evaluation. **Clinical Relevance:** These needleless grasping suture techniques may be an attractive alternative to the commonly used whipstitch techniques for tendon graft fixation in ligament reconstruction.

It is crucial to have a reliable soft-tissue suture technique in ligament reconstruction surgery.[1-3] A secure primary mechanical fixation is important in accelerating rehabilitation programs before the development of a biological fixation that involves healing in the graft tunnel.[3,4]

Various suture techniques have been proposed for preparing and fixating tendon grafts, of which the whipstitch has long been one of the best known.[5] The Krackow technique, published in 1986 as a new locking suture for fixating ligaments, tendons, or capsular components to bone,[6] has also become very common.[1,4] In addition, various whipstitch techniques have been described, such as the baseball stitch and the SpeedWhip technique (Arthrex, Naples, FL).[1,7] Although these stitches are effective, several potential disadvantages should be considered, including time consumption, tendon damage caused by passing a needle through the tendon, and the potential for needle-stick injury.

Several authors have proposed needleless grasping suture techniques for harvesting and preparing autograft tendons in recent years.[8-10] These techniques not only reduce cost and decrease exposure to needles but also shorten the time required to harvest and prepare grafts. Krappinger et al.[8] proposed the modified Prusik knot, which was adapted from a commonly used knot in mountain climbing; Wittstein et al.[9] presented another suture loop technique that has been applied clinically; and Hong et al.[10] established the modified rolling hitch, which was adapted from the rolling hitch, a traditional knot used to attach a rope to an object. Some biomechanical studies have compared the

From the Department of Medicine, National Cheng Kung University College of Medicine (C-K.H., C-H.C.); Department of Biomedical Engineering (M-L.Y.) and Medical Device Innovation Center (M-L.Y., I-M.J., C-L.L., W-R.S.), National Cheng Kung University; and Department of Orthopaedic Surgery, National Cheng Kung University Hospital, National Cheng Kung University (I-M.J., C-L.L., W-R.S.), Tainan, Taiwan.

The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received May 27, 2014; accepted January 9, 2015.

Address correspondence to Wei-Ren Su, M.D., M.Sc., Department of Orthopaedic Surgery, National Cheng Kung University Hospital, No. 138, Sheng-Li Road, Tainan City, Taiwan 70428. E-mail: suwr@ms28.hinet.net

0749-8063/14447/$36.00

http://dx.doi.org/10.1016/j.arthro.2015.01.011

needleless suture techniques and the whipstitch techniques. Krappinger et al.[8] indicated that the modified Prusik knot could be an alternative option because it had greater stiffness and lesser displacement at maximum force than the whipstitch technique. Similarly, Su et al.[3] reported that the modified finger-trap (MFT) suture had lesser elongation after cyclic loading and an equal failure load compared with the Krackow stitch.

The aim of this study was to evaluate the tendon graft holding strength of 3 needleless grasping suture techniques, namely the modified Prusik knot, the Wittstein suture loop, and the modified rolling hitch. We hypothesized that there would be no differences in elongation and load to failure among these needleless suture techniques.

Methods

Three different needleless tendon-grasping techniques were investigated: the modified Prusik knot, the Wittstein suture loop, and the modified rolling hitch. The suture configurations for all 3 tested sutures were completed with a No. 2 FiberWire suture (Arthrex), and all techniques were performed in accordance with their original descriptions.[8-10] The modified Prusik knot starts with passing the 2 free suture ends through the loop; the step is repeated to make the second loop around the tendon before tightening the knot (Fig 1A). The Wittstein suture loop also begins with passing the free suture ends through the loop; the technique continues by creating a second loop around the tendon and passing the free suture ends through the loop to make a second single knot (Fig 1B). The modified rolling hitch begins by wrapping the suture around the tendon, followed by making a second wrap and third wrap; the working limb of the suture is then crossed over the other limb, and the procedure is completed with a half hitch by making a turn around the tendon and passing the working limb through it (Fig 1C). All suture constructs were placed at a 1-cm distance from the end of the tendon (Video 1, available at www.arthroscopyjournal.org) and performed by the same experienced orthopaedic surgeon (W-R.S.) for each specimen.

Thirty fresh porcine hind-leg trotters stored at −20°C were thawed to room temperature before testing. The flexor profundus tendon was dissected, and none of the tendons appeared to have any degenerative or pathologic changes. During preparation and testing, the porcine tendons were kept moist by spraying with 0.9% saline solution. A total of 30 tendons of equal length (18 cm) were obtained and randomly divided into 3 groups of 10 specimens each, with each group randomly assigned to receive 1 of the 3 suture configurations. The elongation test assignment was also arbitrarily ordered.

Biomechanical Testing

A transverse section, about 5 to 6 mm in thickness, was taken from the distal end and photographed alongside a calibration scale before testing. With the use of an 8.9-megapixel digital camera (EOS 60D; Canon, Tokyo, Japan) mounted on a tripod and image analysis software (SigmaScan Pro 5.0; SPSS, Chicago, IL), the cross-sectional areas of the tendon sections were calculated. After completing the suture techniques, we mounted each specimen on the universal materials testing machine (AG-X; Shimadzu, Tokyo, Japan). The proximal end of the tendon was fixed by a sinusoid clamp, which allows an equal length (9 cm) of free tendon for testing. Both ends of the suture were knotted tightly and looped over a post on the adapter of the materials testing machine (Fig 2) to maintain an equal force on both suture limbs.

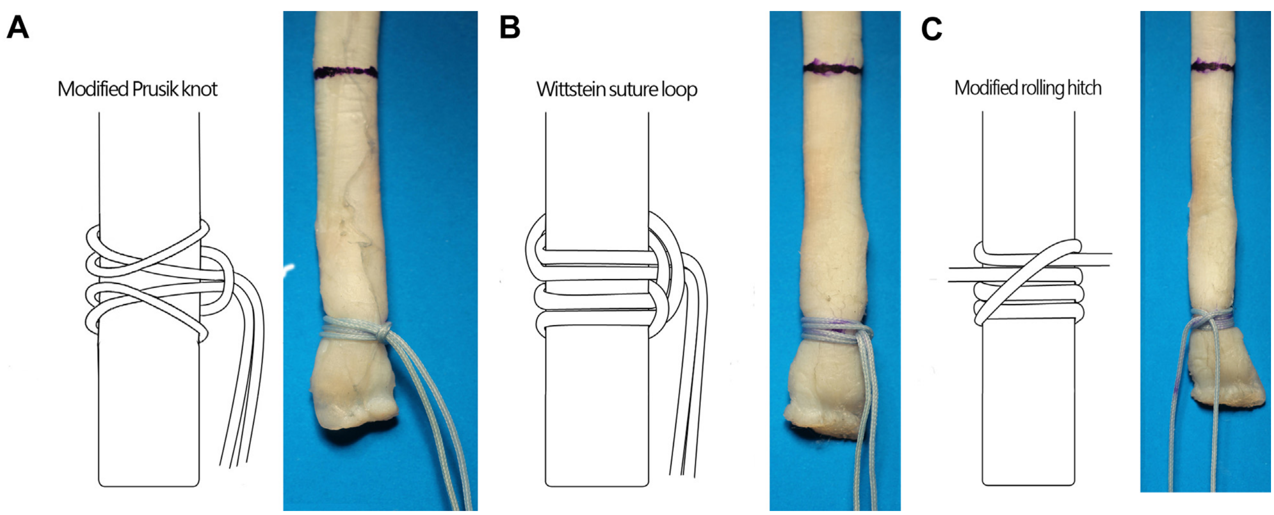

Fig 1. (A) Modified Prusik knot, (B) Wittstein suture loop, and (C) modified rolling hitch.