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Effect of anchor threads on the pullout strength: A biomechanical study

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ABSTRACT

Pullout tests to determine the effect of anchor threads on the pullout strength was conducted by using universal testing machine, synthetic cancellous bone and thread-less metallic anchor. Anchors were inserted at 45°, 90° or 135° from the surface and they were pulled at 45° from the surface. The maximum load to failure was compared among the 3 insertion angles. Pullout strength of the anchors inserted at 45° was significantly greater than those inserted at 90° or 135°. Pullout strength of the thread-less anchor was the greatest when it was inserted at 45° to the bone surface.

Level of evidence: level II.

1. Introduction

Fixing soft tissues using suture anchors are quite common in orthopaedic surgeries.[1–5] Many different kinds of suture anchors are widely distributed, and their fixation strength is said to rely on its design, bone density, insertion depth, and insertion angle.[6–10] Burkhart introduced the deadman theory in 1995, saying that "minimizing the angle insertion of the suture anchor, as well as the angle that the suture makes with the rotator cuff can increase the pullout strength of the anchor and reduce the tension in the suture".[11] This description is difficult to understand. Simply put, it could be interpreted that inserting the anchor perpendicular to the line of pull makes the pullout strength the greatest. This is intuitively understandable because this is exactly what we do when we set up a tent, inserting tent pegs perpendicular to the tent ropes. When we perform rotator cuff repair, the line of pull by the suture passed through the rotator cuff tendon is approximately 45° to the bone surface.[11] Thus, inserting the anchor perpendicular to the line of pull is equivalent to inserting the anchor at 45° to the bone surface. After the introduction of this theory, many researchers and surgeons use 45° as a standard angle of anchor insertion.[6,8–10,12,13] However, biomechanical studies using cadavers and synthetic bones revealed that the pullout strength of the anchor inserted at 90° to the bone surface was greater than that of the anchor inserted at 45°.[14–16] The greatest difference between the commonly-accepted intuitional understanding of tent peg insertion and the outcome of these biomechanical studies is the friction between the bone (ground) and the anchor (peg). Thus, if an anchor has a very small amount of friction, it seems likely to show performance similar to a tent peg in the ground. A previous biomechanical study has demonstrated that the pullout strength of the threaded anchors was greatest when it was inserted at 90° to the surface, suggesting that the deadman theory may not be applicable in clinical conditions.[16] Therefore, to further prove the effect of threads around the anchor on the pullout strength and to substantiate the results of studies using threaded anchors, the current biomechanical study using thread-less anchor was conducted. Our hypotheses were 1) a thread-less anchor inserted at 45° to the bone surface would show higher pullout strength than that inserted at 90° or 135° to the bone surface and 2) the lower the friction, the greater the advantage of 45°-insertion. The purpose of this study was to prove these hypotheses.

2. Methods

Synthetic bones (Sawbones, Pacific Research Laboratories, Vashon, WA) of 0.24 g/cm^3 (solid rigid polyurethane foam) were chosen based on the past reports of its use as a biomechanical testing model with the bone mineral density of the greater tuberosity of normal human humerus.[16,17] The bone was cut into the size of 60 mm in width, 40 mm in depth and 40 mm in height. Thread-less metallic anchor, 2.9 mm in width and 14 mm in length, was created for this biomechanical testing: threads of the metallic anchor (TwinFix™ 5.0 Ti, Smith & Nephew, Andover, MA) was grounded off (Fig. 1). Sutures (#2 Ultrabraid™, Smith & Nephew, Andover, MA) loaded originally to the anchors were replaced to braided polyethylene lines and they were tied to custom-made pulling jig. The sutures were replaced to prevent from the suture cut out and to resemble the threaded-anchor testing condition.[16] After creating a fisherman's knot with quadruple loop, for preventing the

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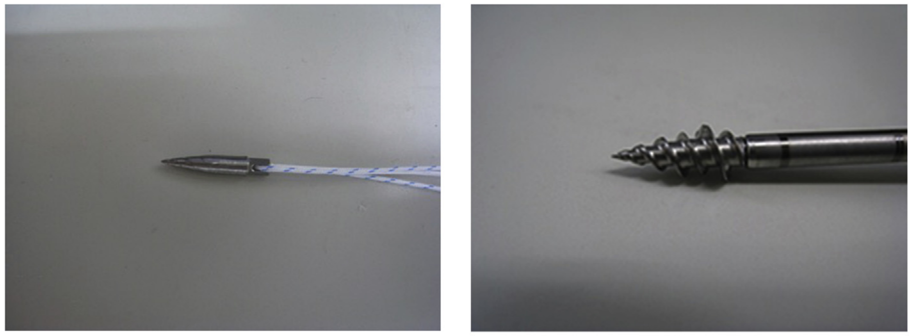

Fig. 1. (**A**). A custom-made thread-less anchor. (**B**). A standard threaded anchor.

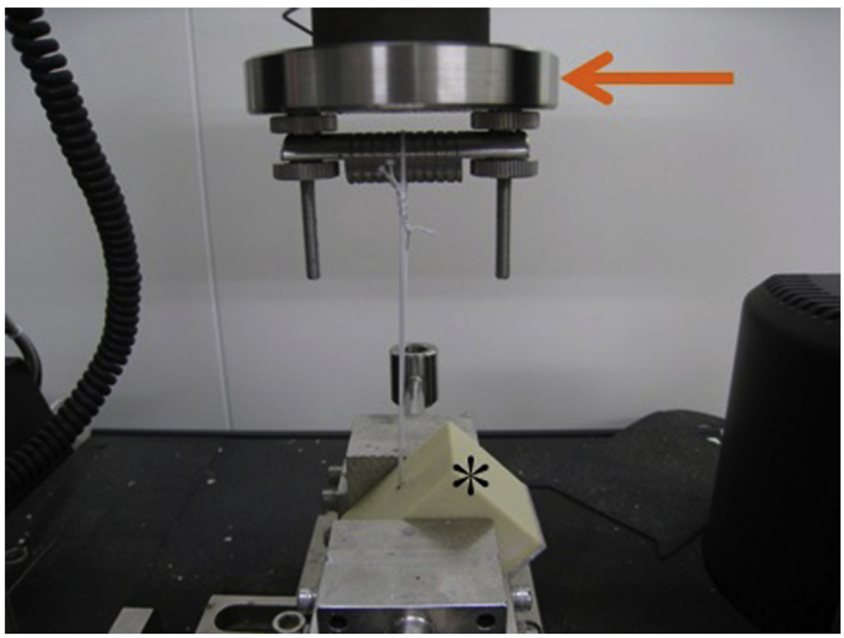

Fig. 2. Experimental setup. * indicate synthetic cancellous bone, and arrow indicates crosshead.

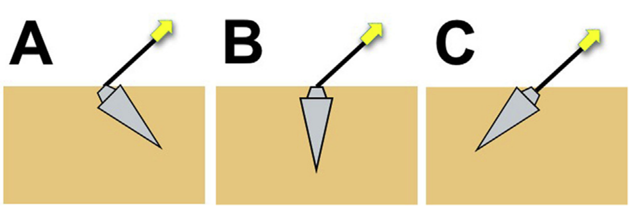

Fig. 3. All the anchors were pulled in the same direction (45° from the bone surface). (A) Thread-less anchor inserted at 45° from the bone surface. (B) Thread-less anchor inserted at 90° from the bone surface. (C) Thread-less anchor inserted at 135° from the bone surface.

knot from loosening and to resist the pulling load, 8 half-hitches were added to each end of the suture, also resembling the previous testing condition.[16] Universal testing machine (Instron® 566, Instron, Norwood, MA) was used to perform the pullout tests (Fig. 2). Synthetic bones were predrilled to create the pilot hole using 2.0- and 2.5-mm diameter drill and they were set up in a custom testing device for holding. The test was done in 2 different diameter holes to analyze the effect of friction between the thread-less anchor and bone, with lesser friction using the larger diameter hole. The anchors were inserted at 45°, 90° or 135° from the surface and they were pulled at 45° from the surface (Fig. 3). The pulling angle was determined using a goniometer. To ensure the full engagement of the anchor to the bone, the anchor was preloaded to 10 N with the extension rate of 1 mm/s followed by suture pull at a crosshead speed of 1 mm/s.[16,18] The maximum load to failure was defined by the load prior to sudden cessation of the testing or gradual load decrease caused by the complete pullout of the anchor. Maximum load was digitally recorded for 10 pullout tests performed for each condition.

3. Statistical analysis

For all the statistical analyses, JMP® Pro 12 software (SAS Institute, Cary, NC) was used. Differences in pullout strength between insertion angles and diameters of the pilot hole were analyzed using ANOVA. For the comparison between the insertion angles, the groups were compared individually by using the post hoc Tukey-Kramer HSD test. Results were considered statistically significant if the p value was less than 0.05. Upon all the testing and statistical analysis, power analysis was performed. Referring from our previous testing results, required sample size was 6 for each condition.

4. Results

Pullout strength of the anchors inserted at 45° (2.0 mm: 56.5 ± 2.6 N (95% CI, 54.7–58.3 N), 2.5 mm: 45.8 ± 3.0 N (95% CI, 43.6–47.9 N)) was significantly greater than those inserted at 90°