Minimum Distance of Suture Anchors Used for Rotator Cuff Repair Without Decreasing the Pullout Strength: A Biomechanical Study

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Purpose: To investigate the minimum distance between the anchors without decreasing the pullout strength using the polyurethane foams and the porcine bones. **Methods:** Metal screw-type anchors and PEEK (polyether ether ketone) coil-type anchors were used. Two same-type suture anchors were placed into the polyurethane foams and porcine bones. The polyurethane foams were 3 different densities simulating severe osteoporosis, osteoporosis, and normal bone. The distances between the centers of anchors were set at 4, 6, 8, and 10 mm. The pair of anchors were loaded to failure if they had not been pulled out after cyclic loading from 50 to 200 N, 10 cycles per each 50-N increment. Mode of failure, ultimate load to failure, displacement of the anchor, and number of cycles completed were recorded. **Results:** In all polyurethane foams of 3 different densities with use of metal screw-type anchors, the 4-mm group demonstrated a significantly lower ultimate load to failure compared with the 6-, 8-, and 10-mm groups ($P < .01$). There were no significant differences in the load to failure among the 6-, 8-, and 10-mm groups. Porcine bone or PEEK coil-type anchor showed results similar to those of the metal screw-type anchors. **Conclusion:** For the 2 tested anchors, the minimum distance between the anchors without decreasing the pullout strength was 6 mm (center to center) regardless of bone density in a biomechanical study. **Clinical Relevance:** Although it has been thought that the minimum distance between the anchors without decreasing the pullout strength was 1 cm (center to center), our data showed that it was 6 mm.

It has been clinically thought that the initial fixation strength is maintained if 2 suture anchors are inserted at least 1 cm apart.[1,2] However, there has been no evidence regarding the distance between the anchors to keep the pullout strength.

Development of arthroscopic instruments and improvement of arthroscopic techniques have contributed greatly to the spread of arthroscopic surgery. Suture anchors are very useful during arthroscopic rotator cuff repair or anterior shoulder stabilization, resulting in improvement of clinical outcomes.[3] The initial fixation strength of suture anchors is important. It has been reported that failure of rotator cuff repair occurs at 3 interfaces between the tissue and suture, suture and anchor, or anchor and the bone.[4-9] The prevalence of rotator cuff tear increases with age.[10,11] This means that patients with rotator cuff tears may have a high possibility of having osteoporosis.[12] Some reports described that the bone mineral density below the footprint in patients with rotator cuff tear was low regardless of age because of less stress from the rotator cuff on the bone.[13] Previous biomechanical studies revealed that pullout strength depends on the bone mineral density.[6,14,15] Some gave the alert that anchor pullout sometimes occurred after arthroscopic rotator cuff repair in patients with osteoporosis.[7,9] Pullout of the anchors results in failure of repair and causes pain and dysfunction. Therefore, it is important to prevent anchor pullout after surgery to improve clinical results.

Multiple anchors are used depending on the size of the tear during arthroscopic rotator cuff repair.[16-18] If many anchors are placed into the footprint of torn rotator cuff tendons, anchors may be too close to each other to maintain the holding strength of the bone.

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The relationships of the pullout strength to the anchor material, anchor design, insertion angle, insertion depth, and bone mineral density have been investigated.[15,19-24] However, these reports focused on the pullout strength of only one anchor. There is one report investigating the pullout strength of 2 anchors.[25] This study demonstrated that the pullout strength of 2 anchors was higher than that of one anchor. The effect of the distance between 2 anchors on the pullout strength has not been clarified yet. The purpose of this study was to investigate the minimum distance between the anchors without decreasing the pullout strength using the polyurethane foams and the porcine bones. We hypothesized that pullout strength would decrease with a distance less than 1 cm between anchors, especially in the polyurethane foam with low density.

Methods

Specimen Preparation

The polyurethane foams and porcine humeri were used for our experiment. The porcine bone was used for the reason that it is similar to the human body.[26] The solid rigid polyurethane foams with 3 different densities (1522-23, 1522-01, 1522-02; Pacific Research Laboratory, Vashon Island, WA) were used. The densities of these polyurethane foams were 0.08, 0.16, and 0.24 g/cm^3, simulating severe osteoporosis, osteoporosis, and normal bone, respectively.[27,28] The polyurethane foam was cut to a size of 43 mm in length, 45 mm in width, and 40 mm in height. Twenty-four porcine humeri were harvested from domestic pigs. The mean age of the pigs was 17 ± 2 weeks (range, 14-19) and the mean body weight was 58.8 ± 7.2 kg (range, 46-72 kg). The use of porcine humeri for this study was reviewed and approved by our University Animal Studies Committee (no. 2015-159). All soft tissues were removed from the humerus and stored in the freezer at −30°C. The humerus was thawed overnight at room temperature before measurement of the bone mineral density with CT scan for small animals (Latheta LCT-200; Aloka, Tokyo, Japan). The range of interest was set at the greater tuberosity, where the anchors were to be inserted. CT scanning was performed (50 kV, 20-μm pixel size, 120-μm slice thickness, 2-mm slice separation). Ten axial scans (20 mm) from the most proximal point of the greater tuberosity were performed and the bone mineral density was determined. The bone mineral density of porcine bones was assessed by a single investigator (J.K.). Twenty-four porcine humeri were divided into 4 groups so as to have no difference in body weight, age, or bone mineral density.

Pullout Tests of Suture Anchors

Two types of suture anchors were used in this study: metal screw-type anchor (TwinFix 5.0 Ti; Smith & Nephew, Andover, MA) and PEEK (polyether ether ketone) coil-type anchor (HEALICOIL PK 4.5; Smith & Nephew; Fig 1). The dimension of the metal anchor was 5.3 mm in diameter, 15.8 mm in length, and 1.3 mm in thread depth. The dimension of the PEEK coil-type anchor was 4.5 mm in diameter, 19.3 mm in length, and 0.7 mm in thread depth. According to the manufacture's data, the original sutures (no. 2 Ultrabraid) loaded in these anchors have 227 to 294 N tensile strength. Because these sutures broke before anchor pullout in our pilot study, the original sutures were replaced with braided polyethylene sutures (Avani Casting PE Max Power; Morris, Irima, Japan), which had greater tensile strength (498 N), to avoid suture breakage.

The distance of 2 anchors was defined as the center-to-center distance of 2 anchors (Fig 2). The distance was set at 4, 6, 8, and 10 mm. When the distance was 4 mm, the threads overlapped by 1.3 mm in the metal anchor and by 0.3 mm in PEEK anchor. The distances between the thread edges of 2 anchors were −1.3, 0.7, 2.7, and 4.7 mm, respectively, in the metal screw-type anchors and −0.3, 1.5, 3.5, and 5.5 mm, respectively, in PEEK coil-type anchors.

Anchor insertion was performed according to the manufacturer's instructions. Anchors were placed perpendicular to the surface of the polyurethane foam and the greater tuberosity of porcine bone. A pilot hole was created with an elite 2.5-mm awl for metal screw-type anchors and 3.8-mm tapered awl for PEEK coil-type anchors. After the anchors were in place, the polyurethane foam was mounted on the testing machine. The porcine humerus with two 2.5-mm-diameter steel wires inserted into the humeral shaft

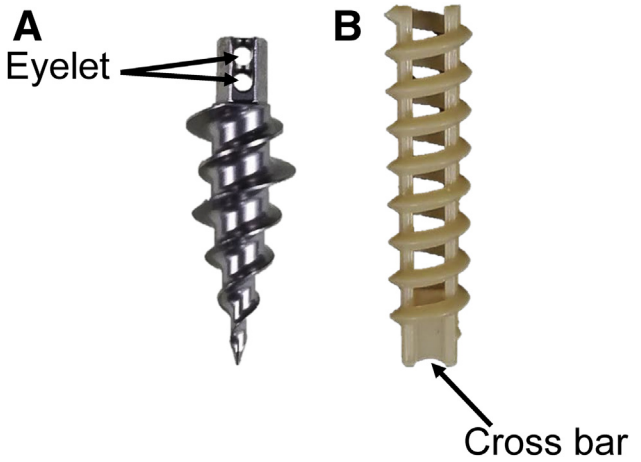

Fig 1. Suture anchors: (A) Metal screw-type anchor. (B) PEEK coil-type anchor. A metal screw-type anchor has a tapered tip portion with sutures through the proximal eyelet. A PEEK coil-type anchor has a fully threaded cylindrical shape, and its tip has a cross bar that sutures looped over. (PEEK, polyether ether ketone.)