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Rotator cuff repair with a tendon–fibrocartilage–bone composite bridging patch

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ABSTRACT

Background: To compare the mechanical performance of a rotator cuff repaired with a novel tendon–fibrocartilage–bone composite bridging patch vs the traditional Mason–Allen repair in an in vitro canine model.
Methods: Twenty shoulders and 10 bridging patches from patellar tendon were harvested. The patches were trimmed and sliced into 2 layers. An infraspinatus tendon tear was created in each shoulder. Modified Mason–Allen sutures were used to repair the infraspinatus tendon to the greater tuberosity, with or without the bridging patch (bridging patch group and controls, respectively). Shoulders were loaded to failure under displacement control at a rate of 0.5 mm/s.
Findings: The ultimate tensile load was significantly higher in the bridging patch group than control (mean [SD], 365.46 [36.45] vs 272.79 [48.88] N; $P < .001$). Stiffness at the greater tuberosity repair site and the patch–infraspinatus tendon repair site was significantly higher than the control repair site (93.96 [27.72] vs 42.62 [17.48] N/mm $P < .001$; 65.94 [24.51] vs 42.62 [17.48] N/mm $P = .02$, respectively).
Interpretation: The tendon–fibrocartilage–bone composite bridging patch achieved higher ultimate tensile load and stiffness at the patch–greater tuberosity repair site compared with traditional repair in a canine model. This composite tissue transforms the traditional tendon-to-bone healing interface (with dissimilar tissues) into a pair of bone-to-bone and tendon-to-tendon interfaces, which may improve healing quality and reduce retear rate.

1. Introduction

Surgical rotator cuff repair is the criterion standard to relieve pain and restore shoulder function after rotator cuff tears. However, up to 17% to 94% of patients are reported to have partial or full-thickness retears when evaluated postoperatively by ultrasound or magnetic resonance imaging (Galatz et al., 2004; Iannotti et al., 2013; Kim et al., 2013). Postoperative retears, especially large ones, greatly affect range of motion, decrease muscle strength, and cause pain (Lubiatowski et al., 2013; Park et al., 2013a). Various mechanical and biological approaches have been developed to prevent retears, including improved suture techniques, bone substitutes, periosteum autografts, growth factors, gene therapy, stem cell transplantation, and others (Boyer et al., 2002; Lim et al., 2004; Martinek et al., 2002; Tien et al., 2004). However, these efforts have not been completely successful because of the unsatisfactory regeneration of the natural tendon-to-bone transition zone.

The slow healing process at the tendon-to-bone interface and the chronic tendon and muscle degeneration associated with rotator cuff injury are believed to cause poor healing after repair (Carofino and Fulkerson, 2005; Deehan and Cawston, 2005; Park et al., 2013b). The natural gradual transition from tendon to uncalcified fibrocartilage to calcified fibrocartilage to bone tissue is difficult to regenerate because of differences in the 2 tissues (Benjamin and Ralphs, 1998). Chronic tendon and muscle degeneration may cause postoperative gap formation between tendon and bone tissues, which increases the risk of rotator cuff retear. Numerous attempts to rebuild the transition zone have been unsuccessful to date. However, anterior cruciate ligament (ACL) reconstruction uses a bone–patellar tendon–bone (BPTB) graft, which strengthens healing by using a bone-to-bone healing interface instead of the weaker tendon-to-bone interface (Hospodar and Miller, 2009). This concept potentially could be applied in rotator cuff repair by replacing the dissimilar-tissue (tendon-to-bone) healing interface with similar-tissue healing interfaces (tendon-to-tendon and bone-to-bone).

Abbreviations: ACL, anterior cruciate ligament; BPTB, bone–patellar tendon–bone; TFBC, tendon–fibrocartilage–bone composite.

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In the current study, we tested a novel approach that replaced the conventional tendon-to-bone repair interface with a pair of homogeneous healing interfaces (i.e., tendon-to-tendon and bone-to-bone interfaces) by using allograft augmentation sourced from a patellar tendon–fibrocartilage–bone composite (TFBC). The purpose of this study was to examine the mechanical performance of rotator cuffs and compare those repaired with the TFBC bridging patch technique vs the traditional repair method in an in vitro model. We hypothesized that rotator cuff repair with the TFBC patch would have better mechanical properties immediately after repair. If confirmed, these results would provide preliminary evidence supporting in vivo evaluation of tendon healing using this technique.

2. Methods

2.1. Rotator cuff repair

Twenty shoulders and 10 TFBC were harvested from 10 mixed-breed dogs that were euthanized for other studies approved by the Mayo Clinic Institutional Animal Care and Use Committee. All muscle attachments, except for the infraspinatus tendon and the infraspinatus muscle, were detached from the humerus for each shoulder. Ten composites of the patella and patellar tendon also were harvested. Each patellar tendon was trimmed to 10 × 15 mm, with its bony attachment segment intact. Because the tendon was soft and slippery, it could not be securely held to be cut while not compressing the tendon. Tissue freezing medium (Tissue-Tek; Sakura, Inc., Torrance, CA) was used to embed and to fix the tendon. The patellar tendons were then cut horizontally into 2 layers. Rotator cuff tears were consistently created according to a previously described model (Smith et al., 2012); briefly, the anterior and posterior extent of the infraspinatus tendon were identified and then the tendon was sharply detached in its entirety from the bone surface.

For rotator cuff repair, 10 specimens were randomly assigned to the TFBC group and 10 to the control group. A schematic of the repairs is shown in Fig. 1. In the TFBC group, the infraspinatus tendon was inserted between patella tendon layers. Modified Mason–Allen sutures of polyester braid and long-chain polyethylene (Fiberwire #2; Arthrex, Inc., Naples, FL) were used to repair the patellar tendon to the greater tuberosity. Two parallel loops were sewn through the full thickness of the sandwich-like tendon interface with 3–0 polyglactin sutures (Vicryl; Ethicon, Inc., Bridgewater, NJ). The bone fragment of the TFBC was fixed to the attachment point of the infraspinatus tendon using a metal wire threaded through 2 bone tunnels introduced into the humeral head. For the control group, the infraspinatus tendons were repaired with modified Mason–Allen sutures of Fiberwire #2 sutures through 2 bone tunnels.

2.2. Mechanical testing

After rotator cuff repair, the specimen was mounted on a servohydraulic test machine (858 MiniBionix II; MTS Systems Corp, Eden Prairie, MN) for mechanical evaluation. A custom-made clamp gripped the infraspinatus muscle. The humerus was potted into a small block of polymethyl methacrylate, mounted, and positioned at an incline of 135° to the long axis of the tendon to model the physiologic pull of the infraspinatus tendon. For TFBC specimens, markers were placed on the greater tuberosity, the bony part of the TFBC, and the infraspinatus tendon (Fig. 2). For control specimens, markers were placed on the greater tuberosity and the infraspinatus tendon (Fig. 3).

Each repaired rotator cuff specimen was loaded to failure under displacement control at a rate of 0.5 mm/s. Load and actuator displacement were recorded at a sample rate of 50 Hz. Ultimate tensile load was defined as the peak force observed during loading. Each specimen's failure mechanism (i.e., suture breakage, suture pullout through tendon, or bone tunnel breakage) was also recorded.

To assess local deformation for stiffness calculations, specimen loading was video recorded (frame rate, 29 frames/s) throughout the testing. Videos were processed with image-analysis software (Analyze 11.0; Mayo Clinic) to measure marker displacement and thereby determine displacement between the TFBC and greater tuberosity and between the TFBC and infraspinatus tendon. Stiffness was calculated from the slope of the linear region of the load–displacement curve.

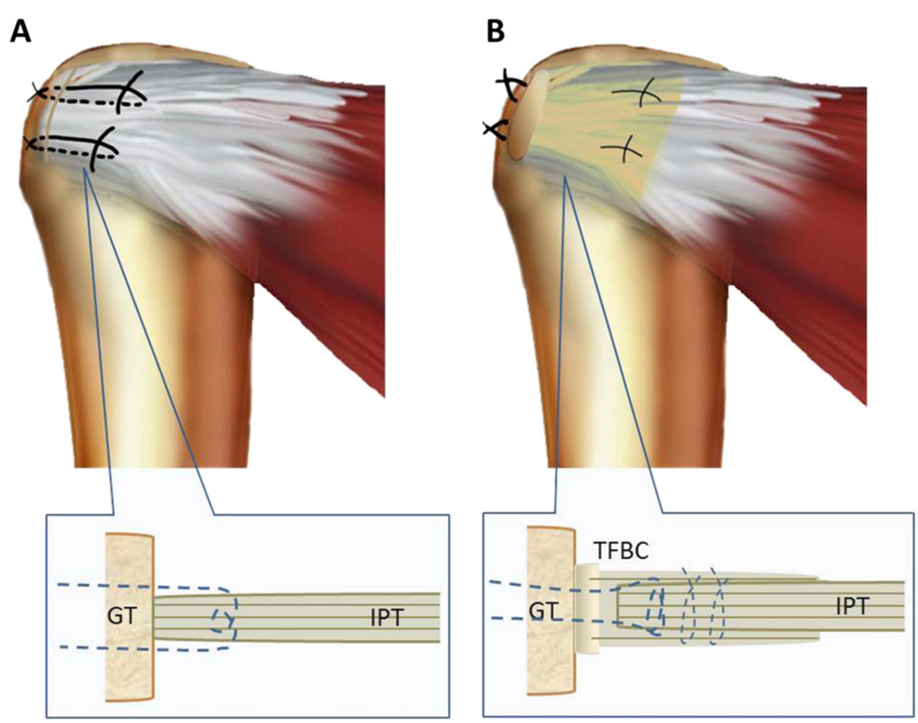

Fig. 1. A) Repair with the Mason–Allen technique (control). B) Repair with the TFBC patch. GT indicates greater tuberosity; IPT, infraspinatus tendon; TFBC, tendon–fibrocartilage–bone composite. (By permission of Mayo Foundation for Medical Education and Research. All rights reservEd.)