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Short communication

Investigation of a hybrid method of soft tissue graft fixation for anterior cruciate ligament reconstruction

Anthony G. Au[a], David D. Otto[b], V. James Raso[c,*], Alidad Amirfazli[a]

[a]*Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G8*
[b]*Department of Surgery, Walter C. Mackenzie Centre, Edmonton, Alberta, Canada T6G 2B7*
[c]*Capital Health Authority, 10230-111 Avenue, Glenrose Rehabilitation Hospital Site, Edmonton, Alberta, Canada T5G 0B7*

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Abstract

To increase knee stability following anterior cruciate ligament (ACL) reconstruction, development of increasingly stronger and stiffer fixation is required. This study assessed the initial pullout force, stiffness of fixation, and failure modes for a novel hybrid fixation method combining periosteal and direct fixation using porcine femoral bone. A soft tissue graft was secured by combining both an interference screw and an EndoButton (Smith and Nephew Endoscopy, Andover, MA). The results were compared with the traditional direct fixation method using a titanium interference screw. Twenty porcine hindlimbs were divided into two groups. Specimens were loaded in line with the bone tunnel on a materials testing machine. Maximum pullout force of the hybrid fixation (588±37 N) was significantly greater than with an interference screw alone (516±37 N). The stiffness of the hybrid fixation (52.1±12.8 N/mm) was similar to that of screw fixation (56.5±10.2 N/mm). Graft pullout was predominant for screw fixation, whereas a combination of graft pullout and graft failure was seen for hybrid fixation. These results indicate that initial pullout force of soft tissue grafts can be increased by using the suggested novel hybrid fixation method.

Keywords: Anterior cruciate ligament; EndoButton; Soft tissue graft; Interference screw; Fixation

1. Introduction

The anterior cruciate ligament (ACL) is one of the most commonly damaged ligaments in the knee, resulting in more than 50,000 ACL reconstructions being performed annually in America [1]. Graft fixation is the weakest link in anterior cruciate ligament (ACL) reconstructions during the early postoperative period [2]. A current fixation technique involves securing soft tissue tendon grafts (e.g., hamstrings) directly to the osseous tunnels with interference screws. While the pullout strength of this construct is considered adequate to withstand expected rehabilitation loads [3], additional fixation strength may be gained by periosteal fixation with other types of fixation devices (such as EndoButtons, Smith and Nephew Endoscopy, Andover, MA), but an investigation into this is required.

Studies on the pullout forces and stiffness of soft tissue grafts using biodegradable interference screws [3–7], titanium interference screws [3,5,6], or EndoButtons [4,8] have shown that no fixation method can reproduce the ultimate failure strength or stiffness of the native cruciate ligament. Combining different methods can present an alternative to using different materials to increase fixation strength and stiffness. We hypothesized that combining these direct and periosteal methods of fixation would improve the pullout strength and stiffness for soft tissue grafts. Clinically, this combination might also be beneficial for patients with suspected lower bone mineral density,

* Corresponding author. Tel.: +1 780 471 2262x2390; fax: +1 780 471 7972.
E-mail address: jraso@cha.ab.ca (V.J. Raso).

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where back-up fixation to the interference screw may be necessary [2].

Laboratory techniques to measure graft fixation commonly use either maximum pullout force or repetitive cyclic loading. Cyclic loading simulates forces sustained by the ligament during postoperative mobilization such as walking and jogging [9]. Maximum pullout force, on the other hand, is designed to imitate a single overload injury mechanism [10], a worst-case scenario. Early and aggressive rehabilitation programs focus on athletes returning to competition within 3 months [2]. The pullout force of graft fixation examines loading above normal activity levels to ensure these aggressive rehabilitation protocols can be implemented safely [11]. This work employed a testing protocol using worst-case scenario loading to examine the maximum pullout force.

To meet the existing need for stronger and stiffer fixation methods to allow current rehabilitation practices, a novel fixation technique has been proposed. To investigate the merit of our hypothesis, an animal model was adopted. The objective of this study was to compare a novel hybrid fixation method (i.e., combining the titanium interference screw with the EndoButton) with the classical method of only using an interference screw to secure soft tissue grafts. The factors studied were the initial pullout force, stiffness of fixation, and failure modes.

2. Materials and methods

2.1. Materials

Porcine patellar tendon (soft tissue graft material) and distal porcine femurs were used. A round-headed titanium interference screw (7-mm-thread-diameter and 25-mm-length RCI, Smith and Nephew Donjoy, Carlsbad, CA) was used to secure the porcine patellar tendon against the bone tunnel. An EndoButton (Smith and Nephew Endoscopy) with two Number 5 Ethibond sutures (Ethicon, Somerville, NJ) secured the soft tissue graft to the femoral cortex.

2.2. Preparation of specimens

Fresh knees of sows aged 1.5 to 3 years and weighing 130 to 160 kg were frozen to −20 °C. The knees were thawed to room temperature 16 h prior to testing. The patella was separated from the knee with the patellar tendon still attached. The tendon was released from its insertion on the tibial tubercle and sized to a 70-mm length and a 14-mm width for a snug fit into a 7.5-mm-diameter template hole. The tendon was tubularized with two Number 5 Ethibond sutures using a baseball stitch. A guide tunnel was drilled parallel to the long axis of the bone offset approximately 1 cm from the intercondylar spine of the femur. It was then enlarged to an 8.5-mm diameter and a 40-mm length using a RCI femoral router. The placement of the tunnel was done for experimental convenience; it is not anticipated that the mechanical testing results would be any different if the tunnel was to be placed in its usual location within the intercondylar notch. The interference screw was inserted from the distal side of the tunnel, and the EndoButton (when required) was seated over the bone tunnel on the femoral cortex. The patellar tendon and the femur from the same knee were used in each fixation construct.

2.3. Study groups

Twenty knees were randomly assigned to two groups of 10. In Group 1, a RCI screw was inserted into the interface between the soft tissue graft and the bone tunnel. In Group 2, a RCI screw was used along with an EndoButton. Ethibond sutures at the distal end of the graft were tied to the EndoButton using several knots. Considering that porcine bone is relatively dense compared to older human cancellous bone, to eliminate artifacts like laceration of the soft tissue when placing the interference screw, it was elected to use a 7.5 mm graft in an 8.5 mm bone tunnel. This graft-tunnel complex is not routinely clinically used; however, the data acquired provides qualitative information about the two fixation groups.

2.4. Testing procedure

Specimens were mounted onto a tensile testing machine (MTS Model 410.31; Materials Test Systems, Minneapolis, MN) with the shaft of the femur was secured to the base of the machine using four threaded metal rods. A smooth rod was passed through a hole drilled in the patella to secure it under the cross arm. The specimens were preloaded with 10 N and a load rate of 3 mm/s. The load was applied parallel to the long axis of the bone tunnel until failure to represent a worst-case loading scenario. Failure mode was determined by visual inspection and recorded as graft sliding past screw, midsubstance graft failure, or suture tearing through graft. Ultimate tensile load and stiffness were determined from the load-elongation curves. Stiffness was determined by fitting a straight line using least squares method to the rising slope of the load-elongation curve. The peak of the load-elongation curve was considered to be the ultimate failure load. Computerized data collection was facilitated using a National Instruments DAQ 1200 card (National Instruments, Austin, TX).

2.5. Statistical analysis

After the data were confirmed to have a Gaussian distribution, it was ascertained the number of specimens