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Does the tibial remnant of the anterior cruciate ligament promote ligamentization?

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ABSTRACT

Background: The purpose of this study was to clarify the difference in ligamentization between the remnant-preserving (RP) and remnant-sacrificing (RS) techniques in anterior cruciate ligament (ACL) reconstruction using magnetic resonance imaging (MRI).
Methods: A retrospective comparative study was carried out on 98 patients undergoing ACL reconstruction using either an RP ($n = 56$) or RS ($n = 42$) technique. MRI was performed at one of four time points postoperatively, and the signal intensity of the ACL graft was analyzed using the signal to noise quotient (SNQ) ratio and inter-bundle high signal intensity, along with an analysis of the survival rate of remnant tissue.
Results: The mean SNQ ratio of grafted tendons in the RP group was significantly higher than that seen in the RS group in the proximal and middle regions two to four months after surgery ($P < 0.05$) and was significantly lower than that seen in the RS group in all regions at 12 – 18 months ($P < 0.05$). The inter-bundle high signal intensity was observed more frequently in the RP group (73.7%) at two to four months. Tibial remnants were observed on postoperative MRI regardless of when MRI was conducted.
Conclusion: The ACL graft of the RP group showed higher signal intensity in the early stage and lower signal intensity in the late stage compared to that of the RS group. The ligamentization of grafts in the RP group proceeded more quickly. Preserving the remnant in ACL reconstruction appears to have a positive effect on ligamentization.

1. Introduction

As arthroscopic techniques for anterior cruciate ligament (ACL) reconstruction have evolved, various techniques aimed at improving clinical results have been developed. The primary goal of ACL surgery is to restore the mechanical stability of the knee. Restoration of mechanical stability is one determinant of a successful surgery but it is not the sole factor. Functional ability and subjective satisfaction of patients are also desirable surgical outcomes, but they do not necessarily correlate with mechanical stability [1,2]. Injury of the ACL not only causes mechanical instability but also disrupts neuromuscular control of the injured knee because of loss or damage to mechanoreceptors of the ACL. Therefore, the success of an ACL reconstruction may also be measured by the recovery of proprioception [3,4], and the ACL should be treated as an organ that includes nerves and blood vessels rather than as a simple mechanical structure for stability.

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Remnant-preservation in an ACL reconstruction may potentially promote the restoration of proprioception and enhance revascularization and remodeling of the graft [5–9]. Therefore, attention has shifted lately to the preservation of the ACL remnant during reconstruction based on many theoretical advantages. Recently, controversy about the necessity of preserving the ACL remnant has grown. Several authors reported better clinical results in ACL reconstruction with preserved remnant tissues [10,11], while others reported no significant differences in clinical results [12–14]. However, there are some limitations in comparing remnant-preserving (RP) to remnant-sacrificing (RS) techniques using current clinical assessment and scoring systems. For instance, the objectivity of current proprioception testing methods is low. We therefore sought an alternative method (not based on scoring or a mechanical test) that would provide a more objective comparison of these ACL reconstruction methods.

Several recent reports described the use of magnetic resonance imaging (MRI) in postoperative evaluations of the reconstructed ACL [6,15–18]. After reconstruction, tendinous grafts change into ligament tissue through the process of early healing, remodeling, and maturation [19]. MRI is an indirect method of evaluating histologic changes of revascularization and cellularity. Weiler et al. [16] reported that the histological changes of the graft after ACL reconstruction were correlated with changes in the signal intensity of the MRI using conventional and gadolinium–diethylenetriaminepenta-acetic acid (Gd-DTPA)-enhanced scans. They used signal-to-noise ratio to quantify the signal intensity of the MRI, and suggested that quantification of MRI signals is useful for follow-up of the tendon graft remodeling process. Murakami et al. [20] suggested that an “interbundle high signal intensity” in MRI was an indirect indicator of blood vessels that had invaded the graft. Therefore, the authors were able to use MRI findings to assess the difference between the RP and RS techniques in an objective manner.

For our study, we assumed that the ACL remnant would enhance revascularization of the graft and lead to stimulating ligamentization. The purpose of this study was to quantify the difference in ligamentization between the RP and RS techniques of ACL reconstruction using MRI. In addition, we investigated changes in the remnant after RP ACL reconstruction.

2. Methods

2.1. Patients

Ninety-eight out of 155 patients who underwent ACL reconstruction using the quadruple-strand hamstring tendon autograft in our hospital during the period between 2011 and 2014 agreed to and provided informed consent for MRI analysis of their ACL grafts. All operations were performed by the same surgeon. A retrospective comparative study was carried out on the 98 patients undergoing ACL reconstruction using either an RP ($n = 56$) or RS ($n = 42$) technique by non-contrast-enhanced MRI after surgery. An RP technique was preferred except in the case of poor quality remnant tissue or a remnant less than 30% (10 mm) of the average length of the ACL. The RP group included 48 males and eight females, with a mean age of 30.1 years at the time of surgery. The RS group included 38 males and four females, with a mean age of 30.4 years at the time of surgery. The two groups did not differ significantly in gender or age.

An MRI scan was carried out at one of four time points postoperatively, decided randomly. In period 1, or one month after surgery, MRIs were conducted on 10 members in each of the RP and the RS groups. In period 2, or two to four months after surgery, 19 MRIs were carried out on the RP group and 11 MRIs on the RS group. In period 3, six to nine months after surgery, 15 MRIs were carried out on the RP group and 10 MRIs on the RS group. In period 4, 12 to 18 months after surgery, 12 MRIs were carried out on the RP group and 11 MRIs on the RS group.

2.2. Surgical technique

2.2.1. Graft harvest and preparation

Upon completion of the arthroscopic evaluation and treatment of possible associated lesions, fibers outside the synovium of the ACL stump were debrided minimally without damage to the remaining synovium. The semitendinosus and the gracilis tendons were harvested. The harvested grafts were prepared by folding them at their midsection and placing whipstitched sutures in each tendon end.

2.2.2. Tibial tunnel preparation

To make a tibial tunnel, a commercial tibial tunnel ACL guide was set at 45° to prepare a seven- to nine-millimeter tunnel determined by the size of quadrupled hamstring grafts. The intra-articular exit point of the guide pin was directed to the center of the anatomic tibial insertion site: two-fifths the medial–lateral width of the interspinous distance in the medial–lateral direction, and the midline between the posterior border of the anterior horn of the medial meniscus and the posterior border of the anterior horn of the lateral meniscus in the anterior–posterior direction. The pointed tip of the drill guide pin (45° Marking Hook, Arthrex Marksman arthroscopic ACL drill guide system) was placed and a 3.2-mm guidewire was passed into the base of the tibial insertion site. Reaming was done to the same size as the hamstring grafts using a cannulated reamer. The tunnel was drilled carefully under arthroscopic control in millimeter increments from five millimeters to at least the diameter of the graft. Perforation of the center of the tibial footprint was performed at low speed under visual control and ceased immediately after entering the joint to avoid any damage to the ACL stump and synovium.

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