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Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology 7 (2017) 1–9
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Review article

Anterior cruciate ligament remnant and its values for preservation

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Received 6 August 2016; revised 5 September 2016; accepted 8 September 2016

Abstract

Controversy surrounds the remnant-preserving anterior cruciate ligament surgery. Advantages of remnant preservation have been reported in regard to better healing and knee function, although no consensus has been reached. This review article discussed the value and meaning of anterior cruciate ligament remnant preservation in several sections such as effects on healing, remnant classification, biomechanical evaluation, relation to proprioception, animal studies, and clinical studies. We hope that this review will facilitate further discussion and investigation for better treatment of anterior cruciate ligament injuries. So far, the current reviews have not provided sufficient scientific evidence to support the value of preserving the remnant.
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Keywords: anterior cruciate ligament; healing; reconstruction; remnant; remnant preservation

Introduction

Ligament surgeons wish to achieve a better clinical outcome after anterior cruciate ligament (ACL) reconstruction. ACL reconstruction, a tendon graft surgery, is a gold standard treatment method for athletic patients who suffer from ACL insufficiency due to injury. Prolonged ACL insufficiency causes decreased athletic abilities, with repeated giving ways or fear of returning to original sports completely. In the long term, ACL injured knees develop arthritic changes combined with decreased meniscus function and articular cartilage injury. By contrast, athletic patients wish to return to sports as early as possible with higher performance, as possible after ACL reconstruction. Therefore, the healing process after ACL reconstruction should be accelerated as much as possible.

ACL surgeons have remaining unanswered questions regarding the ACL remnant and its handling. With ACL treatment history, proprioceptive function of the remnant was the focus in the earlier phase. A wide range of research has been conducted not only on surgical techniques for the remnant-preserving ACL reconstruction, but also on remnant cells for accelerating the healing process of the injured ACL.

How does one treat the ACL remnant? In this review article, in order to answer this question, we searched for articles in PubMed, with the keywords “anterior cruciate ligament” and “remnant,” from 2000 to June 2016. The search hit 157 titles. Forty-three articles were selected for replying to the question content. Another article before 2000 was added to reinforce the historical research direction. Secondary search for the comparative study between remnant-preserving and remnant-non-preserving surgeries found additional two articles. The authors attempted to answer each question accordingly. For the remaining questions, the authors included additional comments and questions for each issue.

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http://dx.doi.org/10.1016/j.asmart.2016.09.002
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ACL healing process after injury

Murray et al[1] investigated the histology of injured ACL remnant tissues from operated cases. It was believed that the ACL had poor healing potential once injured; however, it was later reported that the ACL remnant also has healing potential and accomplished a similar healing process as other soft tissues. However, the report pointed out the concern that a layer of synovial tissue over the injured surface may disturb repair of the ligament. Contractile α-smooth muscle actin, which differentiates into myofibroblasts, causes lack of healing of the ruptured ACL. They suspected that contractile α-smooth muscle actin differentiates into myofibroblasts and causes lack of healing of the ruptured ACL.[1] In another recent report regarding remnant healing, the ACL remnant that reattached to posterior cruciate ligament (PCL) was investigated focusing on α-smooth muscle actin and collagen Type 3. The results showed disorganized fibres with no definite direction and high collagen Type 3 expression.[2] Previous findings suggest that proper mechanical stimulation to the remnant will be necessary for maturation and for obtaining higher function of the remnant. It remains unknown if the functional recovery of the remnant contributes to better knee joint function.

It is not very surprising on a small scale that injured ACL tissue requires the same healing process as other soft tissues. The real problems of the injured and reconstructed ACLs are the mechanical strength and anatomical healing. In our clinical experience, it is very rare to apply primary repair to an injured ACL (Figure 1).

Classification and significance of ACL remnant

Crain et al[3] described and classified the ACL remnant into four types, and investigated the mechanical contribution of anterior–posterior laxity after removal of the remnant based on the type. They found that the remnant reattached to the notch wall had the highest contribution to the anterior–posterior translation evaluated by the KT-1000. Since publication, Crain et al's[3] classification of the ACL remnant has been used as a standard. Remnant morphology of the ACL bundles after injury was assessed with three-dimensional computed tomography. The study demonstrates that the morphological patterns of the ACL remnants on three-dimensional computed tomography were well matched with arthroscopic findings without probing.[4] Oblique coronal and oblique sagittal magnetic resonance images have been recommended to evaluate ACL remnant tissue. Orthogonal sagittal and oblique coronal images could reveal the morphology better than other images.[5]

The authors observe the femoral attachment of the ACL without any removal of the tissue behind the remnant using a 30° scope through the anteromedial portal. The ACL remnant after rupture remains as synovial and adipose scar tissues, which clearly indicates the original footprint, especially in the posterior part of the original ACL[6] (Figure 2). Scoring of femoral ACL attachment with 90° flexion position behind the remnant. The probing on the anterior surface of ACL scar was very important to evaluate the integrity of the front side of the attachment. Femoral attachment of the ruptured ACL was evaluated by five categories (each 0–2) with 10 points as full marks. Direct insertion integrity: two points were given when more than two-thirds of the ligamentous attachment remained, and zero point when less than one-third remained at each third. The direct insertion was evaluated in each one-third portion as proximal, middle and distal. Fibrous extension integrity: two points were given when the fan-like fibrous extension was observed in more than half of the articular surface, and zero point when the fibrous extension was not observed. Synovitis severity: two points were given when only yellow and thin synovial tissue covered the behind-remnant area, and zero point to the severe synovitis as a finger-like proliferation. One point was given between 0 and 2 in each category.[6] The score of the remaining attachment area showed a positive correlation with the preoperative instability and meniscus status (Figure 3).

Biomechanical evaluation of ACL remnant tissue

Nakamae et al[7] evaluated anterior–posterior knee laxity using a navigation system to compare pre- and postremoval of ACL remnant tissue. They found that ACL remnants contributed to anterior–posterior knee laxity evaluated at 30° knee flexion for up to 1 year after injury. Biomechanical function of ACL remnants was relatively preserved up to 1 year after initial injury. However, the ACL remnant did not contribute to preserving rotational stability. Crain et al's[3] classification was not useful in predicting ACL remnants' contribution to knee stability.[8] Nakase et al[9] also found that anterior laxity increased after Crain Type 3 remnant was removed using a navigation system during surgery. Nagai et al[10] tested anterolateral rotatory instability pre- and post-removal of the ACL remnant using their three-dimensional electromagnetic measurement system. They found that ACL remnants attached to the lateral wall of the intercondylar notch partially contributed to anterior–posterior stability, but did not contribute to preserving rotational knee stability.

From the previous studies, remnant tissue has contributed to anterior–posterior knee laxity in some cases, but not to rotational stability. Moreover, it is questionable whether such remnant tissue can be utilized to reinforce graft tissue mechanically during ACL reconstruction.

Significance of ACL remnant preservation and proprioception of the knee

It is well known that many mechanoreceptors are distributed in the ACL tissue and remnant tissue contributes to proprioceptive function of the knee.[11,12] Mechanoreceptors exist not only in the intact ACL, but also in injured and even in reconstructed ones. Georgoulis et al[13] reported the existence of mechanoreceptors in the ACL remnant 3 years after a rupture that attached to the PCL. Normal mechanoreceptors and proprioceptive fibres were positively stained with a monoclonal

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