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Tibial insertions of the anterior cruciate ligament and the anterior horn of the lateral meniscus: A histological and computed tomographic study

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ABSTRACT

Background: A positional relationship between the anterior cruciate ligament (ACL) and the anterior horn of the lateral meniscus (AHLM) has not previously been a topic of interest in the literature because the AHLM is already known to be obviously adjacent to the ACL and is assumed as a lateral border. The objective of this study was to investigate the positional anatomic relationship between the ACL and AHLM by histological evaluation of sequential slices and computed tomography (CT) of the tibial insertion sites.

Hypothesis/purpose: The ACL has a specific positional relationship with the AHLM and there is an identifiable distinct bony border between them. The position of the AHLM could be an important and useful landmark for accurate tibial tunnel positioning in anatomical ACL reconstruction.

Study design: Descriptive laboratory study.

Methods: Twelve ACL-intact knees from embalmed cadavers were used in this study. Six knees were sectioned into four slices for histologic examination in the coronal planes parallel to the AHLM alignment. Before sectioning, these knees were subjected to three-dimensional (3-D) volume-rendering CT. Each of the four slices demonstrated the insertion area of the ACL relative to the position of the AHLM. Each histologic slice was compared with the corresponding CT image. Only histological examination in the sagittal planes was performed in the other six knees.

Results: The ACL fibres were broadly attached at the region anterior to the AHLM. However, the ACL and AHLM shared a clear border identifiable on the coronal CT images and appeared as a prominence of the bony ridge on the 3-D CT images. No dense ACL fibres were attached to the region posterior to the AHLM. Based on the histological data, the geometry of the ACL tibial insertion was L-shaped along the AHLM.

Conclusion: The ACL and AHLM have a specific positional relationship not only in the mediolateral direction but also anteroposteriorly. The AHLM serves not only as a lateral border, but also as a useful reference in an anterioposterior direction for tunnel positioning in ACL reconstruction. Specifically, the ACL fibres were found to be broadly attached onto the bony surface in the region anterior to the AHLM and there was no firm attachment of the ACL in the region posterior to the AHLM on the tibial side, which is useful in avoiding posterior tunnel placement.

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1. Introduction

In anterior cruciate ligament (ACL) reconstruction, precise creation of a tunnel aperture within the anatomical insertion area of the ACL is one of the most important factors influencing clinical results [1,2]. The anatomy of the ACL has been extensively studied using cadaveric dissection and imaging techniques [3–20]. Recently, precise histological examination revealed the direct insertion area inside the ACL femoral attachment area [12,14,17]. It is located in the depression between the resident's ridge and the cartilage margin on the lateral femoral condyle. Iwahashi et al. delineated it on three-dimensional (3-D) volume-rendering computed tomography (CT) [14]. Resident's ridge can be arthroscopically identified and is useful for reproducible creation of the anatomical femoral tunnel during ACL reconstruction [21].

Various macroscopic, histological, radiological, and CT evaluations of the tibial insertion area have shown the bony or soft tissue landmark on the ACL medial border. The lateral border has not previously been a topic of interest in the literature because the anterior horn of the lateral meniscus (AHLM) is already known to be obviously adjacent to the ACL [3–10]. Macroscopically, Zantop et al. measured the quantitative distance between the centre of the ACL and the centre of the AHLM [10]. Purnell et al., using high-resolution volume-rendering CT, demonstrated that there was not a distinct bony lateral border of the ACL footprint because the fibres blended into the AHLM [6]. Tensho et al. performed a histological evaluation and reported that a small groove (termed the lateral groove) on the anterior surface of the lateral intercondylar tubercles was the lateral boundary of the ACL [9]. In 2015, Fujishiro et al. reported, by histological investigation and micro-CT, that the outer fibres of the AHLM adjoined the ACL and the inner fibres of the AHLM formed the attachment area of the ACL [5]. To correctly create the tibial tunnel and avoid damaging the AHLM during ACL reconstruction, their bony borders and anteroposterior relationship should be investigated to meticulously delineate their geometry. This can be accomplished by performing a histological assessment of sequential slices in conjunction with reconstructed CT imaging on the same knee specimens. Histological investigation has the possibility to provide new insight about the geometry of the ACL tibial insertion, which has been mainly investigated by macroscopic examination.

The purpose of the present study was to investigate the positional relationship between the ACL and AHLM insertion sites by performing histological and CT evaluation of the tibial insertion sites. It was hypothesized that dense fibres of the ACL and AHLM are clearly divided by an identifiable distinct bony border, and that the two types of fibres never merge. Anatomical insight into the specific positional relationship between the ACL and AHLM may be helpful during arthroscopic ACL reconstruction.

2. Materials and methods

2.1. Preparation

Twelve ACL-intact knees from 12 embalmed cadavers (two men and 10 women aged 78–95 years, with a mean age of 83 years) were included in this study. All cadavers were Asian. Knees with other ligament injuries or significant osteoarthritis, such as extensive exposure of subchondral bone, were excluded. Knees with macroscopic degenerative changes in the anterior part of the lateral meniscus, such as horizontal cleavage tears, and degenerative changes of the ACL were also excluded. The cadavers were fixed in eight percent formalin and preserved in 30% ethanol. All muscles around the knee joint, patella, and joint capsule were removed to allow thorough examination of the joint interior. The posterior cruciate ligament and ACL were cut at the femoral attachment to allow examination of the tibial ACL insertion. Synovial tissue was kept to preserve the in-situ orientation. The tibia was cut 10 cm from the joint surface, with an oscillating saw in the axial plane.

These 12 knees were randomly divided into two groups. Histological examination and CT assessed the anatomic and spatial relationship between the ACL and AHLM in the coronal plane in six knees (coronal group); the other six knees were only histologically evaluated in the sagittal plane (sagittal group).

2.2. CT scanning and image reconstruction

The CT scan acquisition parameters of the proximal tibia were 120 kV, 100 mA, and 0.5-mm slice thickness (Aquilion; Toshiba, Tokyo, Japan); they were viewed using an Aquarius iNtuition Viewer (Terarecon Inc., Foster City, CA). The 3-D images were reconstructed from the CT data using a 3-D volume-rendering technique.

2.3. Macroscopic and histological examination of tibial attachment of the ACL and AHLM

Six tibial blocks in the coronal group were decalcified in hydrochloric acid before cutting. Each of the six specimens was cut, with a scalpel after marking the cutting line, into four blocks of even thickness in the coronal plane parallel to the AHLM alignment (Figure 1a and b). Before cutting the block the photo of the tibial articular surface was used to measure the oblique angle of the coronal plane because of the unique course of the AHLM fibres between specimens. The angle (Figure 1a) between the cutting line and the posterior articular border tangent line was measured by using Image J software (National Institute of Health, USA). The average angle was $7.4 \pm 3.4°$(standard deviation). Each cutting block was embedded in paraffin for examination by light microscopy. The block sections were then sliced into five micrometre sections that were stained with haematoxylin and eosin, and carefully observed under a microscope (Nikon ECLIPSE 90i; Nikon, Melville, NY) to meticulously examine the insertion site of the ACL and AHLM. Two orthopaedic surgeons performed histological analysis. The length of each dense fibre

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