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Graft bending angle is correlated with femoral intraosseous graft signal intensity in anterior cruciate ligament reconstruction using the outside-in technique

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ABSTRACT

Background: The purposes of this study were as follows: 1) to determine the correlation between the bending angle of the anterior cruciate ligament (ACL) graft at the femoral tunnel and the magnetic resonance imaging (MRI) signal intensity of the ACL graft and 2) to analyze the difference in the MRI signal intensity of the reconstructed ACL graft in different areas of the graft after single-bundle hamstring autograft ACL (SB ACL) reconstruction using an outside-in (OI) technique with bone-sparing retro-reaming.
Methods: Thirty-eight patients who underwent SB ACL reconstruction with the hamstring tendon autograft using the OI technique were enrolled in this study. All patients were assessed using three-dimensional computed tomography (CT) to evaluate femoral tunnel factors, including tunnel placement, tunnel length, tunnel diameter, and femoral tunnel bending angle. At a mean of 6.3 ± 0.8 months after surgery, 3.0-T MRI was used to evaluate the graft signal intensity using signal/noise quotient for high-signal-intensity lesions.
Results: Among various femoral tunnel factors, only the femoral tunnel bending angle in the coronal plane was significantly ($p = 0.003$) correlated with the signal/noise quotient of the femoral intraosseous graft. The femoral intraosseous graft had significantly ($p = 0.009$) higher signal intensity than the other graft zone. Five cases (13.2%) showed high-signal-intensity zones around the femoral tunnel but not around the tibial tunnel.
Conclusion: After ACL reconstruction using the OI technique, the graft bending angle was found to be significantly correlated with the femoral intraosseous graft signal intensity, indicating that increased signal intensity by acute graft bending might be related to the maturation of the graft.
Level of evidence: This was a retrospective comparative study with Level III evidence.

1. Introduction

Recent advances in anterior cruciate ligament (ACL) reconstruction have focused on centering the graft within its anatomic insertions [1,2]. Previous studies have shown that a more anatomic placement will lead to more normal knee kinematics in both anterior-to-posterior translation and rotation [3–5]. Better, more anatomic placement of the femoral tunnel is possible with independent femoral drilling techniques from the tibial tunnel such as the transportal (TP) technique and outside-in (OI) technique [6,7]. Presently, advances have been made in bone-sparing OI retro-reaming techniques. The OI technique may require a more acute femoral tunnel angle than the transtibial (TT) or TP techniques, which could apply repetitive bending stress on the femoral aperture, thus damaging the graft and expanding the tunnel [8–11]. Some studies have compared the graft bending angle at the femoral tunnel aperture between TT and TP techniques and between OI and TP techniques using three-dimensional computed tomography (3D CT). As suggested, the femoral graft bending angles in the TP technique were more acute than those in the TT technique. The OI technique required a more acute femoral graft bending angle than the TP technique [12,13].

Magnetic resonance imaging (MRI) is a widely used clinical tool to qualitatively monitor the health of the ACL graft after surgical reconstruction [14]. MRI can provide information on tissue quality using different sequences to determine the water content, fiber alignment, and tissue density. Alternatively, signal intensity, an MRI parameter for the function of tissue type and water content, has been used to evaluate the integrity and maturation of the ACL graft after ACL reconstruction surgery [15–19]. The correlation between the reconstructed ligament signal intensity and structural properties has been reported [19]. Previous MRI studies have also reported the postoperative decrease in signal/noise quotient (SNQ) with time [19,20]. SNQ was found to be negatively correlated with structural properties in an ovine model [20].

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The purposes of this study were as follows: 1) to determine the correlation between the bending angle of the ACL graft at the femoral tunnel and the MRI signal intensity and 2) to analyze the difference in the MRI signal intensity of the reconstructed ACL graft in different areas after single-bundle (SB) ACL reconstruction using the OI technique with bone-sparing retro-reaming. The following hypotheses were proposed in this study: 1) the graft bending angle and MRI signal intensity are correlated and 2) the highest signal intensity would appear at the aperture of the femoral tunnel.

2. Material and methods

2.1. Demographics

Between September 2010 and July 2012, a total of 52 patients who underwent SB remnant-preserving ACL reconstruction with an ipsilateral hamstring autograft using the OI technique were recruited. All patients agreed to be evaluated using 3D CT. However, MRI scans were only available for 38 (73%) patients. Therefore, these 38 patients were included in the study. The inclusion criteria were as follows: (1) unilateral ACL injury with no other concomitant ligament injury of the involved knee; (2) primary SB ACL reconstruction; (3) 3D CT within one week after surgery; and (4) postoperative MRI scans between five and seven months after surgery. The protocol (KBC14070) of this retrospective case series was approved by the Institutional Review Board of Kangbuk Samsung Hospital.

2.2. MRI (graft factor)

The MRI examinations were performed on a 3.0-T unit. The knee was placed in a neutral position. The grafts displayed in the MRI images were evaluated at five to seven months postoperatively. The signal intensity of the ACL graft was measured using SNQ. The signal intensity was calculated at three zones of the intra-articular graft sites (tibial one-third, mid-substance, and femoral one-third), two intraosseous graft sites (tibial and femoral tunnel zone), and two other sites (posterior cruciate ligament and the background approximately one centimeter medial and two centimeters distal to the medial joint line) using a region of interest (ROI) with a 3.3-mm-diameter circle (Figure 1) [21]. The signal intensity of the tibial tunnel zone was calculated at the lesion proximal to the tibial screw, to prevent its misinterpretation. To quantify the normalized signal intensity of the ACL graft, the SNQ of each graft site was calculated using the following equation: SNQ = (signal of ACL graft − signal of quadriceps tendon) / signal of background) [22,23]. These intra-articular and intraosseous SNQ values for the ACL graft were measured on oblique coronal MRI images. In some cases, a high-signal-intensity lesion in the T2-weighted images between the graft and tunnel wall was reported [21]. Therefore, T2-weighted images were examined for the presence of high-signal-intensity lesions between the graft and the femoral and tibial tunnel apertures (Figure 2).

2.3. CT (femoral tunnel factor)

Three or four days after surgery, 3D CT images of the knee in the extended position were obtained. These 3D CT images can depict the bone tunnel apertures in three dimensions from all views. For 3D reconstruction CT imaging, 128-channel Brilliance iCT SP and 64-channel Brilliance scanners were used. These 3D CT images were reconstructed by scanning with 0.5-mm intervals to obtain sagittal-, coronal-, and transverse-plane views with two-millimeters intervals using Extended Brilliance Workspace.

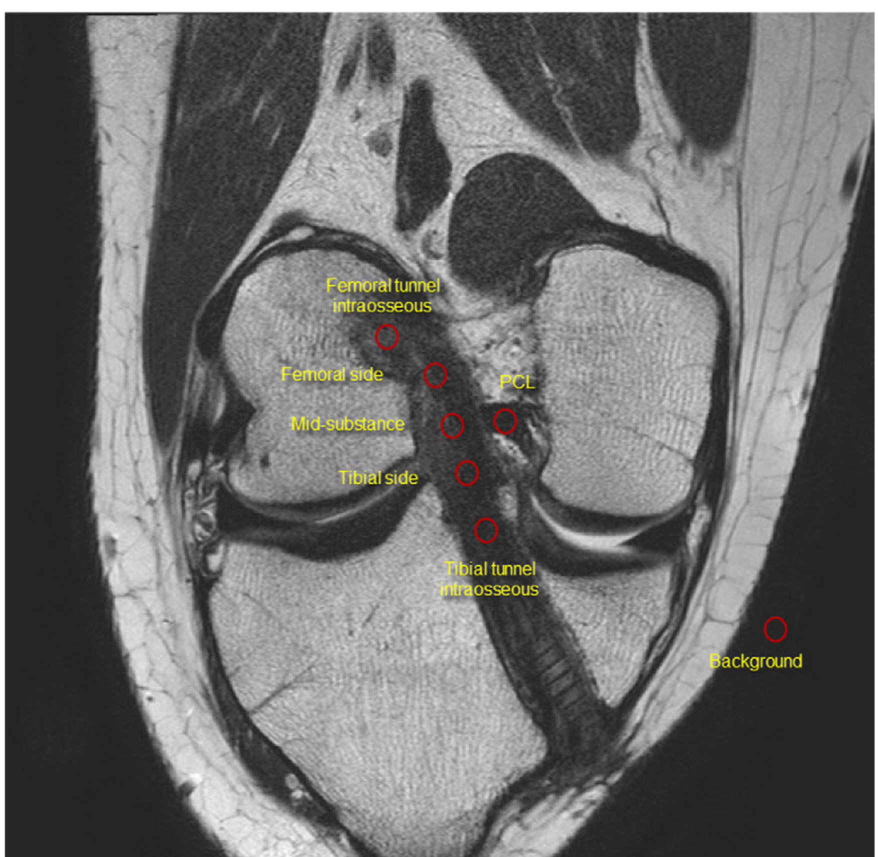

Figure 1. Positions of the regions of interest (ROIs) (diameter of the circle 3.3 mm) of the ACL graft, PCL, and background (one centimeter medial and two centimeters distal to the medial joint line) on the postoperative oblique coronal magnetic resonance image.