The effects of limb alignment on ACL graft tunnel positions estimated from plane radiographs

van Eck, C.F., Wong, A.K., Irrgang, J.J., Fu, F.H., +Tashman, S.
+University of Pittsburgh, Department of Orthopaedic Surgery, USA
tashman@pitt.edu

Introduction
Correct tunnel placement is important for a good clinical outcome after anterior cruciate ligament (ACL) reconstruction. 1-3 Various reference points and landmarks to aid in correct tunnel placement have been suggested. One of the radiographic landmarks most often used in femoral tunnel placement is Blumensaat’s line. Bernard and Hertel developed the quadrant method to evaluate the position of the femoral tunnel on plain radiographs relative to Blumensaat’s line. 4 This method is still frequently used in anatomical studies as well as in studies reporting the outcome of ACL reconstruction procedures.

In recent years, there has been a shift from two-dimensional (2D) to three-dimensional (3D) imaging of the knee, driven largely by the common use of magnetic resonance imaging. However, femoral ACL graft tunnel positions are still predominantly defined using 2D radiographic images, typically using Blumensaat’s line as a reference. 2D measurements of complex 3D structures such as the femur have inherent limitations. Blumensaat’s line is good example since it is not a true structure, but rather the projection of the roof of the femoral intercondylar notch on a lateral radiograph. Therefore, its apparent position can be affected by the rotation of the femur, notchplasty and notch anatomy (roof shape and angle between the roof of the notch and the femur). The purpose of this study was to evaluate the influence of rotation of the femur on 2D measurements of femoral ACL tunnel position based on Blumensaat’s line.

Methods
Knee CT scans were obtained from 5 subjects who had undergone anatomic double-bundle ACL reconstruction by one of the authors. 3 The femur was segmented and a 3D volumetric bone model was created. A custom computer program was used to recreate the geometry of a typical radiographic configuration, so that digitally reconstructed radiographs (DRR’s) could be generated by ray-traced projection through the bone model. This virtual imaging system was used to generate a series of DRR’s representing different rotations of the femur relative to the imaging plane, simulating the effects of misalignment of the leg in the x-ray system. The quadrant method was used to calculate the positions of the femoral ACL tunnel(s) relative to Blumensaat’s line. A grid was drawn onto the digital radiograph using Image J (Image J v1.41o, National Institutes of Health, USA). The grid was drawn parallel to Blumensaat’s line from the distal cortex to proximal cortex of the femoral condyles. The tunnel apertures were outlined and the center was calculated. Positions of the aperture centers were expressed as a percentage of the distances parallel (BL) and perpendicular (Deep) to Blumensaat’s line (Figure 1, a/BL and b/Deep, respectively).

Results
The intra-observer reliability was between .911 and .996 for the different measurements.

Discussion
Internal/external and varus/valgus rotations of the femur typically did not greatly influence ACL tunnel positions expressed as a percentage along and perpendicular to Blumensaat’s line. Statistically significant differences were found in the absolute tunnel positions, but not for the normalized positions. Thus, it is likely that in most cases rotations alter both the reference dimensions and the tunnel positions similarly, so that their ratios remain relatively constant. Although results for the group as a whole were not statistically significant, relatively large effects (up to 15% of Blumensaat’s line) were observed in some individuals. Because Blumensaat’s line is not a true anatomic structure (it is a 2D projection of a 3D structure), it could be influenced by rotation as well as individual anatomy. According to the current study, bone rotation has on average only a limited effect on tunnel positions assessed relative to Blumensaat’s line. However, it is plausible that in some patients the effect may be greater, due to anatomic variability of the bony structures and ACL insertion site. This uncertainty is eliminated with the use of 3D techniques (CT or MRI) that that take into account the individual anatomy of the patient.

References