

Utilizing Weight Bearing CT to Analyze ACL Tunnel Position

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INTRODUCTION: Accurate femoral and tibial tunnel placement during ACL reconstruction (ACLR) is critical for restoring normal knee biomechanics [1-3]. Prior research suggests that deviations from the anatomic ACL footprint can alter rotational stability and compromise long-term outcomes in graft integration [2-4]. The objectives of this study were to use weight bearing CT (WBCT) scans to quantify 3D femoral and tibial tunnel positions in ACLR patients and evaluate the reliability of the measurement methods.

METHODS: Tibia and femur bone models were segmented from 48 bilateral WBCT knee scans at 3-month follow up visits after patients received ACLR. The tibia and femur were aligned to a standardized anatomical coordinate system based upon previous methods that use clinically relevant frames and radiographic landmarks [1]. Cylinders representing the ACL tunnels were fit to both the tibia and femur tunnels in the standardized coordinate system (Figure 1). Vector and position data were derived from the long axis of the aligned cylinders. Tunnel angles with respect to anterior-posterior, medial-lateral, and superior-inferior axes were calculated for both femoral and tibial tunnels relative to the standardized reference system. These angles were used to assess 3D tunnel position. Reliability of the angular measures was assessed by repeated analysis of 10 randomly selected ACLR patients. Measurement reliability assessment used Intraclass Correlation Coefficients (ICCs) for both inter- and intra-observer reliability from two different observers [4,5].

RESULTS: Compared to prior 2012 findings, femoral and tibial tunnel positions measured from WBCT scans were substantially different in average angles from the reference axes. ACL tunnel position also varied substantially between cases (Figure 2). Across 10 randomly selected cases and six angle measures calculated for each case, intra-rater ICC values were 0.88 or higher, while inter-rater ICC values were 0.75 or higher except for the superior-inferior axis angle for the tibia. Mean differences from repeated analysis were $< 3^\circ$, independent of whether it was the same or different rater doing the second analysis.

DISCUSSION: ACL tunnel placement preferences have changed in the past decade, and substantial variation in tunnel placement still exists between individual cases [6]. Four different surgeons were included in this study, adding to the variability in ACL tunnel position. The use of WBCT and a standardized 3D reference frame offers a reliable method for measuring 3D ACL tunnel position. Future work will focus on analyzing more cases, adding analysis of tunnel aperture location, and further evaluating the repeatability and reliability of these methods.

SIGNIFICANCE/CLINICAL RELEVANCE: Accurate anatomic ACL tunnel placement is imperative to restore knee biomechanics. A standardized reference system and measurement approach enables routine evaluation of tunnel placement, which can improve tunnel position to promote better outcomes.

REFERENCES: [1] Ramme AJ, et al. *Biomed Eng Online*. (2012), 11:47. [2] Ramme AJ, et al. *J Knee Surg*. (2013), 26(1):29-39. [3] Wolf BR, et al. *Am J Sports Med*. (2013), 41(6):1265-73. [4] Warme BA, et al. *Comput Aided Surg*. (2012), 17(2):56-63. [5] Sullivan JP, et al. *Arthroscopy*. (2012), 28(8):1080-7. [6] McConkey MO, et al. *J Knee Surg*. (2012), 25(5):361-8.

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IMAGES AND TABLES:

Figure 1. Tibia and femur positioned in the standardized coordinate system with the cylinder fitted to the ACL tunnels.

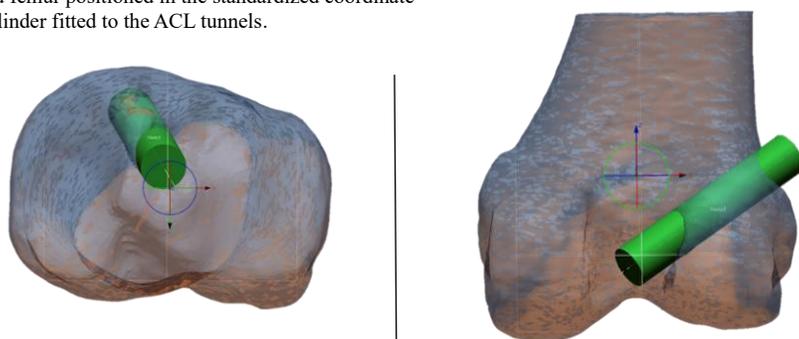


Figure 2. ACL tunnel orientation angles are shown here for the femur and tibia relative to the medial-lateral axis (α), anterior-posterior (β), and superior-inferior (γ) axis.

