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Relationships Between Femoral Tunnel Position and Dynamic Knee Function After ACL Reconstruction

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Summary:
More anterior and distal femoral tunnel positioning was associated with shortened ACL graft length and reduced internal-external rotation motion in the reconstructed knee during running after ACL reconstruction.

Abstract:
INTRODUCTION
Non-anatomic tunnel placement for anterior cruciate ligament (ACL) reconstruction contributes to abnormal knee kinematics, predisposing patients to osteoarthritis and poor clinical outcomes. However, the relationships between femoral tunnel position and knee kinematics during dynamic loading are not clear. By combining dynamic stereo x-ray (DSX) analysis with computed tomography, both tunnel position and dynamic knee motion can be accurately assessed. The purpose of this study was to evaluate relationships between the femoral tunnel position and knee kinematics during running after ACL reconstruction.

METHODS
Thirty patients underwent anatomic ACL reconstruction using quadriceps tendon with a bone block. Femoral tunnel aperture centers were measured by three-dimensional computed tomography (CT) with respect to the line parallel (t) and perpendicular (h) to the Blumensaat line. Tunnel placement was compared to the native ACL insertion, determined by mirroring the contralateral insertion site boundary from magnetic resonance images onto the affected knee CT bone model. Knee kinematics were evaluated during downhill running (downward slope: 10°, speed: 3 m/s) 6 months after surgery using 150 frames/s stereo-radiographic imaging. Tibiofemoral translations/ rotations and ACL graft length from initial contact to mid-stance (gait cycle: 0-15%) were calculated. Pearson's correlations were used to explore the relationships between tunnel position and kinematics during running. $p< 0.05$ were considered statistically significant.

RESULTS
The difference percentage between femoral tunnel position and native insertion site along (t) and (h) were 14.1 ±7.0% and 2.5±11.0%, respectively.

The t difference percentage was negatively correlated with absolute ACL length ($r=-0.53$, $p=0.003$), side-to-side difference of ACL length ($r=-0.70$, $p=0.00002$), internal-external rotation range ($r=-0.55$, $p=0.002$), and side-to-side difference of anterior-posterior translation range during running ($r=-0.38$, $p=0.04$).

The h difference percentage was negatively correlated with internal rotation ($r=-0.38$, $p=0.04$) and anterior tibial laxity (manual maximum force) of the affected side 2 years after surgery ($r=-0.42$, $p=0.02$).

DISCUSSION
The main findings of this study were that more anterior and distal femoral tunnel positioning was associated with

decreased ACL length and decreased internal-external rotation range during running. Moreover, this more anterior and distal location of the femoral tunnel was weakly related to decreased anterior-posterior range during running and increased static anterior laxity. Therefore, non-anatomical tunnel position contributes to abnormal kinematics, which has been suggested as a contributor to osteoarthritis after ACL injury/ reconstruction.

Static laxity measures were also related to tunnel position. Traditionally, tunnel positions are measured with plain film x-ray and clinical measures include static tests and subjective scoring. As ACL reconstruction techniques continue to improve, more precise methods than traditional plain-film x-ray combined with demanding functional tasks are required to assess relationships between femoral tunnel position and knee kinematics during dynamic loading.