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Biomechanical Comparison of Anatomic Single and Double Bundle ACL Reconstructions: An In Vitro Study

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Summary:
A biomechanical comparison of anatomic single and double bundle ACL reconstructions using a robotic system observed comparable anterior tibial translation for anterior loads and simulated pivot shift.

Abstract:
Background:
Precise arthroscopic identification of the anteromedial (AM) and posterolateral (PL) bundle locations of the anterior cruciate ligament (ACL) has facilitated an improved quantitative description of overall ACL anatomy, which anatomic ACL reconstructions must replicate when aiming to restore native ACL function. There is a lack of research that directly compares the biomechanical stability of anatomic single bundle (SB) versus anatomic double bundle (DB) ACL reconstruction techniques based on precise anatomic descriptions. We hypothesized that anatomic positioning of tunnels for both SB and DB reconstruction techniques would produce comparable anterior-posterior and rotatory knee stability results.

Methods:
Nine matched-pair cadaveric knees (18 knees total and average age of 46.7 ± 12.5 years; range: 16 - 58) were used to evaluate the kinematics of intact, ACL-deficient, and either anatomic single or anatomic double bundle ACL reconstructed knees. Reconstruction tunnels were placed either centrally between the native anteromedial and posterolateral footprints or within the footprints for the single and double bundle reconstructions. Using a 6 degree-of-freedom robotic system, knee stability was assessed with an applied 88 N anterior tibial load at 0°, 20°, 30°, 60°, and 90° of flexion and with a simulated pivot shift test of combined 10 Nm valgus and 5 Nm internal tibial torques at 0°, 15°, 20°, and 30° of flexion. Rotational motion was also measured with internal and external torques of 5 Nm applied at 0°, 20°, 30°, and 90° of knee flexion along with varus and valgus torques of 10 Nm at 0° and 20° of flexion. A Student's one sample t-test was used to compare the sectioned, SB, and DB groups to intact. Two sample independent t-tests were used for comparison among the sectioned and reconstruction groups. Differences were considered statistically significant when $P < 0.05$.

Results:
No significant differences were found between the anatomic SB and anatomic DB reconstruction groups during an applied anterior tibial load. Anterior tibial translations in response to a combined 10 Nm valgus and 5 Nm internal rotation torque (simulated pivot shift) had no significant differences when comparing the anatomic SB reconstruction and anatomic DB reconstruction groups to each other. Tibial rotation in response to 5 Nm internal/external torques and 10 Nm varus/valgus torques reported no significant differences between the anatomic SB and anatomic DB ACL reconstruction groups, with the exception of small (< 3°), but statistically significant differences in internal rotation for anatomic SB versus anatomic DB at 20° (2.1° vs. 0.2°, respectively, reported as difference from intact) and 30° (1.8° vs. -1.0°, respectively) of knee flexion.

Conclusions:
We confirmed our hypothesis that comparable anterior-posterior translations could be achieved using either an anatomic SB or anatomic DB reconstruction technique. No significant differences in anterior translation were found between the anatomic SB and anatomic DB ACL reconstruction groups after applying a simulated pivot shift and anterior tibial forces. While significant differences were observed in internal rotation between the reconstruction groups, the small magnitude of these differences (< 3°) between groups may not have clinical significance.

Clinical Relevance:
The present study found no significant differences in anterior translation between the anatomic SB and anatomic DB ACL reconstructions during simulated pivot shift and applied anterior tibial forces. Differences in rotational stability were statistically significant, yet minimal per clinical standards. Future studies should examine this significant time zero rotational difference to identify if there is a long term clinical impact.