Outcomes In Knee Joint Running Kinematics Following Non-Anatomic Anterior Cruciate Ligament Reconstruction: A Comparison Of Three Surgical Methods

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Introduction: Successful outcomes in anterior cruciate ligament (ACL) surgery are dependent on reconstructing the original anatomy as best as possible. This includes placing the grafts as close to the original anatomic ligament insertion sites as possible and maximizing the percentage of reconstructed insertion site area. Drill guides and alternative portal drilling approaches have been developed to maximize the likelihood of drilling the bone tunnels within the native insertion sites. Double bundle reconstruction is thought to restore the native anteromedial (AM) and posterolateral (PL) bundle function and increase the percentage of reconstructed area. Previous studies have assessed kinematic differences between limbs following anterior cruciate ligament reconstruction (ACL-R) during in vivo dynamic or quasi-static activities [1,2,3]. Recent research has explored the relationships between non-anatomical graft placement methods and gait and squatting knee kinematics [1,2]. The purpose of this study was to compare the effectiveness of three reconstruction methods in restoring knee joint kinematics during downhill running: double bundle (DB), single bundle with transtibial drilling of femoral tunnel (TT) and single bundle using an anteromedial portal for femoral tunnel drilling (AMP). It was hypothesized that AMP and DB reconstructions would better restore native insertion sites and normal kinematics compared to TT reconstructions.

Methods: Twenty-two patients (TT= 10, AMP= 5, DB= 7) underwent ACL reconstruction performed by four surgeons. Graft tunnel placement was compared to the native ACL footprint by comparison with the 3D ACL insertion of the contralateral limb, assessed using MRI. Kinematic testing was performed during downhill treadmill running at five months (Day 1) and twelve months (Day 2) after surgery. Knee joint kinematics were assessed using a previously validated dynamic stereo x-ray (DSX) system [3] in the time interval between foot-strike and 100 milliseconds thereafter. Patients’ contralateral, ACL-intact limbs were used as experimental controls. All variables are expressed as the difference between the reconstructed limb and contralateral limb. Repeated-measures analysis of variance was used to assess statistical differences in kinematics (α = 0.05) between testing days, with surgical methods as a between-subjects factor.

Results: Non-anatomic femoral tunnels were placed antero-proximally and tibial tunnels were placed posteriorly relative to native insertion site centers. Double bundle anteromedial tunnels were determined to be non-anatomic (anterior) while double bundle posterolateral tunnels were mostly in the native insertion site but in the anatomical AM location. TT tunnels had the highest anterior misplacement while AMP tunnels more proximal relative to the native ACL insertion. At both five and twelve months TT and DB limbs exhibited losses in extension (Figure 1), but differences between days were not significant (p=0.237). TT knees lost 6° of extension (Figure 1). Over the 100ms time intervals, Day 1 flexion differences varied with time, while Day 2 differences were nearly constant offsets. The interaction of surgical method and flexion differences were not significant (p=0.169). All ACL-R tibias shifted more anteriorly between days (p=0.004) (Figure 2). Surgical method did not have a significant interaction with anterior translation (p=0.478). Knees with TT reconstruction were more posteriorly translated at foot-strike. Range of anterior translation increased between days for both AMP and TT knees. At Day 1, TT and DB had similar tibial rotation to the control limbs until the later part of the time interval assessed (Figure 3), corresponding with increased joint loading. The maximum difference in external rotation for DB and TT was about 3° on Day 1. This decreased to 1.5° at Day 2. Initial external offset at foot-strike was increased for AMP knees by 8.1° at Day 1, and this offset was diminished at Day 2 (5.9°). The interaction between tibial rotation difference and surgical method was significant (p=0.03). Post-hoc tests revealed significant differences (p=0.02) at all time points in tibial rotation offset between the AMP and both the TT and the DB knees 5 months after surgery.

Discussion: The loss in extension that persisted between days for TT knees may be attributed to the more vertical placement of the graft using transtibial drilling, in some cases “blowing out” the notch and resulting in graft impingement. Non-anatomical placement of the AM tunnels may explain the similar, but diminished, pattern in the DB cases. Change in the varying flexion offset from the contralateral limb observed on Day 1 to a near-constant offset at Day 2 may be due to the resolution of muscle strength deficits or neuromuscular adaptations. The more anterior shifts of all ACL-R limbs between test dates indicate an increase in knee laxity possibly due to remodeling and elongation of the graft. The 2mm range in anterior translation difference exhibited by the SB knees (Figure 2) support previously published reports that proximal (vertical) grafts are less effective for controlling anterior translation [1]. While DB AM grafts were not anatomic, the addition of the PL bundle may improve control of anterior tibial translation.

This study found variation in knee behavior during a dynamic functional running task between non-anatomic ACL
reconstructions performed using three surgical methods. It is clear that none of these non-anatomic reconstruction methods succeeded in restoring the normal knee kinematics. These results suggest that anatomical placement of grafts may be more important than the methodology used to achieve reconstruction. However, anecdotal evidence suggests that DB reconstructions, even if partially non-anatomic, may perform better than SB reconstructions. This study is limited by the small and unequal group sizes and the non-anatomical placement of all grafts. To truly assess differences between surgical methods, future work is required to assess anatomical reconstruction kinematic outcomes during dynamic, functional in vivo tasks in conjunction with accurate quantification of the degree of non-anatomic placement error that is still acceptable for patient outcomes.

**Significance:** Variations in knee behavior were detected between non-anatomic ACL-reconstructed knees and their contralateral, healthy controls irregardless of surgical method. These data highlight the importance of anatomical graft placement over the methods used to achieve reconstruction.

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**References:**

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**Figure 1:** Differences in ACL-R limb flexion angle relative to contralateral, ACL intact limbs at 5 and 12 months after surgery.
Figure 2: Differences in ACL-R limb anterior tibial translation relative to contralateral, ACL intact limbs at 5 and 12 months after surgery.

Figure 3: Differences in ACL-R limb tibial rotation relative to contralateral, ACL intact limbs at 5 and 12 months after surgery were significant between surgical groups at all time points (p<0.05).

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