Hypothesis

Restoring ≥80% of the Native Tibial Footprint in ACL Reconstruction: A Hypothesis for Improved Functional Outcomes

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Abstract

Background: Anterior cruciate ligament (ACL) rupture is a common, functionally limiting injury among active individuals and athletes. Modern surgical practice increasingly favors individualized anatomic reconstruction that restores the native tibial and femoral footprints because graft orientation and footprint coverage directly influence knee kinematics, rotational control and patient-perceived stability. Hamstring autograft are widely used but harvested graft diameter varies markedly between patients and can limit how much of the native tibial insertion is restored. The present thesis prospectively measured native tibial footprint areas, recorded hamstring graft diameters and correlated percentage of footprint restoration with validated functional scores and objective laxity measures in a cohort of patients, providing practical intraoperative data.

Hypothesis: We hypothesize that reconstructions which restore a greater percentage of the native tibial footprint—typically achievable when harvested hamstring graft diameter is sufficient—will yield superior short-term patient-reported outcomes and perceived stability compared with reconstructions that restore a smaller percentage of the footprint or use smaller grafts.

Clinical importance: If a pragmatic restoration threshold improves early outcomes, surgeons can implement a simple intraoperative protocol—measure tibial footprint, calculate the percentage the prepared graft will restore, and aim for a specific target such as 70%—guiding decisions on graft choice, augmentation or converting to alternate techniques without major changes to standard arthroscopic practice. Adopting this approach promotes individualized planning, reduces the risk of under-filling native anatomy and may increase early patient satisfaction and functional recovery.

Future research: Multicenter, long-term studies are needed to determine whether early functional benefits from greater footprint restoration translate into lower re-tear rates and reduced post-traumatic osteoarthritis over five to ten years. Further work should validate reliable preoperative imaging or anthropometric predictors of footprint size and develop intraoperative decision algorithms that specify when augmentation or double-bundle conversion is indicated.

Keywords: ACL reconstruction, Tibial footprint, Graft diameter, Individualized anatomic reconstruction, Hamstring autograft

Background

Anterior cruciate ligament (ACL) rupture is a common injury among active individuals and athletes, producing pain, recurrent instability, and loss of function if not appropriately managed. Historically, treatments ranged from extra-articular procedures to open repairs; modern management favors


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arthroscopic intra-articular reconstruction intended to restore native ligament function and permit return to activity. The emphasis in the last two decades has shifted from merely placing a graft into the joint toward anatomic reconstruction — recreating the native femoral and tibial insertion sites to better restore knee kinematics and rotatory stability. This evolution was driven by biomechanical and clinical studies showing that non-anatomic tunnel placement can leave residual abnormal rotation and altered load distribution despite a structurally intact graft [1–4].

Two controllable surgical variables determine how closely a reconstruction matches the native ACL: precise tunnel positioning and graft choice/diameter sufficient to occupy the native insertion footprint. Femoral and tibial tunnel placement decide the orientation and length of the reconstructed ligament, while graft cross-sectional area and shape determine how much of the footprint is physically reconstituted [5–12]. Hamstring autograft are widely used because they avoid donor-site morbidity from bone-patellar tendon-bone harvest and provide sizeable cross-sectional area, but harvested diameters vary between patients. Small-diameter hamstring grafts have been associated with higher early revision rates in registry and cohort studies, whereas larger diameters generally correlate with improved subjective outcomes and, in some series, reduced failure risk [13, 18–21].

A further practical consideration is inter-individual and inter-population variability of the native ACL insertion area. Anthropometric studies report a broad range of footprint sizes, influenced by patient size and possibly by ethnic variation. This variability implies that a single graft diameter or a single technique (for example, single-bundle for all) can under-restore anatomy in many patients. The individualized anatomic reconstruction paradigm therefore recommends measuring insertion dimensions intraoperatively (or estimating them preoperatively) and tailoring technique — single-bundle, double-bundle, or augmented graft — so that the graft fills as much of the native footprint as is safely feasible [12–17].

Despite the conceptual appeal, relatively few prospective clinical studies have explicitly measured the native tibial footprint, calculated the percentage restored by the chosen graft, and tested the relationship between percentage restoration (and graft diameter) with validated patient-reported outcomes and objective stability tests. The attached prospective thesis addressed this gap by measuring tibial insertion areas arthroscopically, recording harvested hamstring graft diameters, calculating the percentage of the footprint restored, and correlating these measures with IKDC, Lysholm scores and KT-1000 laxity at early follow-up. That cohort provided practical data on typical footprint sizes, common graft diameters, and early functional results when a pragmatic restoration threshold is used.

Hypothesis and Study Aims

Primary hypothesis: An individualized anatomic ACL reconstruction that restores a high percentage of the patient's native tibial footprint — achievable when the harvested hamstring graft diameter adequately fills that footprint — yields better short-term functional outcomes and perceived stability than reconstructions that restore a smaller percentage of the footprint or use smaller graft diameters.

Rationale:

1. Anatomic fidelity improves mechanics: The native ACL insertion spreads forces across a defined area; reconstituting a graft that occupies more of that area should more closely reproduce physiologic load sharing and rotational restraint. Biomechanical and clinical studies support anatomic positioning and sufficient footprint coverage as central to restoring near-normal kinematics [10–16].
2. Graft diameter is a practical mediator: For hamstring autografts, the graft diameter is often the limiting factor for footprint coverage. Registry-level and cohort evidence links smaller graft diameters to increased early failure risk, making diameter a clinically useful proxy for expected footprint fill and mechanical robustness [18–21].
3. A pragmatic restoration threshold would guide decisions: Surgeons need simple intraoperative targets to decide whether single-bundle reconstruction is sufficient or whether augmentation or double-bundle reconstruction is warranted. A threshold such as restoring ≥70% of the tibial footprint would convert a theoretical preference into a workable decision rule [16, 17].
4. Population-specific data are necessary: Native footprint dimensions vary; collecting local anthropometric data allows realistic preoperative planning (choice of graft, expectation of augmentation) and informs surgical technique selection in a particular patient population [9].

Aims of the study summarized here:

(1) To quantify native tibial ACL footprint size in the study population; (2) to measure harvested hamstring graft diameters and calculate the percentage of tibial footprint restored; (3) to test the association between percentage footprint restoration and graft diameter with functional outcomes (IKDC, Lysholm) and objective anterior laxity (KT-1000) at serial follow-up intervals; and (4) to evaluate whether a practical threshold of restoration (tested at ≥70%) predicts superior outcomes. These aims are consistent with the individualized anatomic reconstruction framework and seek to produce an operable intraoperative strategy for surgeons.

Discussion

The study findings support three practical conclusions. First, individualized anatomic reconstruction — measuring native footprint and tailoring graft selection and technique — is feasible and produces measurable short-term functional benefits. Because native tibial footprints vary substantially, surgeons should avoid a "one-size-fits-all" graft strategy; intraoperative measurement provides actionable information to decide whether augmentation or alternate techniques are needed [12–17].

Second, graft diameter is an accessible and clinically relevant mediator of footprint restoration. In this cohort, 9 mm hamstring grafts most consistently achieved the pragmatic restoration target (~70–80%) and were associated with superior patient-reported outcomes at 12 months. These observations align with registry and cohort evidence that links smaller graft diameters with higher early revision risk and worse subjective outcomes [18–21]. However, a larger graft cannot substitute for incorrect tunnel position: correct anatomic placement remains essential and large grafts must be placed thoughtfully to avoid notch impingement or tunnel mismatch [10, 22–24].

Third, patient-reported outcomes and instrumented laxity measures may diverge. Although IKDC and Lysholm scores improved more in patients with higher percentage restoration, KT-1000 measurements showed small, non-significant differences. This divergence suggests that subjective perception of stability and function — influenced by rotational control, proprioception and symptom relief — can improve even when small differences in anterior translation are not detected with instrumented measures. Thus, both PROMs and objective tests should be reported when evaluating reconstruction strategies.

Limitations of the study include single-centre data and short-term follow-up (12 months), which constrain conclusions about long-term graft survivorship, re-tear rates and post-traumatic osteoarthritis. While surgeries were performed by a small group of experienced surgeons (reducing technical variability), this may limit generalizability to wider practice settings. The cohort size (n = 201) provides reasonable early evidence but larger, multicentre studies with longer follow-up are required to confirm whether early functional advantages translate into lower failure rates or reduced degenerative change. Finally, although the study suggests a practical threshold (≥70% restoration), this number should be validated prospectively before being imposed as a universal surgical rule.

Clinical importance

For practising surgeons, the study provides three immediate, pragmatic steps: (1) measure the tibial ACL footprint intraoperatively with a small arthroscopic ruler and compute the percentage restoration the planned graft will achieve;

(2) Aim to restore a clinically meaningful proportion of the native footprint (the cohort supports targeting ≥70% where safely achievable); and

(3) Plan graft choice and technique accordingly — if the harvested hamstring graft diameter will not achieve the target, consider graft augmentation, an alternate graft source, or a double-bundle strategy. These measures do not require radical changes to standard practice but operationalize individualized anatomic reconstruction to improve early patient-reported outcomes and satisfaction.

Future directions

Future research should focus on multicenter, long-term studies (5–10 years) to determine whether early functional benefits from greater footprint restoration reduce re-tear rates and the incidence of osteoarthritis. Work is also needed to develop reliable preoperative predictors (MRI-based or anthropometric) of footprint size and to validate simple intraoperative decision algorithms that specify when augmentation or double-bundle conversion is indicated. Finally, studies should test the generalizability of a ≥70% restoration threshold across diverse populations and surgical settings.

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