Editorial Commentary: For Single-Bundle Anterior Cruciate Ligament Reconstruction, Graft Fixation Should Be Performed at a Medium Tension in Full Extension: Multiple Bundle Reconstruction May Require a Different Strategy

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Abstract: Successful anterior cruciate ligament reconstruction requires a multifaceted approach to replicate normal knee anatomy and biomechanics. Graft tensioning force and the angle at which this tension is applied intraoperatively are factors under the surgeon's control. The literature suggests the best tensioning strategy for single bundle reconstructions is at medium tension in full extension, while tensioning multiple bundles is best done at 20° at lower overall tension. Graft tensioning should be individualized with attention paid to graft choice and fixation. Generally, stiffer grafts are thought to require additional force to create the same amount of lengthening. For example, bone-patellar tendon-bone grafts tend to be stiffer than quadrupled hamstring grafts and the native anterior cruciate ligament. Hamstring grafts also are thought to exhibit greater stress relaxation over time, thus elongating and potentially causing increased laxity over time. Pre-tensioning may eliminate some postoperative graft creep, typically more of an issue with hamstring grafts.

See related article on page 2232

Successful anterior cruciate ligament reconstruction (ACLR) requires a multifaceted approach to replicate normal knee anatomy and biomechanics. A host of factors must be considered: graft choice, tunnel placement, fixation strategies, concurrent pathologies, ligamentous hyperlaxity, sagittal and coronal plane alignment, tibial slope, as well as graft tensioning and the angle at which this tension is applied intraoperatively.

Substantial work has been performed to elucidate the "optimal" tension or force required for different grafts and the angle at which to place this tension. Despite this, few surgeons quantify their graft tension in the operating room by using a calibrated tensioning device, begging the question: should we? Would a more analytic approach substantially improve patient outcomes?

In their study, "Tibiofemoral Relationship 3 Weeks After Anatomic Triple-Bundle Anterior Cruciate Ligament Reconstruction With 10 N of Initial Tension Is Closer to the Normal Knee Compared to That With 20 N of Initial Tension,"[1] which examines tensioning strategies in anatomic triple-bundle hamstring autograft ACLR, Tachibana, Mae, Nakata, Matsuo, and Shino perform a well-designed study comparing 10 versus 20 N initial graft tension placed at 20° of knee flexion with femoral screw and tibial post and washer fixation. Computed tomography (CT) scans of the contralateral "normal" knee were used as a reference to compare tibiofemoral relationship of the operative knee at 3 weeks and 6 months postoperatively, showing slight initial overconstraint in both groups in anterior translation and external rotation with side-to-side differences approaching zero independent of graft tension at 6 months. There were no differences between groups in clinical outcomes measured by Tegner activity scores or in side-to-side laxity measurements with KT-1000 at 2 years. Their conclusions were that a lower initial graft tension may be appropriate and would potentially expose the knee joint to lower intra-articular stresses and also prevent theoretical problems with graft healing.

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However, it did not appear that the 20 N group was “overconstrained” as the two groups were indistinguishable at 6-month CT tibiofemoral relationship and at 2-year clinical follow-up.

Extensive literature has been written on how to best tension grafts over the past 20+ years. Overtensioning is concerning both from a microstructural graft standpoint[2,3] and from a macro joint standpoint due to placing added chondral stress, particularly in the lateral compartment.[4] In addition, overconstraint can lead to loss of extension and arthrofibrosis. On the other hand, underconstraint could predispose to increased anterior and rotatory laxity, persistent instability, and failure. It is thought that ligament repair or reconstruction requires some degree of tension to achieve new fibroblast collagen orientation and strength.[5] Ideally, surgeons would restore “normal” constraint and keep this constraint fairly constant throughout rehabilitation to avoid graft elongation or failure.

Graft tensioning should be individualized with attention paid to graft choice and fixation.[6] Generally, stiffer grafts are thought to require additional force to create the same amount of lengthening. For example, bone-patellar tendon-bone (BPTB) grafts tend to be stiffer than quadrupled hamstring (HS) grafts and the native anterior cruciate ligament (ACL). HS grafts also are thought to exhibit greater stress relaxation over time, thus elongating and potentially causing increased laxity over time. Pretensioning may eliminate some postoperative graft creep, typically more of an issue with HS grafts. Fixation choice also may affect graft tension over time. For example, Aune et al. compare interference screw fixation in HS and BPTB grafts and find decreased graft stiffness and load to failure in the HS group.[7]

According to a recent survey by the ACL Study Group, the vast majority of ACLRs worldwide are single-bundle reconstructions.[8] Some studies have suggested that single-bundle reconstructions may be more prone to overtensioning, resulting in an overconstrained joint, thus potentially limiting terminal knee extension when performed 20-30° flexion compared to full extension.[9-11] van Kampen et al. randomized patients with preconditioned BPTB autografts at either 40 or 80 N of tension at 20° of flexion and there was no difference in anterior laxity between groups at 26 and 52 weeks postoperatively, pointing toward a lower tension being adequate.[12] Yasuda et al. compared 20, 40, and 80 N of initial tension in a single-bundle HS ACLR and found increased anterior laxity in patients in the low-tension versus high-tension group.[13] Nicholas et al. performed a Level I randomized controlled trial of patients with single-bundle BPTB autograft set at 45 or 90 N tension in full extension and noted better restoration of native knee tension in the high-tension group but ultimately no difference in clinical outcomes or extensor lag between groups.[14] More recently, Chalal et al. compared single-bundle ACLR with BPTB autograft with an anteromedial portal drilling technique fixed either at 0 or 30° of flexion. Patients had no differences in KOOS metrics at 2 years, but the group fixed in full extension had a higher proportion of patients achieve KOOS MCID and had greater Marx activity scores.[15] Multiple Level II systematic reviews either point toward tension not affecting clinical outcomes[16] or toward a medium tension of 80-90 N of tension more successfully reducing side-to-side anterior laxity differences.[17,18] Surgeons should be aware that some standard clinical measurements of anterior instability (KT-1000, Lachman testing) may not correlate with overall patient satisfaction; persistent rotatory laxity via pivot shift may be a better test.[19] The takeaways from these single-bundle studies is that a “medium tension” in full extension is the best current technique that will lead to more similar side-to-side constraint and fewer complications with loss of extension. However, there is clearly more work to be done in this area.

The literature suggests that tensioning double-bundle grafts is different than that for single-bundle grafts. This study by Tachibana et al. uses a method akin to double-bundle reconstruction with an added tibial fixation point. Mae et al. performed a case series comparing double-bundle HS ACLR showing that grafts placed with both bundles tensioned to 20 N at 20° resulted in minimal side-to-side differences in KT-1000 testing at 2-year follow-up.[20] Murray et al. performed a cadaver study comparing double-bundle HS tensioned with both bundles tensioned at 20° versus the posterolateral bundle tensioned at 15° and the anteromedial bundle tensioned at 45°. Tensioning bundles together at 20° produced reciprocal bundle tension that better approximated normal knee kinematics.[21] A similar study performed by Cuomo et al. supported this result, showing best results with 17 N tension per bundle at 20° of flexion, creating a load-sharing construct that minimizes stress shielding of either bundle.[22] Koga et al. compared double-bundle HS with 20, 25, and 30° of initial graft tension and showed a nonsignificant trend of residual pivot shift in the lowest tension group.[23]

So, what are the takeaways? We certainly have some more work to figure out the best tensioning strategies, although we can be certain that single- and multiple-bundle tensioning is very different, both in terms of total tension placed on the grafts, as well as degree at which we tension. In this study, Tachibana et al. show that low initial tensions of 10 N in a triple-bundle construct result in symmetric assessments of joint constraint by 6-month CT evaluation and by 2-year clinical outcomes. However, there is no apparent detrimental effect of tensioning at 20 N other than the theoretical risks we have discussed. In addition, although the authors note a significant difference in joint constraint at 3 weeks by CT scan, this may be due to a slower rehabilitation protocol during which patients were braced for 2 weeks and full extension was not allowed for 3 weeks.

Given that most ACLRs are performed using a single-bundle technique, likely medium tension placed at full extension does best from the available evidence. There is clearly a dearth of good literature comparing single-bundle tensioning strategies, especially with regard to clinical outcomes in the medium to long term. Several Level I studies from Brown University have used a tension-based (rather than force-based) model, comparing a restoration of normal constraint to slight overconstraint measured intraoperatively, with follow up at 36 and 84 months showing no significant differences between groups.[24,25] However, they included both BPTB and HS grafts with different fixation methods, which increases generalizability but may be best studied separately. We also should consider questions of static versus dynamic constraint. While CT scans may be helpful to obtain very accurate knee "constraint" or "station" measurements, this may be less useful for assessing anteroposterior and rotatory dynamics. Several proprietary devices exist on the market to better assess intraoperative and postoperative dynamic instability but would need to be validated in clinical studies. We need more good-quality literature on these topics to continue pushing the envelope with the goal of achieving better outcomes for our ACLR patients. There are many variables that are under our control in the operating room—for example, graft choice, methods of fixation, and graft tensioning—and we must continue to refresh and refine these paradigms.

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