Editorial Commentary: The Suture-Augmented Anterior Cruciate Ligament Reconstruction Requires Independent Tensioning to Achieve Load Sharing

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Abstract: Countless variations of anterior cruciate ligament repair or reconstruction plus augmentation have existed for decades, but augmentation was associated with complications such as reactive synovitis, instability, loosening, and rupture. Recently, augmentation with ultra-high molecular weight polyethylene suture or suture tape, however, has not been shown to be associated with these complications. The goal when performing suture augmentation is to provide independent tensioning of the suture augment and graft to allow the suture or suture tape to function as a load-sharing device, allowing the graft to see more strain during earlier levels of graft strain until graft elongation occurs to a critical level, whereby the augment will experience more strain and protect the graft. Although long-term outcome studies are pending, animal and human clinical studies do show that ultra-high molecular weight polyethylene, when used as a suture augment for anterior cruciate ligament surgery, is unlikely to cause a significant intra-articular reaction while also providing biomechanical advantages that could prevent early graft rupture during the revascularization phase of healing.

See related article on page 1014

The first synthetic anterior cruciate ligament (ACL) reconstructions were reported in 1914[1] and 1918,[2] using a silver filament and silk ligament, respectively. These were abandoned as failures, but many years later the U.S. Food and Drug Administration approved the Gore-Tex cruciate ligament prosthesis in 1986, which was followed by the 3M Kennedy Ligament Augmentation Device in 1987 and the Stryker Dacron ligament prosthesis in 1988.[3] Other products used in Europe and Asia were the Leeds-Keio ligament and the Ligament Augmentation Reinforcement System. Due to a high incidence of complications, including reactive synovitis, instability, loosening, and rupture, these were abandoned or used much less frequently with time around the world.[4-7] These artificial ligaments were used primarily to replace or reconstruct the ACL and less frequently to augment a repair or reconstruction. Although a typical ACL reconstruction graft must go through ligamentization, the process by which the graft is replaced by an "anterior cruciate ligament-like" structure, a synthetic graft does not. Scientists, surgeons, and patients alike were excited about the possibility of this shaving off significant time from the rehabilitation process, but alas it didn't pan out as expected, with all of the aforementioned complications and failures. Enter back to the future: suture augmentation.

Catastrophic failures cropped up in the 1980s, around the same time that Marty McFly was dominating the silver screen. Great Scott! Can Doc once again say, "I finally invented something that works!" or are we just reinventing the wheel? Get ready, grab your flux capacitor, hop in the DeLorean, and don't forget your seat belt!

My goal when performing suture augmentation is to provide independent tensioning of the suture augment and graft or native ligament/tendon to allow to allow the suture or suture tape to function as a load-sharing device, allowing the graft to see more strain during earlier levels of graft strain until graft elongation occurs to a critical level, whereby the augment will experience more strain than the graft. This is not possible when independent tensioning is not performed, as in static

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augmentation, which increases stiffness but also makes stress shielding possible. In "Suture Augmentation Does Not Change Biomechanical Properties and Histological Remodeling of Tendon Graft in Anterior Cruciate Ligament Reconstruction: A Study in a Porcine Model" by Iwaasa, Takahashi, Tensho, Koyama, Takeshita, and Takahashi,[8] the authors used independent tensioning of ultra-high molecular weight polyethylene (UHMWPE) suture to function as the suture augment in a porcine model. Although there are many studies examining the early biomechanical and histological results of artificial ligament reconstruction or augmentation in ACL surgery, there is a surprising paucity of data for this for the now-popularized UHMWPE suture augmentation (e.g., InternalBrace; Arthrex, Naples, FL). The authors should therefore be congratulated on conducting a novel study on a surgical technique that gains more and more attention.

Iwaasa et al.[8] compared 10 juvenile pigs that were divided evenly into suture augmented (SA) and non-SA ACL reconstruction groups using autologous porcine semitendinosus grafts with suspensory cortical fixation on the femoral side (ENDOBUTTON CL; Smith & Nephew Endoscopy, Andover, MA) and with the Double Spike Plate (Smith & Nephew Endoscopy) on the tibial side and independently tensioned suture augmentation using a No. 5 FiberWire suture (Arthrex, Naples, FL) for the SA group. At 12 weeks' postoperatively, the tibial fixation was removed and anterior knee laxity and structural characteristics of the graft were examined biomechanically. In addition, histologic evaluation was completed using the ligament tissue maturation index and foreign body reaction was assessed. The authors found no significant difference between groups for laxity, maximum load, yield strength, stiffness, elongation at failure, or maturation of ligament tissue, and there were no foreign body reactions. I believe these results are encouraging, albeit with some weaknesses that deserve mention.

First, the authors used suture rather than suture tape, which is used more frequently in suture augmentation. Second, porcine knees cannot exactly simulate biomechanical conditions that a human cadaveric model would allow, and an animal model obviously is not directly applicable to what human tissues may exhibit histologically. Third, the authors used the Double Spike Plate implant for tibial fixation, which is less commonly used in the United States compared with other implants, such as suspensory cortical buttons or interference screws. Therefore, the study may not be broadly generalizable to what we can expect to see in vivo for our human patients, but it is a great step in the right direction toward understanding what we can expect from current-generation suture augmentation as compared with its predecessors, which were plagued with complications such as synovitis and foreign body reaction, while also addressing if the added "seat belt" leads to impaired healing and ligamentization.[9] Another inherent problem with this biomechanical study is that the examination of many of the study outcomes was likely underpowered, given that there were only 5 knees in each group as a result of their a priori power analysis being based on anterior translation of the tibia. Differences that likely escaped statistical significance as a result of this were the mean maximum load, upper yield load, and linear stiffness, all favoring the SA group over the non-SA group. However, the primary purpose of this study was to determine whether SA was noninferior to standard reconstruction techniques, which the authors accomplished while also showing that tendon remodeling of the SA group showed similar characteristics to the non-SA group without signs of stress shielding and without foreign body reactions. These data were the most important to me, because while admittedly I did not train or operate in the age of the Gore-Tex, 3M Kennedy Ligament Augmentation Device, or Stryker Dacron grafts, I have always feared similar synovitis and effusion reactions as those described to me by my wise mentors, who lament the artificial ligament craze of the 1980s and 1990s.

I will not attempt to water down my enthusiasm for suture augmentation in ACL reconstruction. I previously published a comparative clinical study of suture tape augmented versus nonaugmented hamstring ACL reconstructions with 30 patients in each group, matching them by age, sex, body mass index, graft type (autograft vs allograft), and revision status and found that at a mean 30-month follow-up that the augmented reconstructions had improved patient-reported outcomes and time to return to preinjury activity level and percentage of preinjury activity level without a difference in graft failures or revision rates.[10] Parkes et al.[11] later performed a 1:2 matched-cohort comparison between augmented and nonaugmented hamstring autograft ACL reconstructions and found similar return to sports rates, International Knee Documentation Committee, and Lysholm scores but greater Tegner activity scores and a lower proportion of graft failures in the augmented group . In a comparative study of 80 adolescent athletes undergoing ACL reconstruction with and without suture tape augmentation, Kitchen et al.[12] found greater Tegner scores and lower graft rupture rates (5% vs 17.5%) in patients undergoing augmented procedures, although the difference in rupture rate was not statistically significant.

So, it appears with the available body of evidence that UHMWPE, when used as a suture augment for ACL surgery, is unlikely to cause a significant intra-articular reaction, while also providing biomechanical advantages that could theoretically prevent early graft rupture during the weaker revascularization phase of healing. These findings, paired with the emerging clinical data

supporting suture augmentation for ACL reconstruction, are overall positive developments for a surgery and rehabilitation process that is far from perfect. Potentially, this study will allow some naysayers who were scarred from the first iteration of ACL augments and synthetic reconstructions to consider adding suture augmentation to their toolkit. Likely, this issue will not rest until mid- and long-term complication and outcome data are available to definitively say that synovitis and foreign body reactions are rare with the use of UHMWPE.

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