Primary Repair of the Anterior Cruciate Ligament: A Review of the Literature

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Abstract
Anterior Cruciate Ligament (ACL) repair was first performed over a century ago, but reconstruction has overwhelmingly been the surgery of choice for operative ACL ruptures since the 1970s. However, high rates of osteoarthritis and low return to play rates following conventional ACL reconstruction have prompted clinicians to re-examine the utility of ACL repair with emphasis on biologic therapy, operative techniques and patient selection. The purpose of this review is to provide an in-depth summary of the most recent advances pertaining to primary ACL repair. A thorough literature search on studies published up to May of 2016 using Pubmed, Ovid Medline and Cochrane Review databases was performed. Full text articles were reviewed and information pertaining to our institution’s experience was included. There are promising results with good short-term outcomes for primary repair with or without biologic augmentation and newer operative techniques performed on carefully selected patients. However, long-term follow-up is lacking, and therefore these studies cannot conclusively impact clinical practice. Long-term follow-up and further studies are needed to further elucidate the role of primary ACL repair.

Keywords: Anterior Cruciate Ligament; Healing; Autograft; Midsubstance Tears

Introduction and Background
The anterior cruciate ligament (ACL) is one of the most studied ligaments in the body. The research concerning its inherent healing and surgical repair dates back to the late 19th century. Primary ACL repair fell out of favor after unacceptable therapeutic results were produced in the 1970s by multiple groups [1-5].

Mayo-Robson [6], performed the first successful ACL repair on a coal miner in 1895. In his 1903 publication, he described a simple suturing of the patients torn ACL and posterior cruciate ligament (PCL), achieving a favorable outcome in which the patient returned to work with a stable knee. In the 1950s, O’Donoghue et al [7-10], published the first series of papers that documented the operative technique used. Citing the need for early surgical repair and echoing Ivan Palmer’s work in the 1930s [11], O’Donoghue investigated the outcomes of ACLs repaired with wire or silk sutures, and early repair was critical to restoring stabilization, but reconstructive techniques were superior than the repairs tested in the study.

Feagin and his co-researchers produced the first study of long-term results of ACL repair in the 1970s [1-5]. Their participants were cadets at West Point, with ACL tears confirmed via Lachman’s test and a preoperative questionnaire about symptomatology. Early follow up appeared promising, with 25 out of 30 patients reporting satisfactory results of stable knees. Yet at five years, only five of the original 64 patients reported resolution of symptoms, instability was reported in 91% of patients, 17 patients were reinjured and 15 required reoperation. Although reports from Scandinavia showed success rates as high as 75% at six years out [12,13], other American teams produced results that corroborated Feagin’s outcomes [14]. Reconstruction became the surgery of choice for the ACL after Franke pioneered bone-patellar tendon-bone graft in 1969 [15].

ACL reconstruction is proven to be efficacious and safe. ACL reconstruction can be performed utilizing synthetic, allograft, or autograft bone-patellar tendon-bone (BPTB), four-strand hamstring, quadriceps, tibialis posterior, or Achilles tendon. Autografts are associated with a lower aseptic revision rate, faster incorporation, lower cost, and decreased immunologic reaction as compared to allografts [16]. BPTB and hamstring tendons are the most commonly used grafts. BPTB grafts are the “gold standard” of reconstruction as they impart good graft stability due to bone to bone healing, and have a maximum load of 2600 Newtons as compared to the native ACL maximum load of 1725 Newtons [17]. However, BPTB grafts have a high rate of anterior knee pain, pain with kneeling, loss of extension and quadriceps strength, and are associated with patellar fractures and patellar tendon ruptures [17]. Hamstring autografts are easily harvested, and have a variable tensile strength dependent on the number of strands used [18]. This is up to 4000 Newtons with four-strand grafts [20]. Hamstrings grafts additionally have lower donor site morbidity due to smaller incisions, and potential for harvest from the contralateral uninjured leg. The disadvantages of hamstring grafts include residual hamstring weakness, higher incidence of saphenous nerve injury, as well as lower fixation strength than BPTB grafts due to lack of bony adherence [19]. The graft site is ultimately determined by surgeon preference, as many studies have shown similar comparative outcomes, re-rupture rates and patient satisfaction when using BPTB or hamstring grafts [16,20,21].

Although debated which produces better outcomes, the two most common femoral tunnel preparation techniques are the anteromedial (AM) and transtibial (TT) approaches. The traditional TT approach is limited by difficulty in performing anatomic reconstruction. The currently preferred AM technique allows for more reliable anatomic reconstruction. ACL grafts can be fixed with a variety of methods, including interference screws (metal or bioabsorbable), press-fit fixation without screws, screws and washers, screw posts and sutures, staples, endobuttons, cross pins, and bone anchors [22]. Regardless of technique, ACL reconstruction is associated with known complications, which include stiffness, arthrofibrosis, infection, graft failure, and venous thromboembolism.

Rehabilitation following ACL reconstruction is vital to successful surgery. Although not widely agreed-upon protocol exists, physical therapy consists of three main components: immediate therapy, early therapy and injury prevention [23]. Immediate therapy includes icing, early weight bearing, and early full extension. For
early rehabilitation, focus on isometric strengthening of both quadriceps and hamstrings is recommended with caution to avoid isokinetic and open chain quadriceps strengthening. Injury prevention strategies focus on plyometric training to teach the athlete to land from height with decreased valgus, and to decrease the load on the quadriceps. There is no proven role for knee bracing post-operatively [23].

The Argument for Repair

The resurgence of research into ACL repair was prompted by high rates of osteoarthritis after reconstruction as well as lower than expected return to play rates at long-term follow-up [23,24]. Since this procedure is commonly performed on younger patients who are athletes, early onset osteoarthritis is an enormous problem. Additionally, the purpose of the repair is to return patients to sports. While re-rupture rates are low, return to play rates do not necessarily correlate. The MONO group demonstrated an initial return to play rate of 72% but 36% at seven year follow-up [24].

Although ACL reconstruction has given patients a stable knee, the grafts mimic the native ACL in some regards, they fail to reproduce the complex anatomy from shape to diameter. Anatomic ACL reconstruction is a large improvement in restoring more normal kinematics, but it is not the same as a native ACL. Additionally, ACL reconstruction cannot reproduce the nerve fibers and the knee takes a significant insult from the graft harvest and tunnel drilling. Loss of proprioception with ACL reconstruction is a significant concern. This makes ACL repair an attractive option. It is native tissue with all of its intrinsic properties, including nerve supply. There is also minimal disturbance at the time of surgery compared to reconstruction, which potentially makes recovery easier. While this makes repair very attractive, the question remains: can we reliably repair the ACL and get it to heal? Recent studies by DiFelice et al [25,26], have reported a small series of patients that were repaired with a short follow-up (mean 3.5 years) that is satisfactory. This, in combination with basic science work done on biologic therapies to augment ACL repair, represents an attempt to revive the procedure. ACL repair has been called a “holy grail” [27] - an alternative that would offer decreased morbidity compared to ACL reconstruction. Table 1 contains summaries of all major studies pertaining to ACL repair.

Review

Biologic Therapy

The main pitfall of primary ACL repair is that the ACL has a record of poor healing. The synovial environment of the ACL is relatively hostile, and thus a healing ACL is markedly different than a healing medial collateral ligament (MCL), despite their proximity. Although the initial injury response is identical between the two ligaments [28-31], the fibrin plug within the synovial space is broken down by enzymes, myofibroblasts coat the end of the ACL stumps, and primary healing is arrested. Synovial fluid contains lytic enzymes, primarily plasmin. Histological evaluations comparing the intra-articular ACL and extra-articular MCL found reduced concentration of growth factors in the ACL [31]. These results have directed research towards the influence of intra-articular platelets, the injection of various growth factors into synovial space and the use of collagen scaffolding as augmentation.

Platelets are crucial not only as a physical component of the coagulation cascade, but also as a vessel for growth factors such as platelet-derived growth factor, fibroblast growth factor and vascular endothelial growth factor. Platelet-rich plasma (PRP) has been tested on the ACL due to its high concentration of such growth factors [32]. In 2009 Nin et al [33], performed a randomized trial looking into the addition of PRP augmenting allograft ACL healing and found no statistically significant difference between the augmented and untreated groups. Another clinical trial was performed in 2010 by Vogenic et al [34], again looking into healing of reconstructed ACLs using bone-patellar bone and hamstring autografts, which demonstrated that knees supplemented with PRP showed significantly higher rates of revascularization at the graft-bone tunnel interface, but none in the intra-articular portion of the graft. Murray et al [35], found that an improvement of 20–30% on autograft maturation is possible with the addition of PRP. Silva and Sampaio [36] looked into the fibrous interzone between the femoral bone tunnel and a hamstrings autograft in four separate groups: a control group, intraoperative indirect femoral tunnel PRP injection, 2- and 4-week intrarticular PRP injections, and a group with thrombin-activated PRP placed in the femoral tunnel at the end of surgery. There was no significant difference between their four groups on MRI at 3 months. In a systematic review of this literature, Figueroa et al [37], found that there is promising data

<table>
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<tr>
<th>Study</th>
<th>Design</th>
<th>Results</th>
<th>Level of Evidence</th>
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<tbody>
<tr>
<td>Madry et al [38]</td>
<td>Gene Transfer using recombinant adeno-associated viral (AAV) vectors carrying Fibroblast Growth Factor (FGF-2) genes applied to ACL fibroblasts in vitro</td>
<td>Gene expression induced in all samples, causing significantly and durably enhanced levels of proliferation and type I/III collagen production</td>
<td>II</td>
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<tr>
<td>Jalowiec et al [32]</td>
<td>In Vitro Characterization of PRP-gels created from platelet concentrates, activated with human thrombin</td>
<td>PRP-gels can effectively deliver bioactive substances and MSCs for various clinical applications</td>
<td>II</td>
</tr>
<tr>
<td>Murray et al [43]</td>
<td>Eight canine ACLs transected and treated with collagen-platlet composite</td>
<td>The percentage filling of the defects in the treated ACLs compared with the untreated contralateral control defects</td>
<td>II</td>
</tr>
<tr>
<td>Murray et al [39]</td>
<td>Five female Yorkshire pigs, bilateral knees used comparing augmented suture repair and suture repair alone, 3 pigs bilateral knees used as a control</td>
<td>The supplementation of suture repair with a collagen-PRP hydrogel resulted in significant improvements in load at yield, maximum load, and linear stiffness at four weeks</td>
<td>II</td>
</tr>
<tr>
<td>Murray et al [46]</td>
<td>Six 30-kg pigs underwent bilateral suture repair of the ACL. One side was treated with suture repair alone, while the contralateral side was treated with suture repair augmented with PRP</td>
<td>The addition of PRP to the suture repairs did not improve AP knee laxity or linear stiffness</td>
<td>II</td>
</tr>
<tr>
<td>Joshi et al [31]</td>
<td>Eighteen Skeletally Immature female Yorkshire Pigs, bilateral knees used comparing primary repair with contralateral augmented primary repair</td>
<td>Augmented repair resulted in improvements in yield load, linear stiffness, significant increase in cell density, reduction in yield load and stiffness when revascularization was noted</td>
<td>II</td>
</tr>
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</table>
Palmer MP et al [41]: Five female Yorkshire Pigs, bilateral knees used comparing collagen enhanced repair with collagen enhanced repair at different temperature.

Magarian et al [42]: Sixteen female Yorkshire pigs underwent staged, bilateral surgical anterior cruciate ligament transections.

Murray et al, 2010 [46]: Twenty-one Yucatan minipigs (eight juvenile, eight adolescent, and five adult animals) underwent bilateral ACL transection, one side left untreated, contralateral side enhanced suture repair.

Magarian and Fleming [43]: Eighteen porcine ACLs repaired with sutures, a collagen sponge, or a collagen-platelet-composite.

Vavken et al [47]: 19 female Yucatan pigs, bilateral knees used to compare primary ACL repair with no repair.

Haus et al [48]: Skeletally immature, adolescent, and adult Yucatan mini-pigs underwent bioenhanced suture repair.

Kohl et al [59]: Eleven Sheep ACLs reconstructed by DIS, microfracturing and collagen.

Magarian et al [42]: Eighteen porcine ACLs repaired with sutures, a collagen sponge, or a collagen-platelet-composite.

Vavken et al [50]: Twenty-four skeletally immature pigs received bioenhanced ACL repair with a collagen-platelet composite, allograft reconstruction, or no further treatment.

Murray and Fleming [51]: Sixty-four Yucatan mini-pigs underwent ACL transection and randomization to four experimental groups.

Song et al [60]: Fifty Rabbit ACLs transected and divided between remnant repairing and traditional reconstructive surgery.

Clinical Evidence—Supporting ACL Repair

Gaulrapp and Haus [54]: Retrospective analysis of 44 patients treated by various techniques.

Eggli et al [58]: Ten patients repaired with dynamic intraligamentary stabilization (DIS), microfracturing and platelet-rich fibrin.

DiFelice, Villegas, Taylor [25]: Retrospective review and early follow-up of 11 consecutive cases of ACL.

Clinical Evidence—Opposing ACL Repair

Feagin et al [1]: Sixty-four Cadets at West Point had primary ACL reconstruction, 32 followed for 5 years.

O’Donoghue et al [8]: Thirty-eight canines had ACL repair, 20 canines had ACL reconstruction, followed from 6 months to 4 years.

Sherman et al [53]: Fifty primary ACL repairs using the Marshall multiple suture technique were analyzed and followed for a mean of 6.3 months.

Nin et al [33]: One hundred patients undergoing arthroscopic patellar tendon allograft ACL reconstruction with or without platelet-enriched gel.

Silva et al [36]: Forty patients undergoing ACL reconstruction enrolled into four groups.

Table 1: A summary of major studies regarding ACL repair

<table>
<thead>
<tr>
<th>Study</th>
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<tr>
<td>Palmer MP et al [41]</td>
<td>Five female Yorkshire Pigs, bilateral knees used comparing collagen enhanced repair with collagen enhanced repair at different temperature.</td>
<td>In vitro findings were that injection temperatures over 30 degrees C resulted in a faster visco-elastic response.</td>
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<td>Magarian et al [42]</td>
<td>Sixteen female Yorkshire pigs underwent staged, bilateral surgical anterior cruciate ligament transections.</td>
<td>Yield load, maximum load, linear stiffness and anterior-posterior laxity were all adversely affected by delay of six weeks versus two weeks.</td>
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<td>Murray et al, 2010 [46]</td>
<td>Twenty-one Yucatan minipigs (eight juvenile, eight adolescent, and five adult animals) underwent bilateral ACL transection, one side left untreated, contralateral side enhanced suture repair.</td>
<td>ACLs from skeletally immature animals had significantly improved structural properties over those of adult animals.</td>
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<tr>
<td>Vavken et al [47]</td>
<td>19 female Yucatan pigs, bilateral knees used to compare primary ACL repair with no repair.</td>
<td>Maximum load and linear stiffness were independent of VEGF receptor expression, VEGF receptor 1 was associated with displacement (positively) and yield load (negatively).</td>
</tr>
<tr>
<td>Haus et al [48]</td>
<td>Skeletally immature, adolescent, and adult Yucatan mini-pigs underwent bioenhanced suture repair.</td>
<td>Fibroblasts and osteoclasts mediate histologic changes at the insertion site, magnitude of these changes may be a function of skeletal maturity.</td>
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<tr>
<td>Kohl et al [59]</td>
<td>Eleven Sheep ACLs reconstructed by DIS, microfracturing and collagen.</td>
<td>All animals exhibited successful restoration of anteroposterior translation.</td>
</tr>
<tr>
<td>Magarian et al [42]</td>
<td>Eighteen porcine ACLs repaired with sutures, a collagen sponge, or a collagen-platelet-composite.</td>
<td>Type I collagen is safe to use in the knee joint.</td>
</tr>
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<td>Vavken et al [50]</td>
<td>Twenty-four skeletally immature pigs received bioenhanced ACL repair with a collagen-platelet composite, allograft reconstruction, or no further treatment.</td>
<td>No difference between bioenhanced ACL repair and ACL reconstruction for maximum load, maximum displacement, or linear stiffness or anteroposterior laxity.</td>
</tr>
<tr>
<td>Murray and Fleming [51]</td>
<td>Sixty-four Yucatan mini-pigs underwent ACL transection and randomization to four experimental groups.</td>
<td>Macroscopic cartilage damage after bioenhanced ACL repair was significantly less than that in untreated ACL transection and bioenhanced ACL reconstruction.</td>
</tr>
<tr>
<td>Song et al [60]</td>
<td>Fifty Rabbit ACLs transected and divided between remnant repairing and traditional reconstructive surgery.</td>
<td>Acutely repaired ACL remnants showed a high resorption rate, low healing capacity, and poor biomechanical properties.</td>
</tr>
<tr>
<td>Gaulrapp and Haus [54]</td>
<td>Retrospective analysis of 44 patients treated by various techniques.</td>
<td>Good and very good results were obtained in over 75% of cases.</td>
</tr>
<tr>
<td>Eggli et al [58]</td>
<td>Ten patients repaired with dynamic intraligamentary stabilization (DIS), microfracturing and platelet-rich fibrin.</td>
<td>DIS resulted in stable clinical and radiological healing of the torn ACL in all but one patient.</td>
</tr>
<tr>
<td>DiFelice, Villegas, Taylor [25]</td>
<td>Retrospective review and early follow-up of 11 consecutive cases of ACL.</td>
<td>Ten of 11 patients had good subjective and clinical outcomes after ACL preservation surgery at a minimum of 2 years follow up.</td>
</tr>
<tr>
<td>Feagin et al [1]</td>
<td>Sixty-four Cadets at West Point had primary ACL reconstruction, 32 followed for 5 years.</td>
<td>Twenty-four patients reported impairment of athletics, 12 reported impairment of daily activities, 71% reported pain, 66% reported swelling, 71% reported stiffness and 94% reported instability.</td>
</tr>
<tr>
<td>O’Donoghue et al [8]</td>
<td>Thirty-eight canines had ACL repair, 20 canines had ACL reconstruction, followed from 6 months to 4 years.</td>
<td>Resorption of repaired ligament occurred in 14/36 repairs, silk repair showed increased inflammatory changes associated with decreased tensile strength and therefore stability.</td>
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<tr>
<td>Sherman et al [53]</td>
<td>Fifty primary ACL repairs using the Marshall multiple suture technique were analyzed and followed for a mean of 6.3 months.</td>
<td>The postoperative evaluation showed 59% excellent, 18% good, 14% fair, and 8% poor.</td>
</tr>
<tr>
<td>Nin et al [33]</td>
<td>One hundred patients undergoing arthroscopic patellar tendon allograft ACL reconstruction with or without platelet-enriched gel.</td>
<td>No difference in rate of associated injuries, no statistically significant differences in inflammatory parameters, MRI appearance or clinical evaluation.</td>
</tr>
<tr>
<td>Silva et al [36]</td>
<td>Forty patients undergoing ACL reconstruction enrolled into four groups.</td>
<td>No difference between groups when comparing MRI signal intensity of the fibrous interface of the femoral tunnel.</td>
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</table>
being produced, but there is no definite proof that the addition of PRP enhances ACL healing. The key limitations to these studies are small sample sizes and the majority of them being performed on animal models.

Madry et al. [38], looked into the effects of fibroblast growth factor via gene transfer, using adeno-associated vectors on ACLs removed from patients undergoing total knee arthroplasty. Expression of the gene in all of their subjects was successful and associated with enhanced proliferation of the ACL. Gene transfer represents an exciting possibility for enhancement of tissue repair.

Martha Murray has recently produced a large volume of publications [29,31,35,39-52], becoming a key advocate for primary ACL repair. Working with a porcine model, her team established that primary suture repair supplemented with collagen scaffolding and PRP allowed for improved healing in contrast to non-supplemented primary repair. This was measured by load at yield, maximum load and linear stiffness [39]. They also found that, in isolation, neither PRP nor collagen scaffolding improved healing [40,44]. In histological examination of primarily repaired ACLs in pigs, it was found that collagen-PRP scaffolding increased the concentration of growth factors PDGF-A, TGF-β1, FGF-2 and von Willebrand’s factor compared to non-augmented ACL repairs. This appears more like the histological healing pattern of the MCL [37,48,49]. In addition to augmentation of the ACL itself, augmentation of the bone-to-tissue fixation provides enhanced initial stabilization, yield load and linear stiffness - comparable to porcine ACL reconstruction [50]. In short term follow-up, rates of posttraumatic osteoarthritis measured by microscopic cartilage damage were less in the bioenhanced ACL repaired knee than that of the reconstructed knee [47], though the difference was not statistically significant. Murray has been able to show that bioenhancement of the ACL can produce favorable results in animals, whether this can translate to humans is still unknown [37,48,50].

**Patient Selection**

In 1991, Sherman et al. [53], followed 50 primary ACL repairs for an average of five years and published the most definitive subgroup analysis of ACL tears to date. Their subgroups included age, sex, type of sport, tissue quality, location of tear and overall laxity. Based on these subgroups, Sherman et al., determined favorable and unfavorable prognostic indicators of ACL repair and established the first classification for types of ACL tear based upon anatomic location. Figure 1 illustrates and describes the four types of tears established by Sherman et al. [53], Type I is the most proximal avulsion-type tear, Type II is a proximal 1/4 tear, Type III is a proximal 1/3 tear, and Type IV is a mid-substance tear. Football injury, younger age, increased preoperative pivot shift, mid-substance Type IV tear and return of full motion correlated with poor postoperative results. Increasing age, tight jointedness, Type I tears and ≥ 5 degree flexion contractures correlated with good postoperative outcomes. Despite these results, the outcomes were largely unfavorable.

In 2006, Gauaurp and Haus [54] analyzed the outcomes of 43 skeletally immature patients whose ACL tears were repaired by reinserion, internal fixation, semitendinosus augmentation, and patellar tendon primary reconstruction. Only five of these patients underwent reinserion, yet these patients had favorable outcomes - the repaired knee was compared with the contralateral knee with the KT-1000 measurement and illustrated a reduction of only 3 mm. These findings are limited by the study’s small sample size and skeletally immature patients.

These findings were corroborated in the systemic review performed by Taylor et al. [26]. Taylor and DiFelice [55], have begun a trial of primary ACL repair for specifically selected patients. The ideal patient has a proximal type I tear by the Sherman classification [53], excellent tissue quality, and can undergo immediate repair. MRI evaluation of ACL tears allows for an advantage that past surgeons did not have when investigating primary ACL repair. There was no imaging technique that allowed for patient selection due to tear type. Hypothetically, if optimal candidates can be identified, primary repair can be utilized and reduce the need for ACL reconstruction.

**Operative Technique**

One of the biggest shortcomings of primary repair is that the majority of research was performed before arthroscopic techniques became widespread. The original technique for primary repair was the Marshall multiple suture technique and it was performed open. Marshall originally described this technique in 1982, using multiple loop-varying depth sutures to approximate the two ends of the ACL [56].

More recent operative techniques have been described by Nguyen et al. [57], whose 2013 publication focused on the Becker locking suture technique under tension, augmented with small intestine submucosa suture (SIS). The small intestine submucosa was theorized to promote healing of the ACL. Ten goat ACLs were transected and repaired using the Becker locking suture technique, five augmented with SIS and five not, and the contralateral knee was used as a control. Cross-sectional area of the ACL as well as anterior-posterior translational force were measured at three months, and the SIS-augmented group showed 50% cross-sectional area compared to the uninjured control ACL. They concluded that the Becker technique with augmentation of biologic therapy shows promise in an animal model.
Dynamic Intraligamentary Stabilization (DIS), first described by Eggli et al [58], is an operative technique that involves a polyethylene wire passed through the tibial and femoral footprints of the ruptured ACL with a dynamic spring component fixed at the tibial end of the wire. The spring, covered with a screw, holds the knee in posterior translation while the knee is in flexion, and maintains the ACL in anatomic position during full range of motion. The operation also includes microfracturing of the femoral footprint to enhance the inflammatory healing response, and an injection of platelet-rich fibrin. The patients in this pilot study were followed up to two years, and achieved excellent results demonstrated both radiographically and via patient feedback. All patients, except for one patient whom re-ruptured, had nearly normal knee function at one year with Lysholm scores of 99-100. Despite these results, the sample size was small, and there was no control. Kohl et al [59], continued looking into this promising technique, and found similar results, attributing the success to the anatomical repositioning of the ACL as a critical factor.

DiFelice et al [55], are investigating arthroscopic repair, using suture anchors in patients with excellent tissue quality and proximal tears—the guidelines reported by the systematic review. They are investigating the use of two sutures and two anchors placed into the remnant footprint on the femur of the native ACL. Clinical outcomes measured using standardized measurements have shown excellent results at two years follow up. These results, while promising, should be monitored for their long-term progress, as Faegins’s study too showed promise at the two year follow up. More recently, a rabbit model performed by Song et al [60], found the repaired ACL remnants had a high resorption rate, low healing capacity, and poor biomechanical properties.

Our Approach

At this time, the vast majorities of ACL tears are treated with the gold standard, which is reconstruction. The vast majority of patients are not candidates for repair as the tear occurs somewhere in the mid-substance. Many are proximal mid-substance tears. We agree with DiFelice on those that are candidates for repair. At this time the only potential candidates are those with proximal avulsion tears that have good tissue quality. MRI gives us a good indication of those potential candidates; however, we still use ACL reconstruction as a back-up in case the tissue quality is poor or the repaired tissue cannot be directly re-approximated to the wall. We use a Bunnell type suture weave from distal to proximal with the two ends exiting the proximal stump. These are then passed through a 4 mm tunnel and tied into a tight rope button along with an internal brace consisting of Fiber Tape (Arthrex, Inc., Naples, FL). Final arthroscopic views of this can be seen in figure 2. Postoperatively we rehabilitate these patients identically to patients who have undergone ACL reconstruction but progress them quicker through the regimen.

Conclusion

The revitalization of primary ACL repair is an exciting area of research. The recent progress in bioenhancement of the remnant ACL has shown promise in animal models, as well as in limited human studies. Experimentation with new operative techniques and image-based patient selection are promising, and techniques such as dynamic intraligamentary stabilization as well as DiFelice and Taylor’s novel suturing technique will be reported with longer follow-up. While early results seem promising, long-term results are necessary to validate this approach. The vast majority of ACL patients are not candidates for repair, but those that are may see better results.

References


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