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Review Article

All-inside ACL reconstruction: How does it compare to standard ACL reconstruction techniques?

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ABSTRACT

The all-inside ACL reconstruction technique is a relatively new development in ACL surgery. Some features of this technique include closed-socket tunnels, dual suspensory graft fixation, decreased bone removal, and smaller skin incisions. The purpose of this review was to compare the unique features of the all-inside ACL versus standard ACL techniques using biomechanical and clinical studies. The all-inside ACL appears to have similar overall results on subjective and objective outcomes studies compared to standard ACL techniques and may be associated with decreased post-operative pain. There is also a concern for a higher graft failure rate with the all-inside ACL.

1. Introduction

The all-inside ACL reconstruction technique was originally described over twenty years ago.[1] The technique referenced in this manuscript was described by Lubowitz et al., 2011.[2] This technique features several unique components including closed-socket tunnels with less bone removal, dual (femoral and tibial) suspensory fixation, and smaller skin incisions. The mainstream ACL reconstruction techniques (i.e. "standard ACL techniques") that are used for comparison to the all-inside ACL in this review utilize bone patellar tendon bone (BPTB) and hamstring tendon grafts. Fixation with these techniques is usually achieved with suspensory or interference screw femoral fixation in the femur and an interference screw in the tibia. Two recent reviews have addressed some of the controversies and potential benefits of the all-inside ACL technique that are expanded upon in this article.[1,3]

The purpose of this review was to address some of the unique elements of the all-inside ACL and compare it to standard single-bundle ACL techniques. The topics discussed include graft choice, functional deficits associated with autograft harvest, harvest site morbidity, dual (femoral and tibial) suspensory fixation, adjustable loop fixation devices, closed-sockets versus tunnels, skeletally immature patients, technical challenge, and cost. The outcomes of the all-inside ACL studies are then compared with the standard ACL articles cited in the "AAOS Management of Anterior Cruciate Ligament Injuries Evidence Based Clinical Practice Guideline" (AAOS ACL CPG).[4] The parameters compared at two years of follow up included VAS pain score, IKDC, Tegner, Lysholm, Lachman, pivot shift test, KT1000/2000, graft failure rate, reoperation rate, and post-op infections.

2. Graft choice

The all-inside ACL technique typically utilizes a triple or quadruple semitendinosus tendon autograft.[2] In contrast, standard ACL techniques typically utilize a BPTB or semitendinosus-gracilis (S-G) tendon autograft.

Since closed femoral and tibial sockets are drilled rather than full tunnels, a decreased graft length is necessary for the all-inside ACL technique. Therefore, a single hamstring tendon harvest provides sufficient length to serve as the autograft when tripled or quadrupled.[5] A biomechanical study using a human cadaveric model reported that reconstruction using a single hamstring tendon (semitendinosus or gracilis) can restore anterior tibial translation to within 1.3 mm of the native ACL in response to a 134-N anterior load and also reproduces similar rotatory and torque properties.[5] In regards to clinical outcomes, a recent study compared an all-inside ACL technique using a double or triple semitendinosus tendon graft to a standard ACL technique using a S-

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G hamstring tendon autograft.[6] Investigators reported no significant difference between the two groups for IKDC, VAS pain score, Lysholm and Tegner scores at two years of follow up.[6]

Eriksson et al., performed a clinical study that compared a standard ACL technique using quadruple semitendinosus tendon autograft to a standard ACL technique using BPTB autograft.[7] They reported that there was no significant difference between the Stryker laxity test, one-leg hop test, Tegner activity level, lysholm score, patellofemoral pain score, IKDC score or VAS at a median follow up of 31 months.[7] The only difference reported was weaker knee extension in the BPTB group.[7]

Synthesis of these biomechanical and clinical studies suggests that the use of a single hamstring tendon graft in the all-inside ACL technique can reproduce similar knee stability compared to the native ACL. Further, similar clinical outcomes are achieved when comparing to standard ACL techniques using BPTB and S-G hamstring grafts.

3. Functional deficits associated with autograft harvest

Harvest of a single hamstring tendon for reconstruction with the all-inside ACL technique may result in potentially less functional deficits than harvest of both S-G hamstring tendons or the BPTB in standard ACL techniques.

However, there is evidence that hamstring muscle strength when comparing patients that had a semitendinosus versus a S-G hamstring tendon autograft for their ACL reconstruction may not differ.[8] Seven of eight studies found that there was no difference in muscle strength between the different groups.[8] Only a single article found a difference, and reported decreased knee flexion strength in the S-G autograft group in knee flexion angles greater than 70°.[9]

A meta-analysis compared isokinetic muscle strength in individuals who had ACL reconstruction with a hamstring tendon autograft to a BPTB autograft.[10] It was reported that use of BPTB autografts was associated with greater knee extension weakness and use of hamstring tendon autografts was associated with greater knee flexion weakness at 12 months follow up.[10] In almost all of the studies included in the meta-analysis the hamstring autografts were S-G tendons. Only one of the studies analyzed the difference between semitendinsosus, S-G, and BPTB autografts.[11] They concluded that there was no significant difference in muscle strength between the three groups.[11]

4. Harvest site morbidity

In regards to anterior knee pain and donor site pain, both short and long-term studies have found that hamstring tendon autografts tend to be more benign than BPTB autografts.[12] It has been reported that the thickness of the patellar tendon harvest site for the BPTB autograft increases with time, but it can continue to show abnormalities on various imaging and histologic studies two years after harvesting.[12] Meanwhile, MRI and ultrasound studies have shown some regrowth of the hamstring tendons that appears complete at two years after being harvested.[12] Biopsy specimens of the regrown tendons resemble normal hamstring tendons.[12]

To avoid any concern for harvest site morbidity an allograft can be used instead of an autograft. There are two all-inside ACL studies using two strand posterior tibial tendon allografts that have similar successful outcomes to other all-inside ACL studies.[13,14] One of the caveats for the use of allografts in ACL reconstruction is the higher graft failure rate reported in young patients, especially those with high activity levels in sports in comparison to autografts.[3,4]

5. Dual (femoral and tibial) suspensory fixation

One of the most unique aspects of the all-inside ACL technique is perhaps the dual suspensory fixation of the semitendinosus graft on both the femur and tibia.[2]

Several studies have reported the equivalency of the different femoral fixation types in restoring knee kinematics.[15] The suspensory fixation at the tibia is currently the focus of research efforts. A biomechanical study in porcine tibias utilizing bovine extensor tendon allografts compared the strengths of screw, button, and screw-button combination fixation in the tibia.[16] They found that in all strength tests performed (load-to-failure, ultimate loads, and pullout stress) the screw-button combination fixation was the strongest group, followed by screw fixation, and finally button fixation.[16] Another study used bovine tibias and bovine digital extensor tendons to compare between button and screw fixation.[17] This study reported that screw fixation had less elongation and greater pullout stiffness, but suspensory button fixation could survive higher ultimate failure loads.[17]

Porcine tibias with human quadrupled semitendinosus grafts in an all-inside ACL construct with suspensory fixation were compared to doubled S-G grafts secured with interference screws in a standard ACL technique.[15] The ultimate load to failure was higher in the suspensory fixation group and although there was slightly greater cyclic displacement in the suspensory fixation group it was not found to be a statistically significant difference.[15] It is important to note that while there are biomechanical studies of single (femur or tibia alone) suspensory fixation, we are unaware of biomechanical studies comparing dual suspensory fixation (femur and tibia).

A meta-analysis compared clinical outcomes of a BPTB, intra-tunnel hamstring tendon fixation, and extra-tunnel (suspensory) hamstring fixation techniques.[18] Intra-tunnel fixation groups used interference screws while extra-tunnel fixation groups used posts, staples, and buttons.[18] It was concluded that there was no significant difference in the percentage of knees restored to normal laxity measurements and no difference was reported in graft failure rate.[18] Patient satisfaction and return to pre-injury activity rates were similar between the intra-tunnel hamstring tendon fixation and BPTB groups, but they were lower for the extra-tunnel hamstring fixation group.[18] It is important to note that none of the studies in the meta-analysis utilized an all-inside ACL technique.

A clinical outcomes study evaluated patients that underwent an all-inside ACL reconstruction technique using two strand posterior tibial tendon allografts.[13] Graft fixation was performed with either (1) dual suspensory buttons or (2) femoral and tibial interference screws.[13] At two years of follow up there was no significant difference in the primary outcome of knee antero-posterior stability at 25° of knee flexion measured using the KT-1000 device, nor was there any significant difference in their secondary outcomes (VAS pain score, IKDC, KSS, SF-12, narcotic consumption, or socket widening).[13]

As reviewed, inferior biomechanics and clinical outcomes are reported in suspensory fixation compared to screw fixation in some studies.[16–18] However, this has not been reported in biomechanical and early-term clinical outcomes studies utilizing an all-inside ACL technique with suspensory fixation.[13,15]

6. Adjustable loop fixation devices

While standard ACL techniques have utilized both adjustable loop and fixed loop fixation devices, the all-inside ACL technique utilizes an adjustable loop device for the dual suspensory fixation.[2] To our knowledge the only studies currently available that compare

adjustable loop and fixed loop devices look at the suspensory fixation on the femur.

A biomechanical study that compared a fixed loop to two different adjustable loop devices, reported that the ultimate loads of all the devices were greater than any force that a patient's knee should experience in early rehab.[19] However, they also reported that the two adjustable loop products experienced clinically significant elongation (greater than 3 mm) during cyclic testing.[19] The most common points of failure was near the sutures contact with the button for the adjustable loop products and at the mid substance of the suture loop for the fixed loop product.[19] A study comparing three fixed loop to two adjustable loop devices found that there was less cyclic displacement in the fixed loop devices.[20] They also reported that there was no significant change in the amount of displacement of the adjustable loop products after re-tensioning following initial cycling in order to mimic preconditioning in an ACL reconstruction procedure.[20]

In a recently published clinical outcomes study, 188 patients were randomly allocated to either a quadrupled S-G hamstring tendon standard ACL reconstruction with a fixed loop or adjustable loop device on the femoral side.[21] No statistically significant difference between the groups was observed in the KT-1000 results, graft failure rate, or time to graft failure at up to two years of follow-up.[21]

There is some concern that the adjustable loop devices may elongate more than the fixed loop devices according to the biomechanical studies above. However, this has not been supported in clinical outcomes studies.

7. Sockets versus tunnels

Another one of the more unique aspects of the all-inside ACL technique is the drilling of closed sockets instead of the full tibial tunnels typically seen in standard ACL techniques.[2]

Some of the main concerns with suspensory fixation in ACL reconstruction are tunnel expansion and the graft healing process. These two processes may be influenced by the motion of the grafts within the tunnels, and two potential mechanisms causing this have been termed the windshield-wiper and bungee cord phenomenon.[3] Biomechanical studies have reported more graft motion at the intra-articular ends of the tunnel (away from the suspensory fixation points).[22,23] This resulted in decreased graft healing at the intra-articular ends of the tunnels.[22,23] The increased graft motion in suspensory fixation may contribute to greater tunnel expansion seen in suspensory fixation in hamstring grafts versus interference screw fixation for BPTB grafts.[24,25] While these studies report increased tunnel expansion and potentially slower graft healing in techniques that utilize suspensory fixation, multiple studies have found that the tunnel widening does not correlate to any difference in clinical outcomes.[25,26]

While there is some concern for the windshield-wiper and bungee cord phenomenon that may occur with suspensory fixation, the closed-sockets of the all-inside ACL technique may offer a protective effect. Studies using X-ray and CT imaging to evaluate the sockets drilled with an all-inside ACL technique have reported less socket expansion and preserved bone stock compared to full tunnels seen in standard ACL techniques.[27,28] The importance of this is most evident when drilling the tibial socket for the all-inside ACL suspensory fixation since this can reduce tibial microfracture trauma that is seen with full tunnel tibial drilling in standard ACL techniques.[29] Also, when closed-sockets are created, there will be less graft length available for the windshield-wiper and bungee cord phenomena compared to full tunnels.[3]

One article evaluated the clinical outcomes in patients that were randomized to receive an all-inside ACL technique with sockets or a standard ACL technique with full tunnels.[14] They found no significant difference in IKDC, KSS, SF-12, narcotic consumption, or tibial and femoral socket/tunnel widening in up to two years of follow up.[14] However, the patients that underwent the all-inside ACL technique with closed-sockets had lower VAS pain scores at early post-operative (day 1, on day 7, at 1.5 weeks) periods and at two years of follow up.[14] Of note the all-inside ACL technique in this study utilized interference screw fixation instead of dual suspensory fixation.

Interpretation of these studies seems to indicated that the closed-sockets for the all-inside ACL technique may have protective effects that results in decreased tunnel expansion and bone preservation. Further, the clinical study revealed decreased pain scores with the closed-sockets of the all-inside ACL technique compared to the full tunnels of a standard ACL technique.[14]

8. Skeletally immature patients

An all-epiphyseal all-inside ACL technique has been described for use in skeletally immature patients to decreases the likelihood of physeal injury.[30] When comparing physeal injury on MRI in one study there was less physeal injury observed in 10/15 epiphyseal all-inside ACL patients with a mean area of 57.2 mm^2 while all of the partial transphyseal ACL reconstruction group had physeal injury with a mean area of 145.1 mm^2.[31] No cases of growth arrest, articular surface violation, or avascular necrosis were observed on MRI in either group.[31] A recent study in skeletally immature athletes who had an all-inside epiphyseal or partial transphyseal ACL reconstructions reported good subjective and objective clinical outcomes at an average follow up of 16.7 months.[32] There were no growth disturbances observed.[32] The mean return time to participation in competitive sports was 12.5 months after surgery.[32] One patient experienced a graft failure and one had a contralateral ACL rupture out of the forty-two patients enrolled in the study.[32]

9. Technical challenge

One of the common challenges facing surgeons learning the all-inside ACL technique can be drilling the femoral socket using the anteromedial (AM) portal technique. Two studies reported a surgical time of 67.8 and 74.1 average minutes in the all-inside ACL group using the AM portal drilling technique versus 62.3 and 62.7 average minutes with standard ACL reconstruction.[14,33]

Some commonly reported difficulties associated with AM portal drilling include the hyperflexed knee position required to properly drill the femoral socket.[34] A list of "pitfalls and solutions" was prepared by Lubowitz et al. to support adoption of this technique.[34] The use of retrograde reamers allows surgeons to avoid the need for knee hyperflexion and may ease the learning curve.[35]

10. Cost

One study conducted in France compared the cost difference between an all-inside ACL and standard ACL technique.[36] They found that the all-inside ACL technique was 18% more expensive and cost on average 931.06 € versus the standard ACL reconstruction cost 791.59 €.[36] This increase in cost was mostly attributed to the single use equipment required for the retrograde drilling and suture pass in the all-inside ACL.[36] The most expensive components for either technique is the single use equipment that made up 84% of the all-inside ACL costs and 81% of the standard ACL costs.[36] Country and site-specific studies will need to be conducted to better relate to the individual surgeon's costs.

Table 1
The all-inside ACL studies included in this article and the make-up of each study are shown in this table.

	Number of all-inside ACL patients	Graft	Femoral socket technique	Tibial socket technique	Femoral fixation	Tibial fixation	Comparison group
Shurz et al.[35]	92	Quadrupled Semitendinosus autograft	Single-blade retrograde reamer	Single-blade retrograde reamer	Suspensory fixation with adjustable loop device	Suspensory fixation with adjustable loop device	None
Lubowitz et al.[13]	64	2 strand Posterior Tibial Tendon allograft	Flat-head antegrade reamer through anteromedial portal	Retrograde acorn reamer	Suspensory fixation with fixed loop device	Suspensory fixation with titanium cortical button	All inside ACL with dual interference screw fixation
Benea et al.[33]	23	Quadrupled Semitendinosus autograft	Antegrade reamer through anteromedial portal	Single-blade retrograde reamer	Suspensory fixation with adjustable loop device	Suspensory fixation with Titanium suture button	Standard ACL technique with S-G graft and full tunnels with dual interference screw fixation
Blackman et al.[1]	95	Quadrupled Semitendinosus 88%, Quadrupled S-G 12%. Autograft 97%, allograft 3%.	Flat-headed antegrade reamer through anteromedial portal	Single-blade retrograde reamer	Suspensory fixation with adjustable loop device	Suspensory fixation with adjustable loop device	None
Volpi et al.[6]	20	Double or triple Semitendinosus autograft	Antegrade acorn reamer	Retrograde acorn reamer	Suspensory fixation	Suspensory fixation with metallic cortical suture button	Standard ACL technique with S-G graft and full tunnels with suspension or cross pin fixation on femur and interference screw or reabsorbable cross pin fixation on tibia
Lubowitz et al.[14]	76	2 strand Posterior Tibial Tendon allograft	Antegrade reamer through anteromedial portal	Retrograde acorn reamer	Interference screw fixation	Interference screw fixation	Standard ACL technique with 2 strand posterior tibial tendon allograft and full tunnels with dual interference screw fixation

Table 2
Pre-op and Two Year Post-op Scores.

	All-inside ACL Pre-op Scores	All-inside ACL Post-op Scores	Standard BPTB ACL Pre-op Scores	Standard BPTB ACL Post-op Scores	Standard hamstring ACL Pre-op Scores	Standard hamstring ACL Post-op Scores
VAS pain (10-cm)	1.9–5[13,14,35]	0.1–0.3[13,14,35]	NR	2.4[38]	NR	3.6[38]
IKDC	44.6–60.6[13,14,33,35]	83.8–89.7[13,14,33,35]	45[37]	82–85[37,38]	52[37]	80–85[37,38]
IKDC groups	0–4% group A 13–59.1% group B 36.4–59% group C 4.5–35% group D[13,14,33]	55–100% group A 0–40% group B 0–5% group C[6,13,14]	0–1% group A or B 99–100% group C or D[39,40]	18.2–62.3% group A 35–66% group B 0–30% group C 0–9% group D[37,38,41–44] 47–95% group A or B 5–53% group C or D[39,40,45]	0–1% group A or B 99–100% group C or D[39,40]	8.3–57% group A 35–75% group B 0–32% group C 0–7% group D[37,38,41–44] 59–93% group A or B 7–41% group C or D[39,40,45]
Lysholm	53.4[35]	90.9–93.1[6,35]	70–71[7,39]	85–95[7,39,45,46]	68–71[7,39]	86–95[7,39,45,46]
Tegner	2[35]	5.2–6[6,35]	2–3[7,39]	6[7,39]	2–4[7,39]	6–6.5[7,39]
Lachman	NR	77% grade 0 12% grade 1[1]	0% grade 0 6–15% grade 1 31–47% grade 2 7–63% grade 3[37,39]	50–81% grade 0 29.5–50% grade 1 0–6% grade 2[7,39,42,45]	0% grade 0 12–21% grade 1 50–82% grade 2 5–29% grade 3[37,39]	46–75% grade 0 39.5–52% grade 1 0–2.1% grade 2[7,39,42,45]
Pivot shift	NR	88% negative[1]	0–49% negative[37,41,46]	74–93% negative[37,41–43,45,46]	0–43% negative[37,41,46]	61–91.7% negative[37,41–43,45,46]
KT2000/1000 (134 N)	5.3–6.2 mm[13]	KT2000: 1.7 mm[35] KT1000: 1.1–1.3 mm[13]	5.3–7 mm[37,41]	KT1000: 0.43–2.52 mm[37,38,40,41,43,44,46]	6–7 mm[37,41]	KT1000: 0.23–3.26 mm[37,38,40,41,43,44,46]
Graft failure rate	–	0–12.7%[1,13,35]	–	0–6%[7,37–39,45,46]	–	0–8%[7,37–39,45,46]
Reoperation	–	12.2%[1]	–	0–25%[7,37,38,41,45,46]	–	0–25%[7,37,38,41,45,46]
Infection	–	0–3%[1,33,35]	–	0–4%[7,37,38,41,45,46]	–	0–3%[7,37,38,41,45,46]

11. Clinical outcomes

Six articles that reported clinical outcomes in patients who had undergone an all-inside ACL reconstruction were identified through a comprehensive review of the literature (Table 1).[1,6,13,14,33,35] Three of the studies directly compared an all-inside ACL group with a standard ACL group.[6,14,33] Two of three reported that the post-op VAS pain scores were lower in patients who had an all-inside ACL reconstruction at day 1, day 7, 1.5 weeks, 1 month, and at two years.[14,33] In all of the other variables assessed (IKDC, KSS, SF-12, narcotic consumption, and socket widening) there were no statistically significant difference between the groups.[14,33] The third study did not detect a statistically significant difference in any of the variables assessed (VAS pain score, IKDC, Lysolm, and Tegner).[6] Of note, one of these all-inside ACL studies utilized interference screw fixation rather than dual suspensory

fixation.[14] Another study compared an all-inside ACL with dual suspensory fixation to an all-inside ACL with dual screw fixation that reported no difference in any of the outcomes assessed (KT-1000, IKDC, KSS, SF-12, narcotic consumption, and socket widening).[13]

The clinical outcomes of the all-inside ACL studies[1,6,13,14,33,35] are compared to the standard ACL technique studies cited in the AAOS ACL CPG[4,7,37–46] at two years of follow up. The pre-op and two year post-op scores are listed in Table 2.

12. Discussion

Six all-inside ACL outcomes studies were identified; three directly compare results to a standard ACL control group.[1,6,13,14,33,35] Most of the outcomes assessed in these three studies show no significant differences.[6,14,33] However, lower VAS pain scores with the all-inside technique were reported in two of the three studies compared to the standard ACL reconstruction group.[6,14,33] There were no substantial differences appreciated when comparing the clinical outcomes of the all-inside ACL to that of the standard ACL studies listed in the AAOS ACL CPG.[1,6,7,13,14,33,35,37–46] However, we did identify potentially lower VAS pain scores and higher graft failure rate with the all-inside ACL versus the standard ACL techniques.[13,14,35] The all-inside ACL study that reported a higher graft failure rate discussed how positioning the femoral socket more anatomically and maybe having patients return to pivoting sports prior to when the graft ligamentization process was complete as possible explanations for their high graft failure rate.[35] This result may be an outlier, but requires longer-term follow-up.

13. Conclusion

Based on review of the available literature, the all-inside ACL technique has similar overall results on subjective and objective outcome studies and may be associated with decreased amount of post-operative pain. There is also a potential concern for higher graft failure rate in the all-inside ACL. At this time there are only a few early studies available for careful review of the all-inside ACL technique. Long-term outcomes studies are necessary to allow more definitive recommendations regarding the all-inside technique.

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