Anterior cruciate ligament reconstruction with the ligament augmentation and reconstruction system: a systematic review

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Received: 2 August 2012 / Accepted: 20 August 2012 / Published online: 14 September 2012
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Abstract

Purpose The Ligament Augmentation and Reconstruction System (LARS) is a third generation of synthetic ligament, designed to overcome the issues of graft failure and synovitis which led previous generations of synthetic ligaments to fall out of favour. The theoretical benefits of LARS are appealing but this has not led to widespread uptake of the system in preference to autograft. The aim of this systematic review is to assess whether the evidence exists to support the use of LARS with respect to outcomes and complications.

Methods A systematic search process was undertaken from January 1990 to June 2012 to identify primary evidence relating to the use of LARS in anterior cruciate ligament (ACL) single ligament reconstruction.

Results Nine studies were found meeting the search criteria including a single randomised controlled trial, two comparative series and six further observational case series. Overall the methodological quality of the studies was poor with follow-up to a maximum of five years. Reported outcome scores were good for LARS and comparable to autograft techniques.

Complication rates were low and comparable to those published for autograft techniques within the wider literature. Two reported incidences of synovitis were identified in case reports. **Conclusions** The current literature supports the use of LARS in the short to medium term. However, high-quality studies with long-term follow-up are required to determine whether the use of LARS is preferable to autograft for ACL reconstruction over the longer term. Synovitis appears to be a rare complication closely related to imperfect graft positioning.

Introduction

The Ligament Augmentation and Reconstruction System (also known as the Ligament Advanced Reinforcement System—LARS) is a polyethylene terephthalate (PET) graft material which has been available for over 15 years. Synthetic grafts were popular for anterior cruciate ligament (ACL) reconstruction in the 1980s and early 1990s, but subsequent problems, particularly synovitis and graft rupture [1, 2], led to a marked decline in their use. Given the good results achieved with autograft and historical concerns regarding the use of synthetic ligaments, there is an understandable reluctance to embrace the latest generation of PET devices. However, there is interest in the use of synthetic devices from patients, most noticeably in Australia where their use in high profile athletes has highlighted the potential benefits of faster rehabilitation, absence of donor site morbidity and reduced operative time. The LARS device is the third generation of synthetic ligament and according to the manufacturer has been designed to avoid the complications associated with its predecessors. Its intended use is a scaffold to temporarily augment a repaired ACL and protect it during healing. A meticulous surgical technique involving both

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isometry of the LARS device and preservation and suturing of the ACL stump is required. The aim of this systematic review is to assess whether the evidence exists to support the widespread use of LARS with respect to outcomes and complications.

Method

Search strategy

The National Center for Biotechnology Information (NCBI) PubMed database and the online Cochrane Library were searched using the following terms: LARS AND (ligament OR synthetic OR cruciate); polyethylene AND terephthalate AND ligament; synthetic AND ligament AND (outcome OR safety). Studies between January 1990 and June 2012 were included. No language limitations were imposed. The bibliographies of relevant articles and the manufacturer's website were searched to identify further articles.

Once each search was completed, the titles, abstracts and full text were reviewed where available. Any article with new data pertaining to the use of LARS in isolated ACL reconstruction was included. Case reports were not included but were analysed for mention of synovitis-related complications, and these were included in the discussion. Articles were excluded for the following reasons: no full text available (e.g. abstract from scientific meeting only), abstract or full text review indicated that the article did not relate to the use of LARS in ACL reconstruction, article included LARS in the context of multiple ligament reconstruction, a foreign language article for which no English translation was readily available, evidence of data replication or no new data was presented (e.g. review articles).

Assessment of methodological quality

The methodological quality of the articles was assessed independently by two reviewers using an abridged form of Downs and Black's criteria [3]. Questions relevant to assessing potential sources of bias in non-randomised studies were included from the original checklist to create the version that was used for this study, reflecting the methodological nature of the studies on this topic, with a maximum possible score of 15. Disagreements were resolved through discussion. The level of evidence according to the Oxford score [4] was determined for each article.

Data extracted from each article included the number of LARS ligaments implanted, patient age, time to surgery, outcome scores, duration of follow-up, number and nature of reported complications, return to sporting activity and surgical time.

Results

Search strategy

The search strategy produced 149 articles, with a review of article reference lists and the manufacturer's website revealing a further 16 publications. A total of 156 articles were excluded for one or more exclusion criteria: no full text available ($n=2$), abstract or full text review revealing the article was not relevant ($n=126$), foreign language article for which no English translation was readily available ($n=30$), evidence of data replication ($n=13$) and studies relating to first- or second-generation devices not comparable to LARS ($n=37$). Nine studies were included in the final review [5–13].

Methodological quality

The outcome of the abridged Downs and Black's scoring is shown in Table 1 with the Oxford level of evidence rating. Of the nine studies included in this review there was one randomised controlled trial, two retrospective comparisons between LARS and hamstring autograft and six observational case series. With regard to the quality of the studies, there was a notable lack of consideration for confounding factors in many studies including patients who underwent concurrent procedures such as meniscal repair or partial meniscectomy with ACL reconstruction, who were undergoing revision procedures or who had evidence of degenerative change within the knee. None of the comparative studies, including the solitary randomised controlled trial, included a power calculation to justify the sample size.

In total, the papers include 675 LARS ACL reconstructions with considerable variability in the mean age of patients included ranging from 26 to 46; summary details of all included studies are displayed in Table 2. Dericks [13] reported the use of LARS on a female child of 12 and Cerulli [10] reported a mean age of participants greater than might be expected of the typical ACL reconstruction population; no explanation for this is provided. In those studies which included data on gender, male subjects were more commonly represented than female. The mean follow-up period ranged from 18 months to a maximum of five years. One study used LARS as an augmentation to short or thin hamstring autograft [5] rather than a sole constituent of the graft. This study also used a variety of techniques including bioabsorbable screws, single and double bundle reconstructions plus suspensory fixation which is not recommended by the manufacturer. The remaining studies used LARS as the sole constituent of the ligament augmentation following the manufacturer's recommended technique. Nau et al. [11] in their randomised trial looked solely at chronic ACL ruptures (over six months), whereas other studies included patients with more acute ruptures. Their decision to look at chronic ruptures alone is not explained. There was a diverse

Table 1 Modified Downs and Black's criteria to assess methodological quality of included studies

Downs and Black's criteria	Objective described	Outcome described	Exclusion criteria described	Intervention described	Main findings reported	Adverse events reported	Random variability reported	Probability values reported	Representative sample invited to participate	Representative sample included	No data dredging	Use of appropriate statistics	Outcome measures described	Confounders accounted for	Power calculation	Number of criteria met	Level
Author																	
Hamido et al. [5]	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	11	4
Gao et al. [6]	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	11	4
Liu et al. [7]	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	11	3
Huang et al. [8]	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	N	9	4
Fan and Fan [9]	Y	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	N	7	3
Cerulli [10]	N	Y	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	4	4
Nau et al. [11]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	13	2
Lavoie et al. [12]	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	11	4
Dericks [13]	N	N	N	N	Y	Y	N	N	N	N	Y	N	Y	N	N	4	4

array of outcome scores used, with the Lysholm and International Knee Documentation Committee (IKDC) systems proving most prevalent, particularly within the most recent studies as shown in Table 2. Complications reported included a single case of synovitis (associated with ligament rupture), 16 ligament ruptures, five wound infections and four interference screw-related issues. Operative time was not reported in any study.

Discussion

LARS is promoted as the third generation of PET ligaments with the design having built on earlier generations to overcome the issues which were believed to encourage ligament rupture and synovitis. First-generation synthetic devices were intended for use as a permanent ligament replacement without tissue ingrowth. These ligaments were braided, woven or knitted and were prone to elongation with consequent early rupture. A major similarity of this generation of ligament was that they included crossing fibres in their design. During movement of the knee joint, these crossing fibres rubbed against adjacent fibres. The repetitive shear forces weakened the device and increased the production of debris which was believed to induce synovitis.

Second-generation synthetic ligament devices were modified by the addition of longitudinal and transverse fibres. Aside from the change in ligament design, the purpose of the second-generation ligaments shifted from devices that serve as a permanent replacement to devices that act as a scaffold and promote fibroblastic ingrowth. The longitudinal fibres enhanced the life span of the devices, but the persistence of crossing fibres still promoted wear and debris formation. LARS has an extra-articular portion composed of knitted fibres combined with longitudinal fibres, which provide strength and resistance to elongation. In contrast to the previous generations of synthetic ligaments, there are only free fibres in the intra-articular portion of the device. This design theoretically has high resistance to fatigue, as well as porosity favouring ingrowth. A different purification process for PET was designed for the LARS devices to reduce residues from the manufacturing process, which were also thought to promote synovitis and reduce biocompatibility.

The evidence collated in this systematic review provides some encouragement for the more general use of the LARS for ACL reconstruction. Overall failure rates are low [16 documented failures in 675 LARS uses (2.5 %)] and comparable with those achieved by hamstring ACL reconstruction (1.8–12.7 %) [14–16]. Of the failures reported, in many cases authors attribute failure to a technical error in tunnel placement [6, 13]. Other complications such as infection and interference screw-related issues were infrequent. Authors report successful return to sport at two to six months, earlier than is commonly recommended for autograft procedures.

Table 2 Studies included in the systematic review with demographic details, outcome scores, complications and return to sport

Author	Graft	Number of LARS	Gender M: F	Age (mean years)	Mean follow-up (months)	Mean time to surgery (months)	Lysholm	IKDC (% A and B)	Tegner	KOOS	Instrumented laxity	Complications	Return to sports
Hamido et al. [5]	LARS augmenting ham-string	112		26	45.2		83±2.1	96		Pain 81.2 Symptoms 78.2 ADL 92.7	Mean 7 mm anterior drawer (KT1000)		4 months
Gao et al. [6]	LARS	159	105:54	30	50	5	94.5±7	94	6.1±1.5		97.4 % <5 mm difference in anterior draw to opposite knee (KT1000)	1 wound infection 1 loose femoral screw 1 loose tibial screw 3 ligament ruptures with 1 case associated with synovitis 1 screw removal	100 % achieved full sports at 6 months
Liu et al. [7]	LARS	28	21:7	36	49	8	94.6±9.2	93	6.6±1.8		100 % <5 mm difference in anterior drawer to opposite knee (KT1000) 91 % <5 mm difference in anterior drawer to opposite knee (KT1000)		4 months
Huang et al. [8]	4-Strand ham-string	32	24:8	36	49	9	92.1±7.9	87.5	6.2±1.6				9 months
	LARS	43			29.4	6.7	80.8±2	95					100 % achieved full sports at 4 months
Fan and Fan [9]	LARS	15			18		88.9±3.3		5.03				2 months
	4-Strand ham-string	27			22		87.8±3.91		4.93				12 months
Cerulli [10]	LARS	25		46	60	10		96					
Nau et al. [11]	LARS	26	21:5	31	24	57		100		Significantly better scores for LARS at 1 year, no difference at 2 years	LARS significantly more lax at all time points (Telos®)	1 lax joint lost to follow-up 1 infected haematoma at harvest site 1 lax joint lost to follow-up	
	Bone-patellar tendon-bone	27	15:12	31	24	59		100		LARS statistically significantly better at 2 months, no difference at 1 or 2 years			
Lavoie et al. [12]	LARS	47	32:15	31.6	21.9				6.2			1 wound infection 1 tibial screw removal	

Table 2 (continued)

Author	Graft	Number of LARS	Gender M: F	Age (mean years)	Mean follow-up (months)	Mean time to surgery (months)	Lysholm	IKDC (% A and B)	Tegner	KOOS	Instrumented laxity	Complications	Return to sports
Dericks [13]	LARS	220		33.4	30							3 failures of graft fixation 3 infections	61 % achieved full sports at 4 months 83 % achieved full sports at 6 months

KOOS Knee injury and Osteoarthritis Outcome Score, ADL activities of daily living

^a Laxity testing device, Telos, Marburg, Germany

Perhaps the most feared complication is that of synovitis. Only one reported case was identified in the included studies; however, there are two case reports describing synovitis after LARS ACL reconstruction and one reported case in a LARS posterior cruciate ligament (PCL) reconstruction. One of the case reports [17] describes the patient from one of the included case series [6]; thus there are only two reported cases in the world literature of synovitis associated with LARS ACL. In the first case report a LARS ACL was used in a knee that had been injured in an improvised explosive device blast in an Australian serviceman [18]. Injuries to the knee included a medial collateral ligament injury and a posterior cruciate ligament injury which were managed conservatively, with a tibial plateau fracture and an anterior cruciate ligament rupture which were managed surgically at six weeks after injury. The surgical technique used for the ACL reconstruction was not described and comment was not passed on isometricity or tunnel placement. A large effusion and persistent laxity at nine months postoperatively prompted arthroscopic assessment. This revealed a frayed graft with abundant villous synovitis. Graft removal and arthroscopic synovectomy led to complete resolution of the synovitis by the time of revision ACL reconstruction.

In the second case report of synovitis a 26-year-old man had suffered a traumatic re-injury 2.5 years after a LARS ACL reconstruction [17]. This was initially managed conservatively, but failed to settle after six months. Radiographs demonstrated a suboptimal femoral tunnel position. At arthroscopic assessment a complete graft rupture with failure of ligamentisation was noted, as well as abundant synovial hyperplasia and haemosiderin deposition. Thus both cases of synovitis appear to be related to damage to the device, which is presumably associated with release of free PET material within the knee.

Overall the quality of available evidence is surprisingly poor for a device that has been available for over a decade. The highest quality evidence is provided by a randomised controlled trial; unfortunately assessment of outcome was not blinded and there was lack of a power calculation making observer bias and type II errors possible. The remaining studies fail to account for confounding factors such as concurrent surgical procedures or coexisting pathology. The duration of follow-up is relatively short in all studies, with the longest achieving a mean of five years. Synovitis as a potential complication is likely to present in the mid to long term and the lack of long-term follow-up to exclude this is a concern.

The studies do not address the potential benefits derived from avoiding the need for graft harvest in terms of donor site morbidity and reduced operating time. In general, the orthopaedic literature under-reports the significance of donor site morbidity as the conditions being treated with autograft carry an even greater morbidity if neglected. In studies comparing patellar tendon and hamstring autograft used in ACL reconstruction, long-term consequences from

the harvest of each are reported to have a significant prevalence (anterior knee pain and hamstring weakness, etc.) [19–23].

Conclusion

Studies to date provide observational data on the use of LARS in ACL reconstruction over the short to medium term demonstrating that LARS produces comparable outcomes to autograft reconstruction techniques; however, the current literature has poor methodological quality. Complication rates, including for graft failure and synovitis over the short to medium term, are low and comparable to autograft. Further high-quality, ideally controlled, trials with long-term follow-up are required to determine the long-term safety and efficacy of LARS. These should include an assessment of the potential costs/benefits of LARS over autograft techniques such as reduced donor site morbidity, enhanced rehabilitation, reduced surgical time and cost. The current best available evidence supports the ongoing use of LARS as a safe surgical technique over the short to medium term, but further studies will be required to determine any superiority over autograft techniques.

References

- Ventura A, Terzaghi C, Legnani C, Borgo E, Albisetti W (2010) Synthetic grafts for anterior cruciate ligament rupture: 19-year outcome study. *Knee* 17(2):108–113
- Yamamoto H, Ishibashi T, Muneta T, Furuya K, Mizuta T (1992) Effusions after anterior cruciate ligament reconstruction using the ligament augmentation device. *Arthroscopy* 8(3):305–310
- Downs S, Black N (1998) The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 52:377–384
- Phillips R, Ball C, Sackett D (2009) Oxford centre for evidence based medicine—levels of evidence. <http://www.cebm.net/index.aspx?o=1025>. Accessed 15 May 2012
- Hamido F, Misfer KA, Al Harran H et al (2011) The use of the LARS artificial ligament to augment a short or undersized ACL hamstrings tendon graft. *Knee* 18(6):373–378
- Gao K, Chen S, Wang L et al (2010) Anterior cruciate ligament reconstruction with LARS artificial ligament: a multicenter study with 3- to 5-year follow-up. *Arthroscopy* 26(4):515–523
- Liu Z, Zhang X, Jiang Y, Zeng B-F et al (2010) Four-strand hamstring tendon autograft versus LARS artificial ligament for anterior cruciate ligament reconstruction. *Int Orthop* 34(1):45–49
- Huang J, Wang Q, Shen F, Wang Z, Kang Y (2010) Cruciate ligament reconstruction using LARS artificial ligament under arthroscopy: 81 cases report. *Chin Med J (Engl)* 123(2):160–164
- Fan Q, Fan J (2008) Comparison between four-strand semitendinosus tendon autograft and ligament advanced reinforcement system for anterior cruciate ligament reconstruction by arthroscopy. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 22(6):676–679
- Cerulli G (2007) ACL reconstruction using artificial ligaments: five years follow-up. *SIOT* 33(3 Suppl 1):8238–8242
- Nau T, Lavoie P, Duval N (2002) A new generation of artificial ligaments in reconstruction of the anterior cruciate ligament. Two-year follow-up of a randomised trial. *J Bone Joint Surg Br* 84(3):356–360
- Lavoie P, Fletcher J, Duval N (2000) Patient satisfaction needs as related to knee stability and objective findings after ACL reconstruction using the LARS artificial ligament. *Knee* 7(3):157–163
- Dericks G (1995) Ligament advanced reinforcement system anterior cruciate ligament reconstruction. *Oper Tech Sports Med* 3(3):187–205
- Laboute E, Savalli L, Puig P et al (2010) Analysis of return to competition and repeat rupture for 298 anterior cruciate ligament reconstructions with patellar or hamstring tendon autograft in sportspeople. *Ann Phys Rehabil Med* 53(10):598–614
- Mihelic R, Jurdana H, Jotanovic Z, Madjarevic T, Tudor A (2011) Long-term results of anterior cruciate ligament reconstruction: a comparison with non-operative treatment with a follow-up of 17–20 years. *Int Orthop* 35(7):1093–1097
- Wright RW, Magnussen RA, Dunn WR, Spindler KP (2011) Ipsilateral graft and contralateral ACL rupture at five years or more following ACL reconstruction: a systematic review. *J Bone Joint Surg Am* 93(12):1159–1165
- Li H, Yao Z, Jiang J et al (2012) Biologic failure of a ligament advanced reinforcement system artificial ligament in anterior cruciate ligament reconstruction: a report of serious knee synovitis. *Arthroscopy* 28(4):583–586
- Glezos CM, Waller A, Bourke HE, Salmon LJ, Pinczewski LA (2012) Disabling synovitis associated with LARS artificial ligament use in anterior cruciate ligament reconstruction: a case report. *Am J Sports Med* 40(5):1167–1171
- Barenius B, Nordlander M, Ponzer S, Tidermark J, Eriksson K (2010) Quality of life and clinical outcome after anterior cruciate ligament reconstruction using patellar tendon graft or quadrupled semitendinosus graft: an 8-year follow-up of a randomized controlled trial. *Am J Sports Med* 38(8):1533–1541
- Biau DJ, Tournoux C, Katsahian S, Schranz PJ, Nizard RS (2006) Bone-patellar tendon-bone autografts versus hamstring autografts for reconstruction of anterior cruciate ligament: meta-analysis. *BMJ* 332(7548):995–1001
- Holm I, Oiestad BE, Risberg MA, Aune AK (2010) No difference in knee function or prevalence of osteoarthritis after reconstruction of the anterior cruciate ligament with 4-strand hamstring autograft versus patellar tendon-bone autograft: a randomized study with 10-year follow-up. *Am J Sports Med* 38(3):448–454
- Mastrokalos DS, Springer J, Siebold R et al (2005) Donor site morbidity and return to the preinjury activity level after anterior cruciate ligament reconstruction using ipsilateral and contralateral patellar tendon autograft: a retrospective, nonrandomized study. *Am J Sports Med* 33(1):85–93
- Sajovic M, Strahovnik A, Dermovsek MZ, Skaza K (2011) Quality of life and clinical outcome comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction: an 11-year follow-up of a randomized controlled trial. *Am J Sports Med* 39(10):2161–2169