Original article

Augmented short undersized hamstring tendon graft with LARS® artificial ligament versus four-strand hamstring tendon in anterior cruciate ligament reconstruction: preliminary results

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ARTICLE INFO

Article history:
Received 18 September 2014
Accepted 5 January 2015

Keywords:
ACL
Reconstruction
Ligament prosthesis
LARS
Augmentation

ABSTRACT

Background: This retrospective study compares the results of reconstruction of isolated chronic anterior cruciate ligament rupture using augmented short undersized sized hamstring tendon graft with ligament advanced artificial reinforcement system (LARS®) versus a four-strand hamstring tendon graft (4-SHG). Our hypothesis was that postoperative knee stability after using augmented short length or small diameter hamstring tendon graft with LARS artificial ligament could be significant and satisfactory more than 4-strand hamstring tendon graft group.

Materials and methods: Between June 2007–July 2008, 72 patients were divided into a (LARS) augmented group (n = 27) and a (4-SHG) group (n = 45).

Results: Mean FJU is 5 years. KT-1000 examinations showed that the LARS group had significantly less anterior displacement than the (4-SHG) group (P = 0.013). IKDC score demonstrated statistically significant differences (P = 0.05).

Conclusions: Our study indicates that early results of augmenting: short length or small diameter harvested hamstring tendons with LARS in ACL reconstruction provides satisfactory, comparable results and displayed higher knee stability compared to (4-SHG) group.

Level of evidence: Level III (case control study).

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1. Introduction

Once it has been established that an anterior cruciate ligament (ACL) deficient knee is in need for reconstruction, a number of different graft options are available. For the past two decades, the bone-patellar tendon-bone (BPTB) autograft has been considered the gold standard because of its osseous fixation mode, but increasingly the hamstring tendons have been used as an alternative graft due to the reduced donor site morbidity and significantly improved fixation technique. It is currently the most common graft used [1]. Regardless of the graft type, there can be a degree of morbidity following autograft harvest, which may negatively affect recovery after ACL reconstruction [1–3]. Therefore, the use of hamstring advanced reinforcement system (LARS®) artificial ligament may offer an alternative especially in case of short and undersized hamstring tendons [2–4]. LARS® artificial ligament, (Surgical Implants and Devices, Arc-sur-Tille, France) has recently reported to be a suitable device due to its special design, and satisfactory clinical results obtained following its use in ACL reconstruction [2,4–10].

Differing greatly from the older types of artificial ligaments (Dacron Ligament Prosthesis, Versigraft carbon, Kennedy LAD, Xenograft, Leeds-Keio), this generation of artificial ligaments shows encouraging clinical results as it is hydrophobic, chemically inert and has high resistance to fatigue especially flexion-torsion stresses and elongation; its porosity is favourable for fibroblastic ingrowth [2,3,8,10].

The use of LARS® artificial ligament has been gradually increased and become more popular [2.8–15].

Certain patients with short (less than 15 cm length) and small diameter hamstring tendon grafts increase the needs for augmenting such tendons [3]. Pichler et al. [16] explored the correlation between the length, cross-sectional area of the harvested
tendons and the body height and length of the femur. He stated that surgeons should be aware of the possibility of encountering insufficient length of tendon when undertaking reconstructive surgery because of anatomical variations between patients. We used LARS® artificial ligament to reinforce the short length (<15 cm) and the small diameter harvested four-strand hamstring tendon graft (less than 5.5–6 mm) in diameter which is not uncommon in our population [3,16], aiming for having the benefits of getting higher knee stability due to early revascularization and cell proliferation and thus to allow early return to unrestricted sport activity and ensure long term survival of the graft [17–21].

To our knowledge, there are no studies comparing (4-strand hamstring tendon graft) autografts and the augmented LARS® artificial ligament in ACL reconstruction.

The aim of this study was to compare the outcome of ACL reconstruction using augmented hamstring tendon graft with LARS artificial ligament versus a four-strand hamstring tendon graft (4-SHG) to assess the effectiveness of the two grafts regarding to knee stability.

Our hypothesis was that postoperative knee stability was better in LARS® augmented group.

2. Material and methods

From June 2007 to July 2008, 104 patients with isolated tear of anterior cruciate ligament were reconstructed using either (4-SHG) or (LARS) augmented graft. The diagnosis of chronic ligament tear was identified by positive lachman, s-test, anterior drawer test pivot shift test and magnetic resonance imaging (MRI). Exclusion criteria were patients less than 6 months from injury, combined ligament injury, radiological visible degenerative changes, contralateral knee ligament injury and follow-up period less than five years. Seventy-two patients fulfilled these criteria and were included. Twenty-seven patients were found having intraoperatively either short hamstring tendons (<15 cm length) or small diameter harvested four-strand graft (less than 6 mm diameter); they were reconstructed with augmentation using LARS® artificial ligament. Forty-five patients were reconstructed with (4-SHG). Each patient was informed in details regarding to the nature of his injury, possibility of augmentation of the harvested graft with LARS® artificial ligament and the surgical procedure. The patients gave the informed consent prior being included into the study; the study was authorized by the local ethical committee and was performed in accordance with the Ethical standards of the 1964 Declaration of Helsinki as revised in 2000.

The two groups were comparable in terms of gender, age, cause of injury, time from injury to surgery and preoperative Lysholm and Tegner scores. All procedures were done by one senior surgeon (FH) (Table 1).

2.1. Surgical technique

Reconstruction was done under arthroscopic control. The ACL stump with synovial covering was preserved as much as possible. The semitendinosus and gracilis tendon were harvested through 2–3 cm incision medial to the tibial tuberosity. In the (4-SHG) group, the tendons were prepared to form a quadruple strand graft. In case of short length or small diameter tendons, LARS Artificial ligament (3.5 mm) diameter was used to reinforce the tendons with web stitch sutures using coated vicryl rapide 2-0 (Fig. 1A and B). The relative size of the 4-strand augmented LARS graft was (8–9 mm) in diameter as the same as (4-SHG). All the patients underwent arthroscopic single bundle ACL reconstruction (Rigidfix technique Mitek Johnson & Johnson), the tibial tunnel was drilled using the aiming guides. For the femoral tunnel, an appropriate femoral offset guide placed the positions of 2 O’clock and 10 O’clock for left and right knees, respectively. Transitibial drilling of the femur at the correct position to depth of 30 mm. Using the (Mitek) transtibial cross-pin guide, two cross-pin locking holes were fashioned from the lateral aspect of the femur to fix femoral end of the graft with two Rigifx cross-pins (Mitek) once the graft had been drawn into the femoral tunnel to a depth of 30 mm. After tensioning, the tibial end of the graft was fixed with a bioabsorbable screw (Fig. 2).

### Table 1

Demographics in LARS® and 4-SHG groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Male/female</th>
<th>Mean age at surgery</th>
<th>Cause of injury</th>
<th>Mean time to surgery (months)</th>
<th>Lysholm Score (mean ± SD)</th>
<th>Tegner Score (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LARS® (n = 27)</td>
<td>27/0</td>
<td>24 (21–35)</td>
<td>Traffic, Fall</td>
<td>7 (6–31)</td>
<td>43.6 ± 3.6</td>
<td>3.6 ± 0.7</td>
</tr>
<tr>
<td>4-SHG (n = 45)</td>
<td>44/1</td>
<td>20 (18–31)</td>
<td></td>
<td>8 (6–29)</td>
<td>42.3 ± 5.2</td>
<td>3.3 ± 0.3</td>
</tr>
</tbody>
</table>

Rehabilitation protocol was the same in the two groups. Quadriceps isometric closed kinetic-chain exercises and straight leg raises were initiated as early as possible. Knee flexion began from 45° and increased gradually to complete flexion and extension within the first week. Crutches were used for 3 weeks. Static stepping for balance was allowed for the first few weeks followed by full weight bearing after 4 weeks postoperatively. Cycling was permitted 4–5 weeks postoperatively. Patients usually returned to normal daily activity and allowed to participate in non-competitive sports, which did not include pivoting sports or recreational skiing in four months, and returned to sport activity after six months.

2.2. Evaluation

The minimum follow-up was 58 months and the mean follow-up was 59 months (range 58–62 months). All the examinations and results were evaluated at follow-up by a single orthopaedic surgeon (TA) who was not involved in the patient care. All patients evaluations were performed pre- and postoperatively by clinical examination, a patient satisfaction questionnaire [Knee Injury and Osteoarthritis Outcome Score (KOOS)] [22], measurement of joint laxity with the KT1000 arthrometer (Med metric, San Diego, California), the International Knee Documentation Committee objective Scale (IKDC) [22,23], Lysholm, Tegner activity scores and radiological evaluation [24].

2.3. Statistical analysis

The data at the latest follow-up were statistically analysed with SPSS 11.0 software (Nie, Bent and Hull) – Chicago. The results were compared between the two groups using (t-test) for continuous measurements, Chi² test for nominal data and Wilcoxon signed rank test for ordered categorical variables, respectively. P value of <0.05 was considered statistically significant.

3. Results

Patients in both groups had no immediate postoperative complications that required revision or readmission. One patient in 4-SHG group felt paraesthesia on the medial side of the knee recovered around 9 months postoperatively, one patient in (4-SHG) group developed type 2 arthrofibrosis that “required” arthroscopic lysis and patient achieved full knee flexion with loss of last 5–10° of extension. Mean side-to-side difference with KT-1000 was 1.1 ± 0.3 mm and 2.5 ± 0.5 mm in LARS® group and (4-SHG) group, respectively (P=0.013). The side-to-side difference was less than 3 mm in 24 patients (92%) in the LARS® group and 32 patients (71%) in the (4-SHG) group.

The stability results showed that the LARS® group had significantly less anterior displacement than the (4-SHG) group (Table 2).

The mean Lysholm scores were 95.3 ± 7.3 and 90.1 ± 6.9 (P=0.239), and the mean Tegner scores were 7.4 ± 1.8 and 6.7 ± 1.5 (P=0.368) in LARS® group and 4-SHG group, respectively.

In terms of IKDC, 26 patients (96.3%) in the LARS® group and 39 patients (85.5%) in the 4-SHG group were graded as normal or nearly normal at 2 years follow-up (P=0.215). Twenty-six patients (96.3%) in the LARS® group and 32 (71.1%) patients in the 4-SHG group were graded as normal or nearly normal at 5 ± years follow-up (P=0.05) (Table 3).

KOOS pain score averaged 81.2 and 84.6, KOOS symptoms score (stiffness, swelling, catching) averaged 78.2 and 86.3 while KOOS activities of daily living averaged 92 and 94.2 in the 4-SHG group and LARS group respectively, but there were no significant differences (P=0.308). Radiological evaluation during and at 5-year follow-up showed no marked osteoarthritic changes.

4. Discussion

The purpose of this study was to compare the results of ACL reconstruction using either LARS® augmented graft or 4-SHG. The most important finding of the present study is that using LARS® augmented graft in patients with short and undersized harvested hamstring tendons gives superior results than 4-SHG in terms of laxity. In terms of IKDC, LARS® augmented group has significantly better results than 4-SHG group at 5-year follow-up.

Graft tissue revascularization starts within the first 2 to 4 weeks after surgery, highest vascular density in the graft tissue is found at 6 weeks and reaches an end point compared with the vascular status of the native ACL after approximately one year [18–21,25]. Autogenous grafts are thought to be weaker than artificial substances at implantation and undergo a period of morphological change with further weakening [24].

Artificial reconstruction of the ACL with the use of various materials was recommended in early 1980s. The following old types of artificial ligaments were analyzed biochemically and histologically: GORE-TEX (W.L. Gore and Co., Flagstaff, Ariz.), Dacron Ligament

### Table 2
Postoperative KT-1000 examination results at 5 years follow-up.

<table>
<thead>
<tr>
<th>Group</th>
<th>Side-to-side difference (No. of pts)</th>
<th>Average (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LARS® (n = 27)</td>
<td>&lt; 3 mm 3–5 mm 6–10 mm &gt; 10 mm</td>
<td></td>
</tr>
<tr>
<td>4-SHG (n = 45)</td>
<td>24 3 0 0</td>
<td>1.1 ± 0.3 mm</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>P = 0.013</td>
</tr>
</tbody>
</table>

### Table 3
IKDC Score.

<table>
<thead>
<tr>
<th>Final IKDC results</th>
<th>LARS® group (n = 27)</th>
<th>4-SHG group (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative 2nd year postop 5th year postop</td>
<td>Preoperative 2nd year postop 5th year postop</td>
</tr>
<tr>
<td>Normal A</td>
<td>0 21 20</td>
<td>0 32 26</td>
</tr>
<tr>
<td>Nearly normal B</td>
<td>0 5 6</td>
<td>0 7 6</td>
</tr>
<tr>
<td>Abnormal C</td>
<td>10 1 1</td>
<td>17 6 11</td>
</tr>
<tr>
<td>Severe abnormal D</td>
<td>17 0 0</td>
<td>28 0 2</td>
</tr>
<tr>
<td>P = 0.05</td>
<td></td>
<td>P = 0.215</td>
</tr>
</tbody>
</table>

Prosthesis (Stryker), Versi-graft carbon, Kennedy LAD (3 M company USA), Xenograft, Leeds-Keio by (Xiros, Leeds (UK)). All these ligaments proved to induce synovitis [11–15].

LARS® artificial ligament is made of industrial strength polyester fibers (polymethylene terephthalate). Resistance to traction varies with the number of the longitudinal fibers. These resistances are approximately 1500 N for 30 fibers up to 4700 N for 100 fibers. This patented structure allows a high resistance to fatigue especially flexion-torsion stresses and elongation, and its porosity is favourable for fibroblastic ingrowth. The LARS(R) ligament is minimally elastic. Under persistent traction of 1700 N and relaxation over 24 h, the length increased less than 1.5% [10,11,14,15,26].

Trieb et al. [17] stated that biopsies taken from LARS(R) 6 months after implantation show a complete cellular and connective tissue ingrowth. The fibroblasts and osteoblast-like cells encapsulated the ligament fibers by building a cellular net around them; this mechanism might explain the strength and the inert behavior of the ligament without synovitis shown in clinical studies.

Nau et al. [10] conclude that reconstruction of the ACL using the LARS(R) ligament in chronic ACL-deficient patients gives high patient satisfaction during the first 24 months. The results suggest that full return to activity may be achieved earlier and may offer the possibility of a shorter period of rehabilitation especially in the field of sports medicine. The encouraging early results using the LARS(R) ligament are to be maintained, as it could reduce the current prejudice against the use of artificial ligaments.

Bin Li et al. [5] demonstrated in their comparative study that the use of LARS® artificial ligament for posterior cruciate ligament (PCL) reconstruction is clinically more useful than using a 4-SHG regarding restoration of both the knee stability and the knee function.

Beauffils et al. [13] analyzed the results of PCL reconstruction with adjunction of a LARS® ligament for major recent isolated or combined laxity of the posterior cruciate ligament. They conclude that synthetic ligament acts as a tutor for healing of the torn ligament.

There is no available studies in the current literature evaluating the strength of LARS® augmented hamstring tendon graft and after and the course of ligamentization and comparing it with 4-SHG in terms of restoration of the knee function and stability. In this study, better knee stability outcome is obtained in the LARS® augmented group despite the worst scenario (thin or short hamstrings grafts). The strength of 4-SHG decreases after reconstruction by elongation as it undergoes a period of morphological changes with further weakening.

Recently, Ventura et al. [27] evaluated prospectively the outcome of ACL reconstruction using polymethylene terephthalate (PET) artificial ligaments in sportsmen, with a follow-up extending to 19 years. They suggest that artificial ligaments could contribute to the establishment of the degenerative osteoarthritic process.

In our study, we did not find any sign of marked osteoarthritis in LARS® group nor clinical evident synovitis.

This study has some limitations. The total number of patients is not large and the mean follow-up is not too long. The design is non-randomized and retrospective.

Our study indicates that reinforcing short length or small diameter harvested hamstring tendons with LARS® in ACL reconstruction gives higher knee stability and satisfactory comparable results compared to (4-SHG) group.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References