International Orthopaedics (SICOT)
DOI 10.1007/s00264-014-2495-7

ORIGINAL PAPER

A comparison of ACL reconstruction using patellar tendon versus hamstring autograft in female patients: a prospective randomised study

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Received: 21 May 2014 / Accepted: 17 July 2014

Abstract
Purpose The incidence of an anterior cruciate ligament (ACL) tear is highest in female patients; however, it is not apparent whether graft choice affects clinical results. The aim of this prospective randomised study was to evaluate clinical results of an ACL reconstruction using patellar tendon [bone–patellar tendon–bone (BTB)] or hamstring graft (HS) in female patients.
Methods Inclusion criteria were traumatic instability, no signs of osteoarthritis, no previous instability and no contralateral knee instability. Inclusion criteria were met in 150 patients, mean age 26 (17–47) years. Patients were randomised into two groups of 75 patients according to graft type; all had the same rehabilitation protocol. Tegner Lysholm knee score and stability were evaluated pre-operatively and one and two years postoperatively. The difference between groups was statistically evaluated using unpaired *t* test.
Results Of the 150 patients, all completed one year follow-up; three were lost to follow-up at two years. There was no significant difference in functional scores and knee stability between groups. The HS group had significantly less anterior knee pain in the first six months postoperatively.
Conclusion ACL reconstruction significantly improves clinical results and stability of the knee. Difference in Lysholm score and stability between groups was not significant. Neither group showed higher tendency to graft failure within two years. Graft choice for reconstruction in female patients should be surgeon specific and individualised, as both grafts studied achieved comparable results.

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Published online: 17 August 2014

Keywords ACL reconstruction · Graft comparison · Female patients · ACL · Clinical outcome

Introduction

Anterior cruciate ligament (ACL) injury is a common cause of knee instability, and the most common method of treatment is an ACL reconstruction. The incidence of an ACL injury is rapidly growing in the female population [1]. According to epidemiologic studies, women are nine times more vulnerable to an ACL tear and resulting instability [2]and are also more vulnerable to repeated ACL reinjury after reconstruction [3].

ACL injury causes limitation to the level of activity and sports performance due to symptomatic instability. There is also a high prevalence of osteoarthritis (OA) of the knee in patients with a deficient ACL [4]. The onset of OA is within 13 years of injury, regardless of treatment method [5, 6]. Therefore, ACL reconstruction is suitable for patients willing to return to their previous level of activity, and it provides good clinical results. The most frequently used grafts are the patellar tendon graft [bone–patellar tendon–bone (BTB)] and semitendinosus-gracilis hamstring graft (HS). There are no exact indication criteria for different reconstruction graft types. Therefore, graft choice is surgeon dependent and patient specific. Each graft type has its specifications considering graft harvesting, preparation and fixation. HS graft fixation is more demanding than BTB grafts, and with the development of new fixation methods, HS grafts provide comparable results in knee stability [7]. Graft preparation and preconditioning is also vital for HS graft function [8]. On the contrary, graft harvesting-site morbidity, such as hypesthesia or numbness, anterior knee pain, scar-related pathology and limitations of full extension is higher in BTB grafts early postoperatively.

Female patients comprise 60 % of our patients, so we evaluated results selectively for female patients. A large number of studies compare the two main types of ACL grafts, but few studies are gender specific. Our aim was to prospectively compare functional long-term results of an ACL reconstruction using BTB and HS grafts on a cohort of female patients. The study's null hypothesis was that there would be no significant difference in knee stability between groups; however, we assumed there would be a difference in knee range of motion (ROM) and anterior pain.

Materials and methods

Inclusion criteria for the study were ACL deficiency due to recent trauma, with clinical signs of instability, no signs of OA grade II or worse on radiographs, no previous history of knee instability and no clinical contralateral knee instability. One hundred and fifty patients indicated for primary ACL reconstruction and met inclusion criteria were randomised into two groups using the envelope method. Each group consisted of 75 patients: group 1 had reconstruction using a BTB graft and group 2 had an HS graft. Mean patient age was 26 (17–47) years. Postoperative Tegner–Lysholm knee scoring scale (Lysholm) is shown in Table 1; knee stability, anterior knee pain and complication rates were compared. Return to previous sports activity was also recorded for athletes in competitive sports. There were four professional- and 35 amateur-level athletes in the BTB group and six professional- and 36 amateur-level athletes in the HS group. The remaining patients were not in competitive sports. Average time after knee injury was 2.5 months (two days to six months). All patients had the same standardised rehabilitation protocol (Table 2).

Surgical technique

All patients were treated according to the standards for an ACL reconstruction in our department at the time of the study. Tibial tunnel positioning was standardised in both groups using the same instrument set (Arthrex, Naples, FL, USA). The tibial tunnel was targeted in the centre of the footprint of the native ACL using a tibial guide. The femoral tunnel was targeted transtibially using a standard femoral guide. Targeting was performed to leave a 2- to 3-mm posterior wall of the femur and was aimed at the 11 or 2 o'clock position, respectively. For BTB graft fixation, we used a combination of crosspin femoral and interference-screw tibial fixation. In the HS graft group, we used a suspension femoral fixation and interference-screw tibial fixation. The choice of screw diameter was 2-mm less than the bone-tunnel diameter for BTB graft and 1-mm greater than the bone-tunnel diameter for HS graft. Surgery was performed by three surgeons experienced with ACL reconstructions. All patients were clinically evaluated by a single surgeon according to a standardised protocol.

Postoperative follow-up was two years, with a minimum of one year. Lysholm score was evaluated preoperatively, six weeks, three months, six months and one and two years postoperatively, knee stability was evaluated at the same time and compared with the contralateral knee. Graft failure and re-arthroscopy rates were recorded. Instrumented Lachman's test was used to objectively assess knee stability using the Rolimeter device. At first the healthy contralateral knee was evaluated using a calibrated Rolimeter device that records the anterior shift of the tibia in millimeters, then the knee with reconstructed ACL was measured. The difference between the obtained values was recorded as a level of knee stability; difference in knee laxity of up to 2 mm compared with the contralateral knee was considered normal and abnormal knee laxity was considered if the difference was > 5 mm. Mean values between graft groups were then compared and tested for statistically significant difference ($p=0.05$). Anterior knee pain based on the visual analogue scale (VAS) and postoperative complications such as infection, haematoma and deep venous thrombosis (DVT) and restriction of movement were recorded.

Statistical analysis

Results were compared and statistically evaluated using the unpaired t test. All descriptive values are stated as a mean ± standard deviation (SD). Both groups comprised 75 patients each at the start of the study. The p value was set to 0.05 as a level of significance.

Results

Of the 150 patients, 147 completed the full follow-up period. In the BTB group, 74 patients (98 %) and the HS group 73 (97 %) completed the follow-up period. All patients completed at least one year of follow-up. The main objective of this study was to evaluate clinical knee scores for both groups using the Lysholm score (Table 3). Pre-operatively, the mean knee score was 56 for the BTB group and 52 for the HS group. In both groups, the score improved significantly after surgery ($p<0.01$). The highest increase was within the first three months postoperatively. At six weeks, results were 74 in the BTB group and 77 in the HS group; at three months, further improvement was found in 84 and 85, respectively. At two years, no significant difference in knee score was found between groups, with a mean score of 88 ad 90 for BTB group and HS, respectively ($p=0.30$).

Pre-operatively, mean Lachman's test laxity was 11 mm for the BTB group (range 7–14 mm) and 10.6 mm (range 6–15 mm) for the HS group. At 6 weeks postoperatively, mean

Table 1 Results according to Tegner Lysholm Knee Scoring Scale (< 65 poor; 65–83 fair; 84–90 good; 91–100 excellent)

Patient number and characteristics according to results		
Section 1: limp	Section 2: support	Section 3: pain
None: 5	None: 5	None: 25
Slight or periodic: 3	Stick or crutch: 2	Inconstant and slight during severe exertion: 20
Severe and constant: 0	Weight bearing impossible: 0	Marked during severe exertion: 5
		Marked on or after walking > 2 km: 10
		Marked on or after walking < 2 km: 5
		Constant: 0
Section 4: Instability	Section 5: Locking	Section 6: Swelling
Never giving way: 25	No locking or catching sensations: 15	None: 10
Rarely during athletics or other severe exertion: 20	Catching sensation but no locking: 10	On severe exertion: 6
Frequently during athletics or other severe exertion (or incapable of participation): 15	Locking occasionally: 6	On ordinary exertion: 2
Occasionally in daily activities: 10	Frequently: 2	Constant: 0
Often in daily activities: 5	Locked joint on examination: 0	
Every step: 0		
Section 7: Stair-climbing	Section 8: Squatting	
No problem: 10	No problem: 5	
Slightly impaired: 6	Slightly impaired: 4	
One step at a time: 2	Not beyond 90°: 2	
Impossible: 0	Impossible: 0	

knee laxity in the BTB group was 0.6 mm (0–1 mm) and 0.5 mm (0–2 mm) in the HS group. No patient had knee laxity evaluated as abnormal, and at one and two years, it was the same for BTB graft group [1 mm (0-12 mm)]. One patient in the BTB group did not attend the two year follow-up. Between one and two years postoperatively, three patients (4 %) were arthroscoped again for recurrence of knee instability (subjective and clinical). Two of these patients had a repeated knee injury during sport activity, with a finding of graft rupture in the second follow-up year. The third patient had an extension deficit of 10° and increasing anterior knee pain, and a graft-versus-cyclops lesion was found, with no evidence of graft failure. Extension improved to full extension after surgery.

For the HS group, knee laxity at one year was 1.0 (0–6) mm and at two years was 1.3 (0–10) mm. Two patients were lost to follow-up at two years in the HS group. In this group, four patients (5 %) were arthroscoped again for recurrence of knee laxity and meniscal lesion during the second year of follow-up. In two of the patients, graft failure was found without any record of recent trauma; the other two patients sustained a new injury in competitive sports, and the finding was traumatic graft rupture (Table 4).

The BTB group showed slightly better mean knee laxity, but there was no significant difference between groups (p= 0.62) (Table 4). The rate of re-arthroscopy was comparable between groups, with no statistical difference (p=0.70). The

Table 2 Rehabilitation protocol

	Weight bearing	Quadriceps/hamstring exercise	Range of motion exercise	Activity
Stage I (0–2 weeks)	1/3 weight, crutches	Isometric quadriceps exercise	Passive 0–90°	Bedrest, cryotherapy, standing, short ambulation with crutches
Stage II (2–6 weeks)	1/2–2/3 weight, crutches	Closed-chain exercises, isometric exercise	Passive/active 0–90°	Continuous ambulation with crutches
Stage III (6–12 weeks)	Full	Eccentric quadriceps strengthening, isokinetic hamstring strengthening	Full	Bicycle ergometer, walking
Stage IV (3–6 months)	Full	Eccentric quadriceps strengthening, isokinetic hamstring strengthening, open-/closed-chain exercise	Full	Jogging, bicycle, balance training, squats, running

Table 3 Tegner–Lysholm knee score comparison

	Preoperatively	6 weeks	3 months	6 months	1 year	2 years
Patellar tendon (BTB)	55 (±9.0)	75 (±4.0)	84 (±5.4)	86 (±4.9)	88 (±5.3)	88 (±7.5)
Semitendinosus–gracilis (HS)	52 (±8.9)	77 (±4.1)	85 (±5.5)	88 (±5.0)	89 (±6.0)	90 (±7.6)
Difference (*p* value)	Not significant $p=0.09$	Not significant $p=0.10$	Not significant $p=1.00$	Not significant $p=0.98$	Not significant $p=0.42$	Not significant $p=0.30$

BTB bone–patellar tendon–bone, *HS* hamstring graft

absolute value of knee stability did not influence the Lysholm knee score and clinical outcome.

In the BTB group 19 of the 39 athletes returned to their original level of activity during the follow-up period, with an average of 8.3 (five to 13) months, 15 patients returned to a lower level and five did not return to sports activity. In the HS group, 26 of the 42 athletes returned to their preinjury level of sports activity during the follow-up, with an average time of 7.8 (4.5–14) months, 12 returned to a lower level and four did not return to competitive sport. The only significant difference was in anterior knee pain based on the VAS (abnormal pain was considered ≥ 3 of 10): 20 % of patients (15 of 75) in the BTB group experienced abnormal anterior knee pain compared with only 6 % (six of 75) in the HS group during the first six months after the surgery ($p=0.020$). At two years, the difference decreased to 6 % and 2 %, respectively, which was not significant ($p=0.15$). Complication rates were comparable for both groups, with DVT rate of 6 % for both groups (four in each group) and one superficial wound infection for the HS group. These complications were treated with no clinical sequelae. We also recorded one case of severe restriction of knee extension in the BTB group due to cyclops lesion, which was treated surgically.

Discussion

Results of this study show that in a controlled group of female patients undergoing the same surgical technique and postoperative rehabilitation protocol, there was no significant difference in Lysholm knee score and knee laxity between BTB and HS grafts. Our results are in contrast with recent findings of multicentre studies from Scandinavian registers [9, 10], which report that HS grafts have worse results at two years postoperatively; however, in our study, HS grafts appear to be accepted much better subjectively by patients and have comparable results in knee scores as with BTB grafts. In Scandinavian registers [9, 10], large groups of patients were evaluated, but these patients were treated under different conditions in various departments, and when compared with our results, this may indicate that results are more dependent on surgical technique and postoperative protocol than on graft type. The rate of graft failure in our study was lower than presented by Ageberg et al. [11]. Evaluation of female patients showed a low revision rate and comparable clinical results. Based on our results, and as female patients have worse postoperative results, we are planning a prospective study to evaluate sex differences after ACL reconstruction.

Comparison of the long-term results of the two main graft types is a subject of many studies. Initially, the BTB graft was considered to produce better knee stability over HS graft. It was preferred for its superior osteointegration and healing properties. On the contrary, BTB graft has higher early harvesting-site morbidity [12]. The introduction of new fixation methods of HS grafts has helped minimise graft fixation issues that were responsible for graft failure or a higher knee laxity [13]. In our patient group, we found no issues related to graft fixation, such as failure.

Several studies show superior stability of BTB over HS grafts. Gobbi [14] reported that women have greater knee laxity after HS grafts compared with men. In the BTB group, there was no significant difference at 36 months postoperatively. On the contrary, previous findings that anterior knee pain may reduce patient compliance with postoperative protocol emphasise the use of HS grafts. Aggravation of anterior knee pain early after surgery is commonly present in the BTB group [15]. Feller [16] also reported that pain in the early postoperative period may alter patient compliance with the rehabilitation protocol. Outcomes of our study for a female population support these findings. We assumed that the anterior knee pain would influence significantly the knee score postoperatively in female patients postoperatively, as significantly higher pain was observed in the BTB group 6 months postoperatively. However, at two years postoperatively, the difference was no longer significant. The influence of knee pain on Lysholm score appeared to be compensated by slightly superior stability of the knee in BTB grafts during the early postoperative period. Struewer [17] et al. studied the clinical outcomes of ACL reconstruction in patients > 50 years. They found no significant difference between HS and BTB grafts. Clinical outcome was very good despite the fact that 30 % of patients developed signs of OA. Functional outcome was more dependent on knee stability than on X-ray findings. This study suggests that age is not a contraindication for ACL reconstruction and that even in this group, graft choice is patient specific, as the clinical outcome was comparable.

Table 4 Knee stability and revision rate

	Preoperatively	6 weeks	3 months	6 months	1 year	2 years	Re-arthroscopy
Patellar tendon (BTB)	11 mm (±1.8)	0.6 mm (±0.5)	0.8 mm (±0.8)	0.6 mm (±0.7)	1 mm (±1.1)	1 mm (±2.0)	3
Semitendinosus-gracilis (HS)	10.6 mm (±1.8)	0.5 mm (±0.6)	1.1 mm (±0.8)	0.9 mm (±0.8)	1 mm (±1.0)	1.3 mm (±2.1)	4
Difference (*p* value)	Not significant $p=0.154$	Not significant $p=0.300$	Not significant $p=0.055$	Not significant $p=0.064$	Not significant $p=0.941$	Not significant $p=0.624$	Not significant $p=0.701$

BTB bone–patellar tendon–bone, *HS* hamstring graft

Sañudo [18] reports a difference in muscle activation during exercise between women and men. In women, there is higher preactivity in HS muscles prior to strenuous exercise, which may cause the gender-specific difference, as HS muscles are more important in females during sporting activity. In female athletes, muscle activation rates for quadriceps muscles grow with the level of exercise, whereas HS show very low difference in activation [19]. This increases the quadriceps/hamstring activation ratio, which increases the risk of rotational knee injury during sport activity. However, long-term comparison between graft types does not show a higher rate of failure of HS grafts. Rotational stability is the important issue in female patients due to this muscle activation ratio.

A limitation of our study is in femoral tunnel placement. Transtibial aiming of the femoral tunnel was used, as this was common practice in our department during the time of the study. After the year 2000, research concentrated on the biomechanical properties of an ACL and rotational stability, as long-term results with transtibial femoral tunnel placement were not optimal [20]. The double-bundle techniques and partial ACL augmentation were introduced, which are more commonly used with good clinical results. This more anatomic approach to graft positioning ensures better knee function and minimises the risk of graft failure [21]. Currently, the more anatomic approach to femoral tunnel placement is recommended, and aiming of the femoral tunnel through the anteromedial portal should be used [22]. This more anatomic placement of the femoral tunnel ensures better rotational stability, reduces the risk of ACL impingement during flexion and may influence long-term results [23]. However, as transtibial aiming was used for all patients in our study, the positioning of the femoral tunnel did not bias our comparative results but only affected long-term outcome.

The other aspect of the different graft types is dynamic thigh muscle strength postoperatively. As described by Ageberg [24], patients with HS graft have inferior knee flexion strength compared with patients with BTB graft. HS grafts are responsible for stabilising shear forces acting in the knee during pivoting sports activities. On the contrary, patients with PT grafts have lesser quadriceps strength after surgery. Quadriceps muscle strength is important in general knee stabilisation and during various sports activities, such as running, kicking or jumping [25, 26]. According to these studies, we found limitations in our study design. We did not evaluate muscle function and strength, which are also important for long-term results. However, again, there was no difference in long-term results of knee stability in women, as reported by Gobbi [14].

Genuario et al. [27] evaluated the cost-effectiveness for three main graft types: HS, BTB and allograft. In their study, HS grafts were the most cost-effective for an average patient, which might, however, be different for individual patient scenarios. As results of comparison studies show that functional outcomes of reconstruction using different graft types are comparable, cost-effectiveness is also a factor that can influence surgeons to prefer one graft type over the other.

Conclusions

Our results demonstrate no significant differences in Lysholm knee score and knee laxity two years postoperatively and no significant difference in postoperative complications such as DVT or deep infection, but there was a significantly higher incidence of anterior knee pain early postoperatively in patients in the BTB group. Rehabilitation and regaining full ROM of the operated knee was faster in the HS graft group. The return rate to preinjury sports level was comparable for both graft types. According to these results, either graft may be used for ACL reconstruction in female patients and be based on surgeon preference, because there was no significant difference in long-term results between groups.

Acknowledgments The study was supported by the grant project GAČR - P304/10/0326 and the research institution grant project No. 00064203. Authors acknowledge the kind review input to the manuscript by Robert LaPrade and Bruce Reider.

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