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ORIGINAL PAPER

Hamstring tendon autograft versus fresh-frozen tibialis posterior allograft in primary arthroscopic anterior cruciate ligament reconstruction: a retrospective cohort study with three to six years follow-up

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Abstract
Introduction Selection of various grafts for anterior cruciate ligament (ACL) reconstructions have been employed in order to improve on stability and function of the knee. This study aimed to compare stability and function of the knee after ACL arthroscopic reconstruction by single-loop tibialis posterior (TP) allograft and four-strand hamstring tendon (HT) autograft.
Materials and methods The retrospective cohort study included 104 patients in the TP group matched with 118 patients in the HT group in terms of demographic characteristics, associated meniscus injury, subjective and objective knee characteristics. All patients were followed up for at least three years with regards to mentioned criteria and time of return to former activities.
Results The mean (range) age of TP (88 males and 16 females) and HT (99 males and 19 females) groups was 34.4 (19–48) and 36.9 (20–51) years, respectively. Median (range) follow-up durations were 55 (37–71) and 56 (36–72) months, respectively. No significant differences were observed post-operatively, regarding subjective and objective evaluations. Additionally, time duration for return to former activity was similar in both groups. Post-operative paresthesia and numbness of medial aspect of the calf were observed for two months in eight patients of the HT group which persisted to the final visit in one case. No similar symptom was seen in the TP group.
Conclusion In arthroscopic ACL reconstruction, fresh frozen doubled TP allograft compared to HT autograft was equally effective in restoring function and stability of knee, permitting return to former activities.
Level of evidence Retrospective comparative, Level III

Keywords Anterior cruciate ligament · Hamstring tendon · Tibialis posterior tendon · Autograft · Allograft · Functional outcome

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Abbreviations

AATB	American Association of Tissue Bank
ACL	Anterior cruciate ligament
BPTB	Bone-patellar tendon-bone
HT	Hamstring tendon
HTA	HT autograft
IKDC	International Knee Document Committee
MRI	Magnetic resonance imaging
ROM	Range of motion
SSD	Side to side difference
TP	Tibialis posterior
TPA	TP allograft

Introduction

Anterior cruciate ligament (ACL) reconstruction has been performed with various autografts and allografts [1]. Generally, arthroscopic ACL reconstruction includes tendon autografts such as hamstring tendon (HT) and bone-patellar tendon-bone (BPTB) or tendon allografts such as patellar, tibialis posterior (TP), tibialis anterior and Achilles tendons [2–7]. In recent decades, HT has been employed more often, as the introduction of a new fixation method promoted acceptable stability and good performance results [4, 8, 9]. Advantages of allograft include absence of donor site morbidity, minimization of incision length, surgery time and post-operative pain, maintenance of normal mechanisms of flexor and extensors, better cosmetic results, lower incidence of arthrofibrosis and larger size graft [1–4, 10]. However, risk of infection transmission has prevailed, which can be prevented by serological and microbiological donors' screening, aseptic graft harvest and suggested methods of sterilization [10].

Although using single-loop TP allograft was evaluated and considered as biomechanically acceptable [11, 12], the number of studies with long-term follow-up on its functional and clinical outcomes are quite scarce. Therefore, the aims of the present study were to evaluate and compare stability and function of knee after ACL arthroscopic reconstruction between single-loop TP allograft (TPA) and 4-strand HT autograft (HTA).

Materials and methods

Ethical statements

The protocol of this study was approved by the Local Ethical Committee of Guilan University of Medical Sciences. The study was designed based on the Declaration of Helsinki. Advantages and disadvantages of both methods were explained to the patients and informed consent was obtained before their inclusion.

Participants and settings

The sample size was determined by taking objective and subjective criteria into consideration, and also based on a previous study which indicated the requirement of at least 85 patients in each group [13]. We considered larger sample size with the addition of a 20 % drop out. Therefore, all patients who underwent surgery between September 2007 and September 2010 by the senior author (MMK) were evaluated. The surgeon preferred to use TPA in the obese patients with body mass index > 40, because of harvesting difficulties, and in women to avoid small size HTA. Skeletally mature patients, aged 19–55 years, initially diagnosed ACL tear by magnetic resonance imaging (MRI), with at least two weeks' interval from the time of injury until full range of motion (ROM) were included. Our exclusion criteria were having meniscal tear which led to subtotal or total meniscectomy or meniscal graft, indication for major cartilage restoration or resurfacing, associated fracture, history of ligament injury, ipsilateral or contralateral knee surgeries, no agreement for study participation or follow-up sessions.

Demographic information, associated injuries, objective characteristics such as side to side difference (SSD) and ROM and subjective characteristics such as visual analogue scale (VAS), Lysholm score, and International Knee Document Committee (IKDC) were obtained from all included patients. All patients were followed-up for the next three years from 2010 to 2013 and both groups received similar peri-operative care.

Surgical technique

Autogenous HT was harvested using conventional technique as described previously [9]. TP grafts were provided from a certified soft tissue bank. Allografts were non irradiated fresh frozen type. Serological and microbiological tests were performed on the donors in accordance with American Association of Tissue Bank (AATB) Standards for Tissue Banking [14]. On the day of surgery, the allograft tendon was transported to the hospital on dry ice and under temperature controlled conditions (−70 to −60 °C). Packaging and expiry dates were checked before use and the grafts were immersed in sterile saline, warmed to 37 °C for 30 minutes. No antibiotics were added to the solution and grafts were used within one hour at room temperature.

Krackow suture number 5 Ethibond (Ethicon, NJ, USA) was used for both ends of the HT and TP tendons. Both tendons were folded in half and looped on a Cortico Femoral Ancrage (ORTHOMED, St Jeanet, France) to result in a four-strand and double strand, respectively. Tibial and femoral tunnels were reamed using anteromedial portal technique as previously described [9]. The tibial side was fixated by a MISBIO® Bio-absorbable interference screw (ORTHOMED, St Jeanet, France). In patients with meniscus injury beyond repair, partial meniscectomy was performed.

Post-operative protocols

Post-operative evaluations were conducted by the same orthopaedic surgeon. Briefly, the knee was placed in a brace in an extension position and both groups had a similar rehabilitation period. Immediate post-operative non-weight bearing leg raising exercise was instituted to reinforce the quadriceps muscle and prevent extension loss. One day after the surgery, the brace was opened and hamstring, gastrocnemius and soleus muscle stretching were instructed along with passive knee

motions. A Bledsoe brace was prescribed from 0 to 90° flexion from post op day one. ROM was gradually increased till the fourth week after surgery. Patients were made to walk with crutches during this period and encouraged to bear weight. At the end of the first month, the brace was discontinued and patients were instructed to discard crutches. They were allowed to have limited sports activities that included exercising on a stationary bicycle in the third month. Return to former sports activities after six months was observed in patients with good interaction. In others, muscle strengthening programs were continued till the ninth month, followed by return to sport activities.

Outcome measures and follow-up

Post-operative maximum passive knee ROM was measured once every week from the second to eighth week. Monthly follow-up for six months, re-evaluation after one year followed by a final visit were performed. Activity levels that included walking without crutches, normal activity, walking fast and sports exercises were recorded. Anteroposterior laxity SSD was measured and recorded at pre-operative and final visits using a KT-1000 device (MedMetric Inc, San Diego, USA). Less than 3 mm difference between two sides was considered as treatment success, between 3 and 5 mm as borderline failure, and more than 5 mm was identified as failure [1, 4, 10]. A standard form of subjective evaluations of knee ligament based on IKDC and Lysholm knee scores were also evaluated. Questionnaires were coded for anonymity. Thus, the statistician was unaware of adopted reconstruction grafts.

Statistical analysis

Data were analyzed using SPSS for Windows version 16.0 (SPSS Inc., Chicago, IL, USA). Quantitative variables were described and compared using the mean scores with 95 % confidence interval (CI). Baseline data for both groups were compared by chi-square test for qualitative variables and independent sample T-test for parametric quantitative variables. The trends of changes in outcome measures were analyzed using repeated measure analysis of variances for within-subject factor (visits) as well as between-subjects factor (groups). $P < 0.05$ was considered to be significant for all the analyses.

Results

Demographic information

The TP group included 104 patients (88 males and 16 females) who were matched with 118 patients (99 males and 19 females) in the HT group. The mean age of TP and HT groups was 34.4 (range, 19–48) and 36.9 (range, 20–51) years, respectively. There was no significant difference with age and gender ($P > 0.05$). Median duration of patients' follow-up was 55 months (range, 37–71) in the TP group and 56 months (range, 36–72) in the HT group ($P > 0.05$). In the TP group, 55 patients (52.9 %) had no meniscus injury, 25 patients (24.1 %) had medial meniscus tear, and 12 patients (11.5 %) had lateral meniscus tear. In 12 patients (11.5 %) both lateral and medial meniscus tears were observed. The meniscus of 61 patients (51.7 %) in the HT group was intact, medial and lateral meniscus tears were observed in 23 (19.5 %) and 10 (8.5 %) cases, respectively. Both medial and lateral meniscus tears were seen in 24 (20.4 %) cases. There was no significant difference in frequency and type of meniscus injury between the two groups ($P > 0.05$).

Objective evaluations

No significant difference in required time to return to work was observed between the two groups (Table 1). Prior to surgery, the SSD was more than 5 mm in all patients and was similar in both groups ($P > 0.05$). In the final follow-up, SSD measured was insignificantly lower in the HT group in comparison to the TP group (1.9 mm, 95 % CI 1.4–2.2 vs. 2.1 mm, 95 % CI 1.7-2.4, respectively, $P = 0.301$). Successful outcomes were observed in 99 patients (83.9 %) of the HT group and 85 patients (81.7 %) of the TP group. Fifteen patients of the HT group (12.7 %) and 17 patients of the TP group (16.3 %) were categorized as borderline failure, whereas four patients of the HT group (3.4 %) and two patients of the TP group (1.9 %) were considered as failures and no significant difference was found between the two groups ($P = 0.133$). However, significant differences were observed according to the SSD scores pre and post operation in both groups ($P < 0.001$). Three out of four HT patients and both patients in the TP group who were classified as failed had recurrent ACL tears because of repeated injury due to contact sport and soccer, respectively. One patient in the HT group incurred a graft failure. ROM in both groups significantly improved after surgery ($P < 0.001$) but differences between two groups was not significant ($P = 0.833$). There was no motion limitation observed at the final visit (Fig. 1).

Subjective evaluations

At the final follow-up, the average patients' satisfaction with the surgical repair based on VAS in the HT and TP groups was 9.66 (95 %CI 9.57–9.76) and 9.77 (95 %CI 9.69–9.85), respectively ($P = 0.075$). The subjective scores of Lysholm and IKDC at final visit in both groups improved significantly in comparison to pre-operative scores ($P < 0.001$) (Table 2). Eight

Table 1 Mean (95 % CI) of weeks required to begin activities after anterior cruciate ligament (ACL) reconstruction in week

Reconstruction	Walking without crutches	Normal daily activities	Jogging	Exercise
HTA	4.61 (4.45–4.77)	8.40 (7.98–8.81)	14.02 (13.40–14.65)	27.84 (27.29–27.40)
TPA	4.78 (4.60–4.95)	8.09 (7.74–8.44)	13.52 (12.91–14.13)	28.38 (27.82–28.95)
P value[a]	0.186	0.611	0.231	0.182

HTA hamstring tendon autograft, *TPA* tibialis posterior allograft

[a] Mann–Whitney test was used for pair wise comparison

patients in the HT group complained of numbness and paresthesia in the medial tibial region and around the knee until the second month. The symptoms persisted at the sixth month and final visit in one patient. There was no symptom of saphenous nerve injury in any of the patients of the TP group. Two patients of the HT group presented with acute infection after the first post-operative week. Both cases were hospitalized and successfully treated with drainage and intravenous antibiotics.

Discussion

Evaluation of stability and function of knee after ACL arthroscopic reconstruction between single-loop TPA and four-strand HTA were investigated in the present study. Our results demonstrated that ACL reconstruction by both HTA and TPA have satisfactory and similar knee stability, ROM, knee function and similar post-operative complications.

Tendon length and its flat shape, promoting secure fixation, and comparable subjective and objective outcomes make TP suitable for ACL reconstruction [15]. Various studies have been performed to compare autografts and allografts of the same or different muscle tendons, muscle tendon vs. tendon with bone plug, and irradiated with non-irradiated grafts. Similarity of clinical and functional results of ACL reconstruction by the relatively recent HTA versus BPTB autograft along with fewer post-operative complications promotes the use of HTA method, which is commonly practised worldwide [8, 16]. This has initiated the comparison of HTA with other soft tissue allografts in recent years. Several comparative allograft versus autograft studies observed longer intra-operative and recovery time with autograft, however, allograft was not cost effective [3, 17, 18]. Biomechanical studies have shown that TPA was similar to and in some cases better than BPTB autograft in terms of maximum load, stiffness,

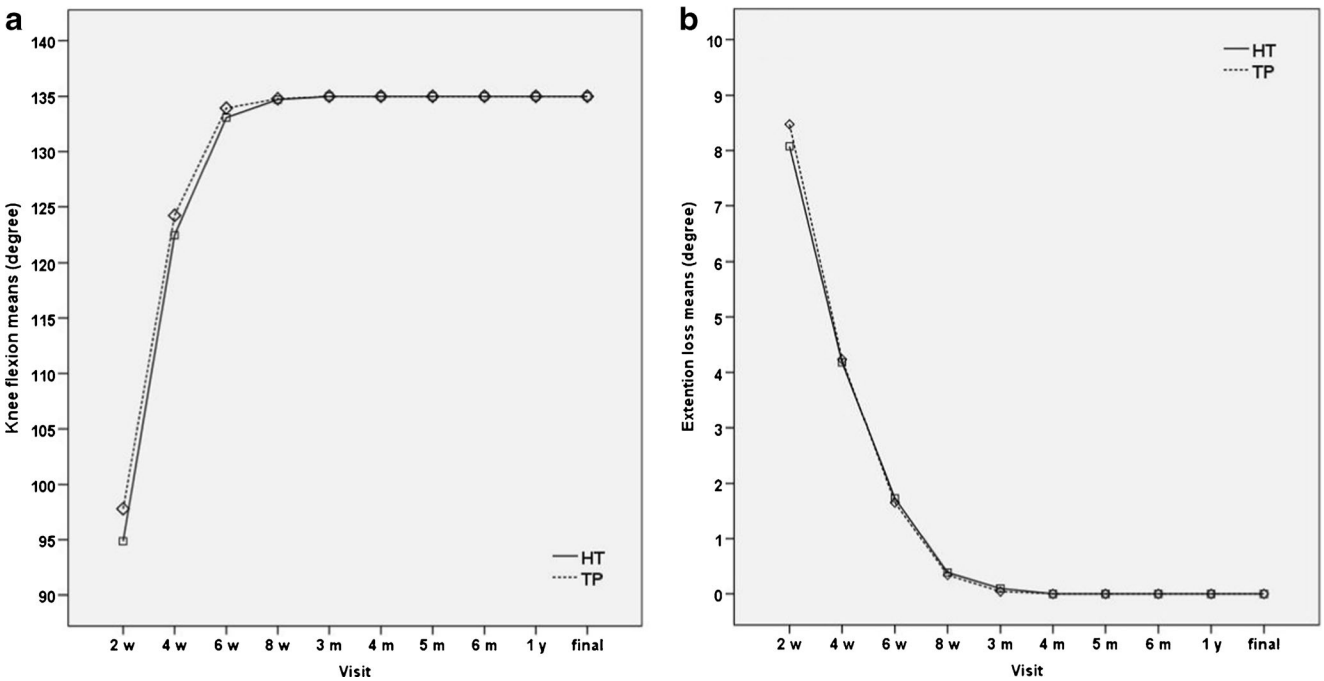

Fig. 1 Mean of knee joint motion in degrees after anterior cruciate ligament (ACL) reconstruction at different times of follow-up. **a**, degree of knee flexion; **b**, degree of extension loss. HT, hamstring tendon; TP, tibialis posterior

Table 2 Mean (95 % CI) of knee subjective scores at the visit before the anterior cruciate ligament (ACL) reconstruction and final visit

Reconstruction	IKDC score	Lysholm score		
	Pre treatment	Final follow-up	Pre treatment	Final follow-up
HTA	56.94 (55.91-58.01)	92.39 (91.56-93.22)	61.15 (60.25-62.06)	94.48 (93.73-95.23)
TPA	56.91 (55.81-58.02)	92.74 (91.98-93.50)	61.67 (60.68-62.66)	94.96 (94.25-95.68)
P value[a]	0.846	0.896	0.514	0.550

IKDC International Knee Document Committee, *HTA* hamstring tendon autograft, *TPA* tibialis posterior allograft

[a] Mann–Whitney test was used for pair wise comparison

elongation and cross section [11, 12, 19]. Interestingly, Pearsall et al. demonstrated stiffness and ultimate failure load of TPA superior to native ACL [11]. Most studies select allografts and autografts with similar tissues. In an older study, soft tissue allograft was reported as a suitable replacement for multiple ligament injury and revision surgery [20]. Recently, soft tissue allograft in primary ACL reconstruction has drawn special attention.

Despite concerns over delayed remodeling [7] and allograft durability in highly active young patients [17, 21], acceptable results have been reported by some recent studies for primary ACL reconstruction by bone plug-free graft [2, 4, 5, 13, 22, 23]. A two-year follow-up of 177 patients with double bundle ACL reconstruction with tibialis anterior allograft based on IKDC criteria demonstrated that 169 patients had normal or near normal knees with improvement of SSD mean from 3.72 mm to 1.2 mm after surgery [23]. Lawhorn and colleagues compared the results of HTA and tibialis anterior allograft in a randomized controlled study. They found IKDC of 90.9 and 91 for two groups, respectively, and all patients, except one case of HTA method with SSD > 5 mm, had normal or nearly normal knee [2]. Noh et al. performed a randomized controlled prospective study on 33 HTAs and 32 free tendon Achilles allografts. Nearly 94 % (30 patients) and about 81 % (26 patients) in the first and second groups had normal or near normal knee on IKDC score, respectively. Median Lysholm score was 98 and 99, while SSD mean was 1.9 ± 2.4 mm and 1.4 ± 2 mm, respectively. Also, no significant differences were found between two groups [5]. Edgar et al. [13] and Sun et al. [6] compared the results of HT allograft and autograft of ACL repair. A three- to ten-year follow-up in both studies showed no significant differences in IKDC, Lysholm score and SSD. Although we employed a different allograft, our findings were similar to the above-mentioned studies.

In the present study, no significant differences were detected between two groups in objective and subjective criteria. In an approximately similar study, Nakata et al. compared ten-year follow-up results of fresh-frozen bone plug-free Achilles, TP and tibialis anterior. They concluded that allograft produced adequate stability and knee function without donor site morbidity in young and active patients [22]. In addition, no significant difference existed in the time interval required for return to the former activities between two groups.

Irradiated allografts have poor results [6, 24], and a recent meta-analysis concluded that ACL reconstruction with allografts that have been previously sterilized is not recommended [1]. We measured the long-term viability of fresh frozen TPA compared to HTAs. Although Giannini et al. [15] reported that freezing induced significant biomechanical and structural changes in PT tendon, several authors report no adverse changes in main mechanical property [2, 4–6, 19]. On the other hand, concerns were mentioned over risk of infection and immunodeficiency virus (HIV) transmission [1, 2, 15, 25]. However, prophylactic serological and microbiological evaluations of donors along with suggested sterilization was acceptable. Interestingly, in a very recent meta-analysis of randomized controlled trials and ten systematic reviews by Zeng et al. [26], no significant differences in end results between autografts and non-irradiated allografts were observed. Contrarily, irradiated allografts had poorer function and stability than autografts.

Limitations

Our study suffers from some limitations. First, patient's selection was performed as a non-randomized pattern in both groups. To minimize the bias effects of this selection, two groups were matched with respect to pre-operative features and findings. Second, socioeconomic status may influence patient rehabilitation progress, which was not noticed in our study, but complete coverage of management expenses is a suggested future protocol. Third, graft failure in patients lost during follow-up could not be ruled out. To reduce the confounding effect of this factor, 20 % loss was considered on estimating sample size to provide sufficient test strength. Finally, VAS score of patient's satisfaction in our early follow-up was not evaluated and differences between groups remain a probability.

Conclusion

Despite the above-mentioned limitations, the results of the present study provide more evidence than other studies regarding TPA status in ACL reconstruction. Conclusively, arthroscopic ACL reconstruction by fresh frozen doubled TPA compared to HTA was equally effective in restoring function and stability of knee, permitting return to previous activities.

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Compliance with ethical standards

Conflict of interest The authors have declared there are no conflicts of interest.

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