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Bone-patellar Tendon-bone Versus Four Strands Hamstring Grafts for Anterior Cruciate Ligament Reconstruction

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SUMMARY

Introduction. The goal of the present meta-analysis was to compare bone-patellar tendon-bone (BPTB) versus four-strands hamstring tendon (4SHT) autografts for primary anterior cruciate ligament (ACL) reconstruction.

Methods. The present meta-analysis was conducted according to the PRISMA guidelines. The literature search was performed in July 2019. All the randomized clinical trials comparing BPTB versus 4SHT autografts for primary ACL reconstruction were considered for inclusion. The statistical analysis was performed through the Review Manager Software.

Results. The BPTB detected lower values of pivot-shift test ≥ 3 mm ($p = 0.0009$), Lachman test ≥ 5 mm ($p = 0.03$), arthrometer displacement ≥ 3 mm ($p = 0.001$), mean arthrometer displacement ($p = 0.50$), higher rate of kneeling pain ($p = 0.01$), anterior knee pain ($p < 0.0001$) and graft failures ($p = 0.03$). Concerning the clinical scores (IKCD and Lysholm score), any statistically significant results were detected.

Conclusions. Providing more stability, we hypothesize that young and demanding patients may gain more benefits from BPTB graft. In the case of treating patients with reduced performances, it may be more reasonable to use a 4SHT because of the lower incidence of graft rupture, kneeling, and anterior knee pain.

KEY WORDS

ACL reconstruction four strands hamstring tendon; bone-patellar tendon-bone tendon; autograft

INTRODUCTION

The anterior cruciate ligament (ACL) is one of the most important stabilisers of the knee. It prevents the antero-posterior sliding of the tibia against the femur, along with excessive knee extension, tibial rotation, and varus-valgus movements (1,2). Sudden decelerations combined with directional change and landing with nearly full extended knee after a jump are the most common causes of ACL injury (3). A direct trauma causing a posterior translation of the tibia in respect to the femur is another cause, but very uncommon (4). Short-term complications of the ACL rupture are represented by soft tissue damages (5) along with joint instability (6). The most important long-term complication is represented by the osteoarthritis (7,8). These complications lead to a poor quality of life and to a reduction of the recreational activities (9, 10). A timely intervention is of paramount importance to restore the normal joint biomechanics and avoid additional complications. The most used grafts for ACL reconstruction are the bone-patellar tendon-bone (BPTB) and the four strands hamstring tendon (4SHT) autografts. Despite the huge number of clinical trials, there are still controversial opinions concerning which one is the best choice for ACL reconstruction (11-17). In the literature, many randomized clinical trials (RCTs) and prospective studies compare the two grafts (13, 18-21). In the last years, the number of studies comparing the two grafts has remarkably improved (16, 17). The purpose of this work is to review the current literature and to summarize and update the current evidences concerning BTPB versus 4SHT for primary ACL reconstruction.

MATERIAL AND METHODS

Search strategy

The literature search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (22). To guide the search, we preliminary drafted a protocol:

- type of study: clinical trials (level of evidence I or II (23));
- patient Group: tear of the anterior cruciate ligament;
- intervention: anterior cruciate ligament reconstruction;
- comparison: bone-patellar tendon-bone graft versus four strands hamstring tendon;
- outcomes: joint laxity, clinical scores, further complications.

We used the following keywords for the literature search: ACL, rupture, reconstruction, hamstring, B-PT-B, autograft, pivot-shift, Lachman, laxity, arthrometer, IKDC, Lysholm, failures, anterior knee pain, kneeling, revisions. Disagreements between the authors were debated and mutually solved.

Data extraction and eligibility criteria

Two independent authors (FM, BR) performed the data extraction. All the published study comparing bone-patellar tendon-bone versus four strands hamstring tendon for ACL reconstruction were considered for inclusion. According to the Oxford Center of Evidenced-Based Medicine (23), articles level of evidence I to II were enrolled in the present study. Retrospective cohort studies, case series, editorials, expert opinions or other reviews were excluded from the present work. Biomechanical, cadaveric, animal and in-vitro studies were rejected. Studies providing navigation system or robotic surgery, along with revision setting were excluded. Studies concerning 2 or 6 strands hamstring tendon were not considered. Studies performing the surgeries with synthetic grafts, allografts or xenografts were rejected. According to the authors languages capabilities, studies in English, German, Italian, Spanish, French were included. Studies published in a timeframe from 2000 to November 2018 were included. Only studies reporting quantitative data under the outcomes of interest were considered in this study. Disagreements between the authors were debated and mutually solved.

OUTCOMES

We reported the generalities of the included studies (author and publication's year, number of patients, mean age, mean follow-up). To measure the post-operative knee laxity, we referred to the Lachman and pivot-shift tests. We considered pathological a displacement ≥ 5mm for the Lachman test and ≥ 3mm for the pivot-shift test. We included studies that measured laxity instrumentally with KT-1000, KT-2000 (MEDmetric Corp, San Diego, California) or CA-4000 (Orthopaedic System Inc, Hayward, CA, USA). These devices reproduce the sagittal translation of the tibia plateau in respect to the femur, considering pathological a displacement of ≥ 3 mm. To assess the clinical outcome, we referred to the International Knee Documentation Committee (IKDC) and the Lysholm Knee Scoring Scale (LKSS). Further complications (kneeling pain, anterior knee pain, graft rupture) were also evaluated.

Methodological quality assessment

Two independent authors (FM, BR) evaluated the methodological quality and reliability of the included studies with the PEDro appraisal tool (24). This instrument evaluates randomization, blinding, follow-up adequacy, baseline comparability of the groups at the start, analysis for intention of treatment. Every analyzed article is then ranked from 0 (low quality) to 10 (high quality). An overall result of ≥ 6 is considered acceptable.

STATISTICAL ANALYSIS

The statistical analysis was performed with Review Manager Software 5.3 (The Nordic Cochrane Collaboration, Copenhagen). For continuous variables, the effect estimates (EE) were evaluated with the inverse variance method. For the effect measure, the arithmetic mean was used. For dichotomous variables, the Maentel-Haenszel statistical method was used in combination with the odd ratio (OR) to evaluate the final effect. The confidence interval (CI) was fixed at 95% in all the comparisons. To analyze the heterogeneity, both ^{2} and I^2 tests were performed. Value of ^{2} >0.5 indicated heterogeneity. The I^2 evaluates the heterogeneity as low (<25%), few (25-50%), moderate (50-75%) and high (>75%). A fixed analysis model was used. In front of moderate-high heterogeneity, to a random analysis method were switched. Value of $P<0.05$ were considered statistically significant.

RESULTS

We obtained 356 RCTs from the database search and the cross-references screening. Of these, 112 were removed because of duplicates. Other 175 articles were rejected because they did not focus on the topic of interest. Another 49 studies were rejected because they did not analyze our outcomes of interest. This left 20 articles for the study. The flow-chart of the literature search is shown in **figure 1**.

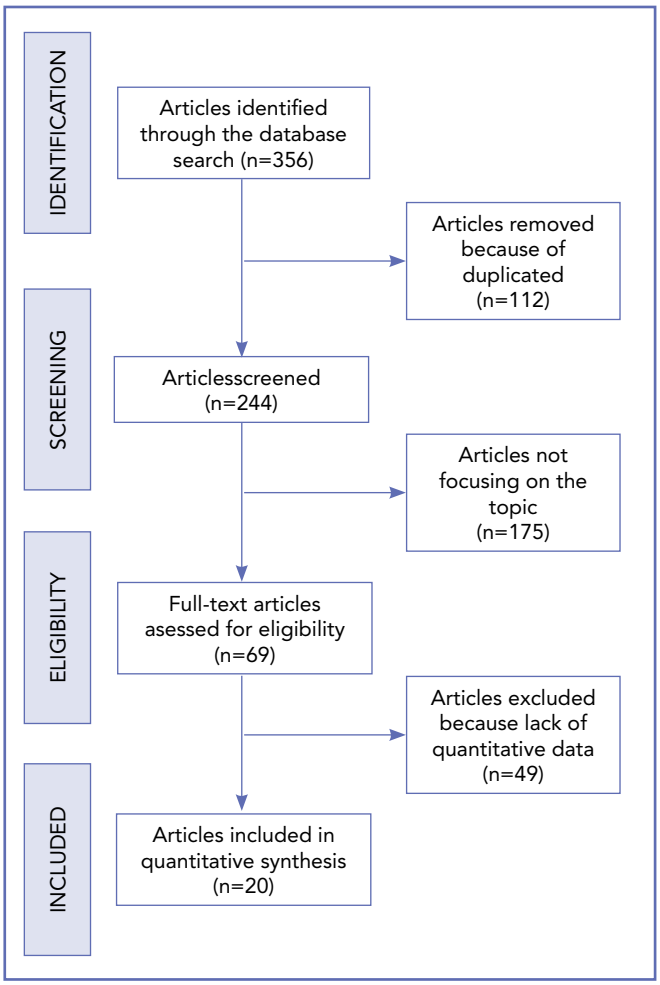

Figure 1. PRISMA flow-chart of the literature search.

METHODOLOGICAL QUALITY ASSESSMENT

The analysis of the PEDro score reported a high level of evidence and a very good analysis of the results in the included studies. All authors performed randomization in their studies and the baseline of the demographic data was comparable, representing points of strength for this meta-analysis. On the other hand, the absence of blinding methods represented an important limit of the included studies, influencing negatively the PEDro score. The overall result of the PEDro score was 7.74 points, proving the high methodological quality of this work. The results of the PEDro score are shown in **table I**.

ANALYSIS OF PUBLICATION'S BIAS

To analyze the publication's bias, we performed the funnel plot of the most reported outcome (failures). All studies locate in the range of acceptability and are positioned symmetrically to the non-effect line, indicating a low risk of publication's bias. The funnel plot is shown in **figure 2**.

PATIENT'S DEMOGRAPHICS

We examined in this study 1651 patients that underwent a mean follow-up of 62.42±54.86 months. We enrolled 819 patients in the BPTB group, with a mean age of 28.35±4.7 years, and 832 patients in the 4SHT group, with a mean age of 28.3±3.59 years. The demographic baseline is shown in **table I**.

OUTCOMES

Concerning the joint laxity, in the BPTB group we observed a lower number of patients with pivot-shift test ≥3 mm (OR: 0.59; CI: 0.43, 0.80; *P*=0.0009), Lachman test ≥5 mm (OR: 0.54; CI: 0.31, 0.94; *P*=0.03), and arthrometer displacement ≥3 mm (OR: 0.61; CI: 0.45, 0.83; *P*=0.001, **figure 3**). Moreover, in the same group we reported a reduction of the mean arthrometer displacement (EE: -0.15; CI: -0.59, 0.29; *P*=0.50).

Concerning the clinical scores, we observed better results of the IKDC score in the BPTB group (EE: 0.72; CI: -2.28, 3.73; *P*=0.64) and a higher improvement of the mean Lysholm score in the 4SHT group (EE: -2.40, CI: -5.27 0.47; *P*=0.10).

Regarding the complications, we observed a higher rate of kneeling pain (OR: 1.72; CI: -2.28, 3.73; *P*=0.014) and anterior knee pain (OR: 2.84; CI: 1.75, 4.61; *P*<0.0001) in the BPTP group. In this group, we also reported a reduction in graft failures (OR: 0.62; CI: 0.41, 0.95; *P*=0.03, **figure 4**). **Table II** summarizes the results of the meta-analysis.

DISCUSSION

The main findings of this meta-analysis are that BPTP provides more joint stability and reduced the rate of graft rupture but exposes the patients to an increased risk of developing kneeling and anterior knee pain. Giving the greater stability observed in the BPTB group, we hypothesize that young and demanding patients can get more benefits from this graft. Patients with reduced performances, it may be more reasonable to use a 4SHT because of the lower incidence of graft rupture, kneeling and anterior knee pain. Evaluating the joint stability is of fundamental importance after ACL reconstruction, since laxity lead to acute injuries (sprains, soft tissue lesions) and to long-term articular degenerative changes, such as osteoarthritis (38-40). Many different factors leading to instability have been recognized:

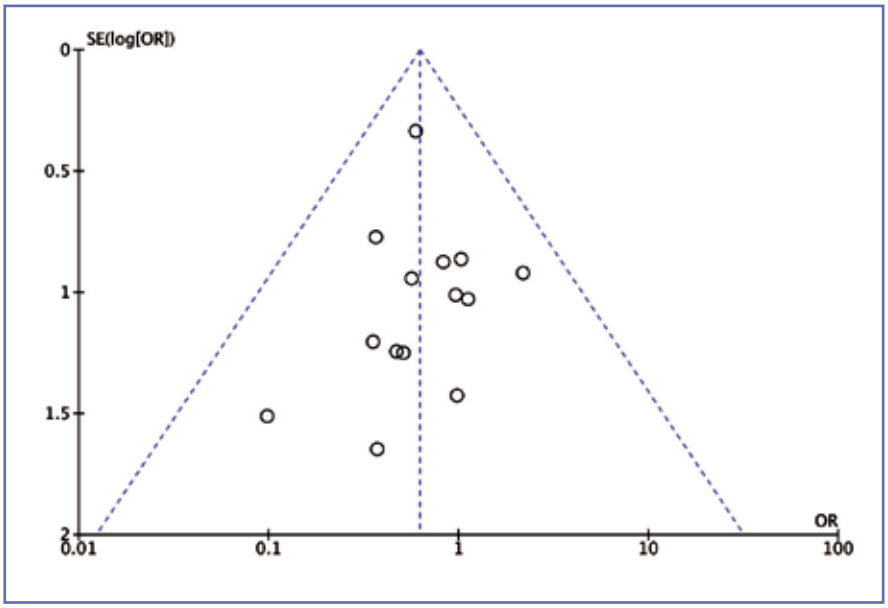

Figure 2. Funnel plot to assess the publication's bias.

graft tension and knee flexion during the graft fixation, bone to bone versus bone to tendon healing, cycling of the graft (41-43). Most of enrolled studies referred to pivot-shift, Lachman test and to the arthrometer for the stability evaluation. Lachman is very sensible test, but the accuracy to detect accurate postero-anterior tibial translation is not reliable (44). Using of the arthrometer provides more reliable results and precise evaluation of the translation (45,46). All the analyzed tests evidenced a better joint stability in favor of the BPTB group. These results were statistically significant across all the analyzed comparisons. The comparisons evidenced a good weights distribution, and the overall effect is affected by low level of hetero-

Table I. Baseline demographic and PEDro quality methodological assessment of the included works.

Author, year	Patients (n)	Follow-up (months)	PEDro Score	BPTB		4SHT	
				Patients (n)	Mean Age (years)	Patients (n)	Mean Age (years)
Aglietti et al. 2004 (12)	120	24	8	60	25	60	25
Aune et al. 2001 (25)	72	24	8	35	25	37	27
Barenius et al. 2010 (13)	153	100	8	78	33	75	35
Beynnon et al. 2002 (26)	56	36	8	28	28,5	28	29,9
Drogset et al. 2009 (14)	115	24	7	58	26	57	27
Feller et al. 2001 (27)	65	4	7	31	26	34	27
Gifstad et al. 2013 (15)	77	84	8	41	27	36	27
Harilainen et al. 2006 (28)	74	60	7	37		37	
Holm et al. 2010 (29)	57	120	8	28	25	29	27
Ibrahim et al. 2005 (30)	85	81	8	40	22	45	22
Laxdal et al. 2005 (31)	79	26	8	40	28	39	26
Maletis et al. 2007 (32)	99	24	8	46	27.2	53	27.7
Mohtadi et al. 2015 (33)	206	39	8	102	28.7	104	28.5
Razi et al. 2014 (34)	87	36	8	46	30.8	41	28.2
Sajovic et al. 2018 (16)	48	204	8	24	45.5	24	42.5
Shaieb et al. 2002 (35)	70	24	8	33	32	37	30
Taylor et al. 2009 (36)	53	36	7	24	21.7	29	22.1
Webster et al. 2016 (17)	37	180	7	17	26.6	20	26.1
Wipfler et al. 2011 (37)	48	105.6	7	26	40	22	34
Zaffagnini et al. 2006 (21)	50	60	7	25	31	25	31

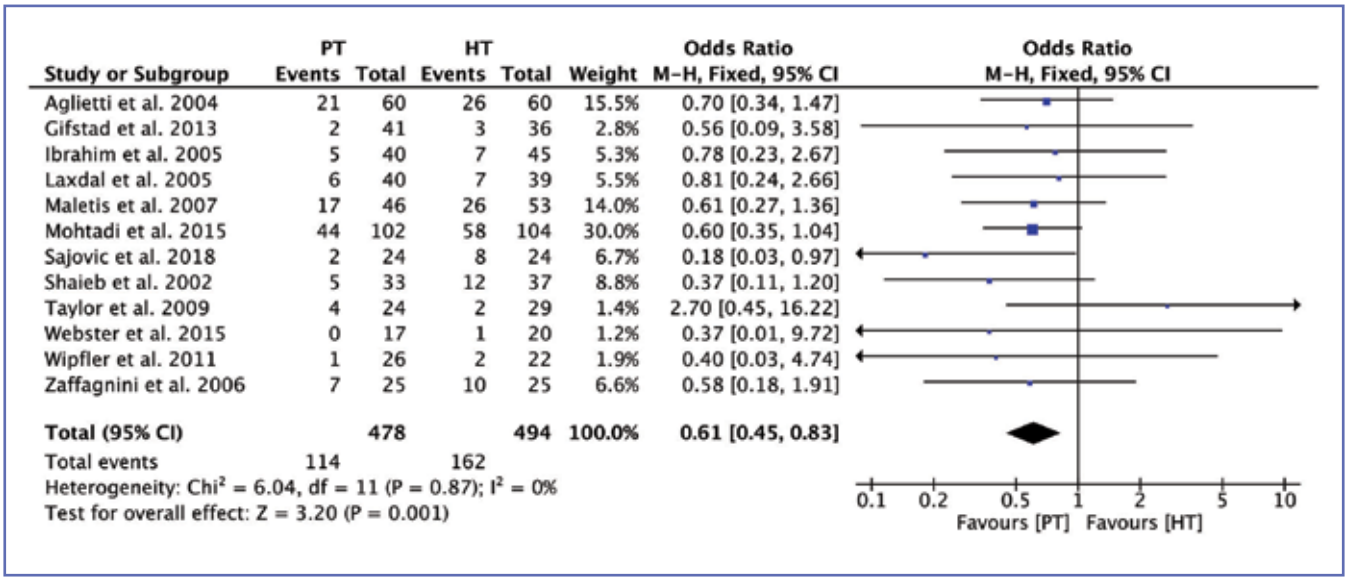

Figure 3. Meta-analysis of the comparison arthrometer laxity ≥3 mm.

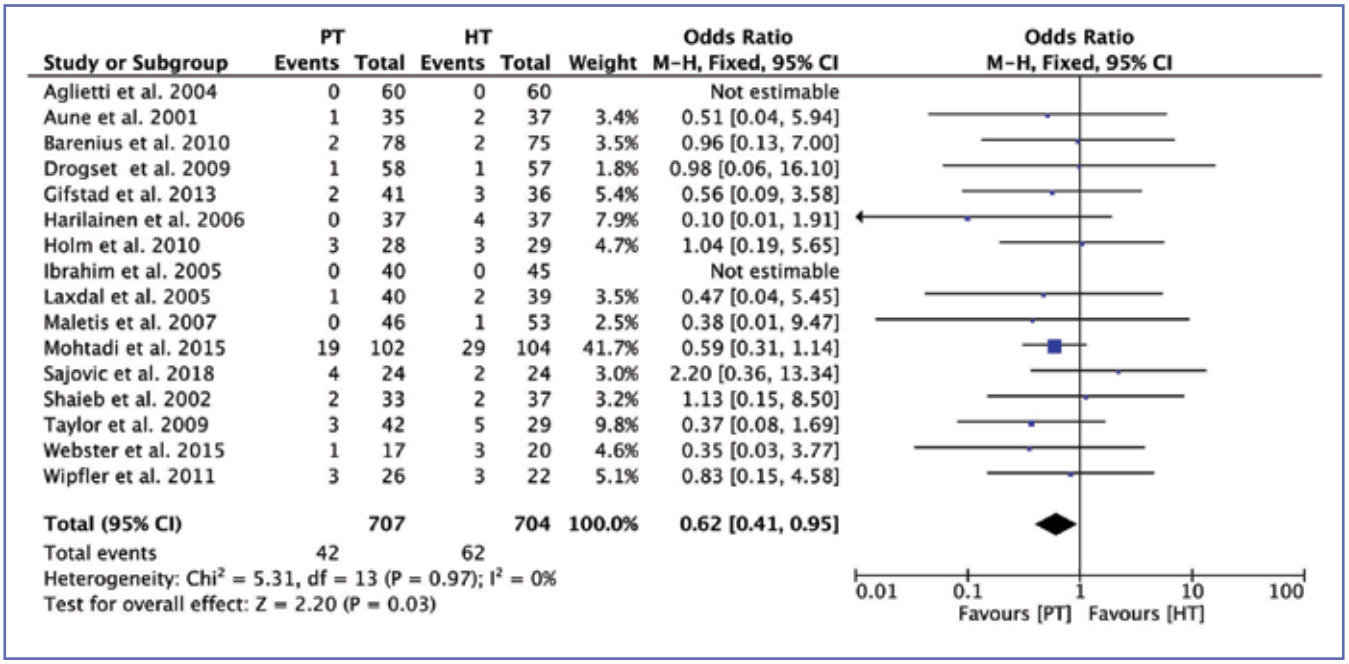

Figure 4. Meta-analysis of the comparison graft failures.

geneity. All the comparisons were analyzed under a fixed effect model, revealing a consistent result.

Kneeling and anterior knee pain were statistically significant more common in the BPTB group. The morbidity of the harvesting site plays the most important role. Even if improvement in the surgical techniques, post-operative care and rehabilitation programs, these patients reported a higher incidence of kneeling and anterior knee pain (47-50). Furthermore, there can be other several explanations to the higher incidence observed in the BPTB group. From an

Table II. Overall meta-analysis results.

Outcome	Studies (n)	Samples (n)	Overall Effect	
			Effect Estimate [95% CL]	P
Pivot-shift test ≥ 3 mm	11	1089	0.59 [0.43, 0.80]	0.0009
Arthrometer laxity ≥ 3 mm	12	972	0.61 [0.45, 0.83]	0.001
Lachman ≥ 5 mm	8	695	0.54 [0.31, 0.94]	0.03
Mean arthrometer laxity	9	734	-0.15 [-0.59, 0.29]	0.05
IKDC	3	293	0.72 [-2.28, 3.73]	0.64
Lysholm	4	268	-2.40 [-5.27, 0.47]	0.10
Kneeling	7	560	1.72 [-2.28, 3.73]	0.014
Anterior knee pain	8	569	2.84 [1.75, 4.61]	<0.0001
Graft rupture	16	1411	0.62 [0.41, 0.95]	0.03

anatomical point of view, surgery damages the infrapatellar branches of the saphenous nerve, thus possibly creating an alteration of the sensitive paths (50, 51). The bone defect induced by BPTB harvesting in the patella and the tibial tubercle can lead to increased pain during kneeling over a surface or during quadriceps contraction (52). Furthermore, has been observed that during a BPTP procedure, there may be a higher risk of implanting the graft under excessive tension, thus increasing the joint pressure (53).

In a normal knee, the endurance of the graft fixation depends on the quality of the bone, type of graft and type of fixation, tunnel position, rehabilitation's program (54, 55). A statistically significant higher rate of graft ruptures was evidenced in the 4HST. The analysis of this outcome provided good weights distribution and poor data dispersion. The level of heterogeneity was acceptable and the result is reliable.

The analyzed clinical scores, the Lysohlm and IKDC, reported no consistent results. These comparisons are statistically not significant and affected by high level of heterogeneity and data dispersion. Furthermore, the results are not clinically relevant, since the differences between BPTB and 4SHT are negligible.

The lack of a deep analysis of failures represent the most important limitation of this study. Only graft ruptures were analyzed, but abnormal laxity, patient perception of instability, and pain and stiffness in the operated knee (56, 57) are important outcomes to evaluate. Further studies should provide long-term follow-up and blinded randomized clinical trials to increase the value of the findings. A strength of this meta-analysis is the baseline comparability and the comprehensive nature of this study, along with the strictly eligibility criteria. This is very important to reduce the level of heterogeneity and obtain more reliable results. Another strength of this work is the choice to include only level I and II clinical trials, thus sensibility reducing the risk of publication's bias and providing high scientific evidence.

CONCLUSIONS

The main findings of this meta-analysis are that BPTP provides more joint stability and reduced the rate of graft rupture but exposes the patients to an increased risk of developing kneeling and anterior knee pain. Giving the greater stability observed in the BPTB group on the one side and the lower incidence of graft rupture, kneeling and anterior knee pain of 4SHT the graft, the recommend the individual selection of the graft for every patient.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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