Invited Review

Hamstring, bone-patellar tendon-bone, quadriceps and peroneus longus tendon autografts for primary isolated posterior cruciate ligament reconstruction: a systematic review

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Abstract

Introduction: Several autografts are available to reconstruct the posterior cruciate ligament (PCL).

Source of data: Current scientific literature published in PubMed, Google scholar, Embase and Scopus.

Areas of agreement: Hamstring, bone-patellar tendon-bone (BPTB), quadriceps and peroneus longus (PLT) are the most common tendon autografts used for primary isolated PCL reconstruction.

Areas of controversy: The optimal tendon source for PCL reconstruction remains nevertheless debated. Identifying the most suitable tendon autograft could assist the surgeon during primary PCL reconstruction.

Growing points: The present study compared the outcome of PCL reconstruction using hamstring, BPTB, quadriceps and PLT autografts. The focus
was on patient-reported outcome measures (PROMs), joint laxity, range of motion and complications.

**Areas timely for developing research:** All autografts are viable options for PCL reconstruction, with BTB and hamstring autografts demonstrating superior PROMs. However, further clinical investigations are required to determine the ideal autograft construct.

**Keywords:** posterior cruciate ligament, autograft, quadriceps, bone-patellar tendon-bone, hamstring, peroneus longus

**Introduction**

The posterior cruciate ligament (PCL) is the primary restraint to posterior tibial translation. The incidence of PCL rupture ranges from 1 to 40% of all acute knee injuries. PCL tears typically occur during high-energy trauma, such as motor vehicle accidents or fall on the knee with the foot in a plantar flexed position. PCL tears are diagnosed by physical examination and magnetic resonance imaging. Symptomatic PCL ruptures with posterior displacement >8 mm and instability may be managed by surgical reconstruction. Several tendon autografts for PCL reconstruction have been employed, such as the hamstring, bone-patellar tendon-bone (BPTB), quadriceps and peroneus longus tendon (PLT). Hamstring autografts are the most commonly used tendons for PCL reconstruction. BPTB has been also employed for PCL reconstruction, with fast incorporation, quick return to preinjury activity levels and low risk of graft rupture. Quadriceps tendon autograft represents another valuable option for PCL reconstruction, demonstrating high level of activity after surgery. PLT autografts have been employed for PCL reconstruction with satisfying clinical outcomes. The optimal tendon source for PCL reconstruction remains nevertheless debated. Identifying the most suitable tendon autograft could assist the surgeon during primary PCL reconstruction. The present study compared the outcome of PCL reconstruction using hamstring, BPTB, quadriceps and PLT autografts. The focus was on patient-reported outcome measures (PROMs), joint laxity, range of motion (ROM) and complications.

**Material and methods**

**Search strategy**

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The PICOT algorithm guided the initial search:

- **P (population):** PCL tears;
- **I (intervention):** primary isolated PCL reconstruction;
- **C (comparison):** hamstring, BPTB, quadriceps, PLT autografts;
- **O (outcomes):** PROMs, ROM, laxity, complications;
- **T (Timing):** > 12 months of follow-up.

**Literature search**

Two authors (F.M. & A.P.) independently performed the literature search in April 2021. The following databases were accessed: PubMed, Google Scholar, Embase and Scopus. The following keywords were used for the search: ‘posterior cruciate ligament, autograft, graft, tendon, quadriceps, bone-patellar tendon-bone, hamstring, peroneus longus, BPTB, PCL, ligament, Lysholm, PROM, patient reported outcome measures, laxity, stability, instability, range of motion, anterior knee pain, reoperation, revision, pain’. Titles and abstracts were screened by the same authors in a separate fashion. If the abstract matched the topic of interest, the full text of the article was accessed. The bibliographies were screened to identify additional
articles. Disagreements were resolved by a third author (**).

**Eligibility criteria**

All the clinical studies investigating the outcome of PCL reconstruction using an autograft were accessed. Only studies that clearly stated the source of the graft were included. The autografts of interest were hamstring, BPTB, quadriceps and PLT. Studies reporting data on other autografts, allografts or synthetic grafts were excluded. Given the authors’ language abilities, articles in English, German, Italian and French were eligible. Comments, reviews, letters, notes, protocols, editorials, guidelines and registries were not considered. Computational, animal, biomechanical and cadaveric studies were also not eligible. Only studies reporting data from a minimum of 12 months of follow-up were included. Articles combining PCL reconstruction with anterior cruciate ligament (ACL) reconstruction or other procedures were excluded. Studies that enhanced PCL reconstruction with cell therapies or experimental physiotherapy regimens were not suitable. Only articles which reported quantitative data under the outcomes of interests were considered for inclusion.

**Data extraction**

Data extraction was performed by one author (A.P.). The following data at baseline were collected: author, year, journal, length of the follow-up, number of procedures, mean age of the patient age, percentage of women and type of autograft used. For each autograft, the following data were retrieved at last follow-up: Lysholm Knee Scoring Scale, International Knee Document Committee (IKDC), ROM, joint laxity measured by KT-1000 arthrometer, rate of revision and anterior knee pain.

**Methodology quality assessment**

For the methodological quality assessment, the Coleman Methodology Score (CMS) was used.34 CMS is widely used to evaluate the methodological quality of systematic reviews and meta-analyses and is highly reliable.26–28 This score allows for an analysis of the included papers based on several points of interest, including study size, follow-up duration, surgical approach, type of study, description of diagnosis, surgical technique and rehabilitation. Additional outcome criteria assessment, the procedures for assessing outcomes and the subject selection process were also evaluated. The CMS rates articles with values between 0 (poor) and 100 (excellent). Articles with values of >60 are considered to be satisfactory.

**Statistical analysis**

The statistical analyses were performed by the main author (F.M.) using the STATA Software/MP (Stata-Corporation, College Station, TX, USA). For descriptive statistics, mean and standard deviation was used. For dichotomic data, the frequency was estimated. Continuous data were analysed using the analysis of variance. The Tukey Honestly Significant Difference post hoc test was also performed. The confidence interval (CI) was set at 95% in all the comparisons. Values of $P < 0.05$ were considered to be statistically significant.

**Results**

**Search results**

The initial literature search resulted in 1061 articles of which 361 were excluded because of redundancy. Another 650 articles were excluded because they did not match the eligibility criteria: other autografts, allografts, synthetic grafts ($N = 203$), comments, reviews, letters, notes, protocols, editorials, guidelines or registries ($N = 301$), biomechanical and/or cadaveric studies ($N = 50$), multiligaments reconstruction ($N = 46$), short duration of the follow-up ($N = 13$) and enhancing PCL reconstruction with other procedures ($N = 37$). A further 29 articles did not report quantitative data under the endpoints of interest. Thus, a total of 31 articles were eligible for this systematic review (Fig. 1).
Methodology quality assessment

The study size and the duration of the follow-up were acceptable in most of the included studies. Surgical approach, diagnosis and rehabilitation were described in most articles. Outcome measures and timing of assessment were often defined, providing moderate reliability. General health measures were rarely reported. The average CMS for the articles was 68.9, attesting an acceptable quality of the methodologies for the included articles.

Patient demographics

Data were retrieved for 946 patients, with a mean age of 28.1 ± 0.8 years and a mean follow-up of 40.1 ± 10.8 months. Study generalities and patient demographic at baseline are shown in Table 1.

Outcomes of interest

The BPTB group demonstrated the greatest mean Lysholm score (91.9 ± 6.7), followed by hamstring
Table 1 Patient demographics of the included studies (BPTB; PLT: peroneus longus tendon)

| Author, year     | Design    | Autograft | Follow-up (months) | Patients (n) | Mean age (mean) | Female (%) |
|------------------|-----------|-----------|--------------------|--------------|-----------------|------------|
| Cooper et al. 2004 | Prospective | BPTB     | 39.4              | 16           | 28              | 24.4       |
| Lin et al. 2013  | Retrospective | BPTB    | 51.6              | 25           | 26.8            | 32         |
| Ahn et al. 2005  | Retrospective | Hamstring | 35               | 18           | 30              | 16.6       |
| Boutefnouchet et al. 2012 | Retrospective | Hamstring | 49.2             | 15           | 25              | 0          |
| Chan et al. 2006  | Prospective | Hamstring | 40               | 20           | 29              | 25         |
| Chen et al. 2002  | Prospective | Hamstring | 26               | 27           | 27              | 33.3       |
| Chen et al. 2006  | Prospective | Hamstring | 54               | 52           | 31              | 32.7       |
| Cury et al. 2017  | Retrospective | Hamstring | 24               | 16           | 31              | 6.2        |
| Deehan et al. 2003 | Prospective | Hamstring | 40               | 31           | 27              | 7.4        |
| Deie et al. 2015  | Retrospective | Hamstring | 150              | 27           | 34              | 33.3       |
| Hagino et al. 2018 | Retrospective | Hamstring | 24               | 23           | 28.9            | 27.7       |
| Jackson et al. 2008 | Prospective | Hamstring | 120              | 26           | 28              | 3.8        |
| Jain et al. 2016  | Retrospective | Hamstring | 28.1             | 22           | 27.4            | 0          |
| Li et al. 2014    | Retrospective | Hamstring | 27.6             | 18           | 31.3            | 27.7       |
| Li et. al. 2008   | Retrospective | Hamstring | 28.8             | 15           | 20–43           | 13.3       |
| Lin et al. 2013   | Retrospective | Hamstring | 51.1             | 34           | 26.2            | 21         |
| Ma et al. 2019    | Prospective | Hamstring | 28               | 60           | 33.6            | 30         |
| Mestriner et al. 2019 | Retrospective | Hamstring | 24               | 18           |                 |            |
| Norbakhsh et al. 2014 | Prospective | Hamstring | 42               | 52           | 27              | 19.2       |
| Rhatomy et al. 2020 | Prospective | Hamstring | 24               | 27           | 30.3            | 59.2       |
| Saragaglia et al. 2019 | Retrospective | Hamstring | 27               | 8            | 24.5            | 0          |
| Sun et al. 2015   | Retrospective | Hamstring | 37.2             | 36           | 31.1            | 25         |
| Tornese et al. 2008 | Randomized | Hamstring | 12               | 7            | 24              | 14.2       |
| Wang et al. 2017  | Retrospective | Hamstring | 71.6             | 41           | 32              | 44.9       |
| Xu et al. 2014    | Retrospective | Hamstring | 51               | 16           | 29.1            | 43.7       |
| Zaho et al. 2007  | Retrospective | Hamstring | 31.2             | 21           | 23–46           | 23.8       |
| Rhatomy et al. 2020 | Prospective | PLT       | 24               | 28           | 29.1            | 21.4       |
| Setyawan et al. 2019 | Retrospective | PLT     | 24               | 15           | 25.9            | 26.6       |
| Aglietti et al. 2002 | Prospective | Quadriceps | 42              | 18           | 26.7            | 38.8       |
| Chen et al. 1999  | Retrospective | Quadriceps | 12–18            | 12           | 29              | 25         |
| Chen et al. 2004  | Retrospective | Quadriceps | 46               | 29           | 28              | 38         |
| Wu et al. 2008    | Prospective | Quadriceps | 66               | 22           | 27              | 22.7       |
| Zayni et al. 2011 | Retrospective | Quadriceps | 29               | 21           | 29              | 14.3       |

(88.5 ± 4.3), quadriceps (86.9 ± 4.6) and the peroneus longus tendon cohorts (81.7 ± 2.1) (Table 2).

The BPTB group reported the lower mean instrumental laxity (2.8 ± 0.9), followed by the hamstring (3.2 ± 0.9) and quadriceps tendon groups (3.0 ± 1.0) (Table 3).

Patients undergoing PCL reconstruction using hamstrings exhibited the higher IKDC (82.8 ± 2.7),
Table 2 Results of the Lysholm score

| Lysholm | BPTB | Hamstring | Peroneus | Quadriceps |
|---------|------|-----------|----------|------------|
| BPTB    | 1    | 1         |          |            |
| Hamstring | MD: −3.4; 95% CI: −6.1 to −0.6; P = 0.005 | 1         |          |            |
| Peroneus | MD: −10.2; 95% CI: −12.9 to −7.4; P < 0.0001 | MD: −6.8; 95% CI: −9.5 to −4.0; P < 0.0001 | 1         |            |
| Quadriceps | MD: −3.8; 95% CI: −6.5 to −1.0; P = 0.001 | MD: −0.4; 95% CI: −3.1 to 2.3; P = 0.9 | MD 6.4; 95% CI: 3.6–9.1; P < 0.0001 | 1         |

Table 3 Results of the mean instrumental laxity

| Arthrometer | BPTB | Hamstring | Quadriceps |
|------------|------|-----------|------------|
| BPTB      | 1    | 1         |            |
| Hamstring | MD: 0.4; 95% CI: −0.1 to 0.9; P = 0.2 | 1         |            |
| Quadriceps | MD: 0.6; 95% CI: 0.0–1.1; P = 0.02 | MD: 0.2; 95% CI: −0.3 to 0.7; P = 0.9 | 1         |

followed by the PTL (79.7 ± 2.2), BPTB (75.3 ± 1.6) and quadriceps (74.5 ± 3.1) tendon groups (Table 4).

Similarity was found in ROM between the BPTB and hamstring (MD: −1.1; 95% CI: −4.4–2.2; P = 0.8) autografts group (Table 5).

Complications

The quadriceps tendon groups showed a rate of revision of 1.0% (1 of 102), and the hamstring showed 0.8% (6 of 755). No revision was experienced by any patients of the PLT and BPTB cohorts. Anterior knee pain was observed in 9.1% (6 of 66) of patients in the BPTB group, and this was observed in 7.0% (3 of 43) in the PTL group and in 1.0% (7 of 735) in the hamstring group. No anterior knee pain was experienced by patients in the quadriceps group. The complications related to each graft are shown in detail in Table 6.

Discussion

PCL reconstruction using an autologous ipsilateral BPTB graft and hamstring likely represents the most suitable graft for primary isolated PCL reconstruction. BPTB demonstrated the greater Lysholm score and the lower joint laxity at arthrometer. Hamstring produced the higher IKDC score. BPTB and hamstring evidenced similar ROM. BPTB and PLT are associated with the highest rate of anterior knee pain.

Hamstring is the most common autograft employed for cruciate ligament reconstruction. Compared to BPTB and quadriceps autografts, hamstring grafts are associated with less morbidity, especially with regard to anterior knee pain during kneeling and extension deficit. In addition, the harvest of hamstring autografts is associated with greater posterior stability compared to BPTB. Following adequate rehabilitation, no decrease in hamstring muscle strength should be expected. On the other hand, hamstring autografts may have disadvantages, including their small size, the high risk of saphenous nerve injury, thigh hypotrophy and pain along the hamstring region. From a biomechanical point of view, hamstring autografts demonstrated less stiffness...
Table 4 Results of the IKDC score

| IKDC     | BPTB     | Hamstring | Peroneus | Quadriceps |
|----------|----------|-----------|----------|------------|
| BPTB     |          |           |          |            |
| Hamstring| 1        |           |          |            |
|          | MD: 7.5; 95% | CI: 5.0–9.9; | $P < 0.0001$ |           |
| Peroneus | MD: 4.4; 95% | CI: 1.9–6.8; | $P < 0.0001$ |           |
|          | MD: −3.1; 95% | CI: −5.5 to −0.6; | $P = 0.002$ | 1          |
| Quadriceps| MD: 1.8; 95% | CI: −0.6 to 4.2; | $P = 0.2$ | 1          |
|          | MD: −5.7; 95% | CI: −8.1 to −3.2; | $P < 0.0001$ | 1          |
|          | MD: −2.6; 95% | CI: −5.0 to −0.1; | $P = 0.02$ |            |

Table 5 Results of the ROM

| ROM     | BPTB     | Hamstring |
|---------|----------|-----------|
| BPTB    | 1        |           |
| Hamstring| MD: −1.1; 95% | CI: −4.4 to 2.2; | $P = 0.8$ |

Table 6 Analysis of complications

| Variable       | BPTB     | Hamstring | Peroneus longus | Quadriceps |
|----------------|----------|-----------|-----------------|------------|
| Revision       | 0% (0 of 66) | 0.8% (6 of 755) | 0% (0 of 43) | 1.0% (1 of 102) |
| Anterior knee pain | 9.1% (6 of 66) | 1.0% (7 of 735) | 7.0% (3 of 43) | 0% (0 of 102) |

than the native PCL along with decreased flexion and internal rotation strength of the knee.\textsuperscript{32,54–56}

PCL reconstruction with BPTB allows fast return to sport and enables bone-to-bone healing in \textasciitilde 4–6 weeks.\textsuperscript{12,18} A biomechanical comparison of tibial inlay and tibial tunnel techniques for PCL reconstruction using BPTB grafts demonstrated that both techniques result in significant greater strength than that measured in the native PCL with the knee flexed beyond 85°.\textsuperscript{57} Posterior tibial translation between BPTB and hamstring PCL reconstruction was compared under 100-N cyclic loading in a cadaveric study\textsuperscript{58}; the hamstring group demonstrated greater laxity than BPTB.\textsuperscript{58}

Quadriceps tendon autograft is a viable alternative for PCL reconstruction. Patients treated with a quadriceps tendon autograft reported satisfactory clinical outcomes, with optimal knee stability and quick return to preinjury level of activity.\textsuperscript{20} The quadriceps tendon is thicker, longer and wider than the patellar tendon, demonstrating sufficient size and strength for PCL reconstruction.\textsuperscript{49,59} The ultimate tensile failure load for quadriceps complexes occurred at 2173\,±\,618 N compared with 1953\,±\,325 N of the BPTB.\textsuperscript{59} However, in a cadaveric study, quadriceps and BPTB autografts demonstrated similar load to failure, no difference in load to failure stiffness and displacement at failure.\textsuperscript{60} PLT autografts are recommended for athletes who require dominant hamstring strengths to reduce the low incidence of anterior knee pain and kneeling pain.\textsuperscript{23} PLT autografts have been used in ACL
reconstruction with minimal donor site morbidity, good clinical outcomes and tensile strength compared to hamstring autografts. Previous studies demonstrated that PCL reconstruction using PLT autograft showed good functional outcome at 2-year follow-up.

Several studies have compared the clinical outcomes of PCL reconstruction with autograft versus allograft and have demonstrated no significant differences in outcomes. Although autografts produce comparable results to allografts, the use of allografts can eliminate donor site morbidity and minimize operative trauma. However, complications such as tissue rejection and delayed revascularization are a concern. To overcome these complications, the Ligament Advanced Reinforcement System has been introduced with satisfying clinical outcomes.

The present study has several limitations. The design of the studies included for analysis was mostly prospective and retrospective, and only one randomized controlled trial was included. The limited study size along with the heterogeneous inclusion eligibility criteria were other important sources’ bias of the present study. The analyses were conducted irrespective of the type of the technique used for reconstruction (double or single bundle). The limited number of samples included for analysis may have jeopardized the reliability of these results. Thus, given these limitations, data must be interpreted with caution. Strengths of the present work were the comprehensive nature of the literature search along with the strict eligibility criteria and the adequate baseline comparability. The timing of the evaluation of the results was clearly indicated by most of studies. Most studies used outcome criteria with good reliability. The selection criteria were often reported and unbiased. Future high-quality studies involving a larger number of patients and longer follow-up are required to detect less common complications.

Conclusion

The BPTB may represent the most suitable tendon for primary isolated PCL reconstruction. Further clinical investigations are required to infer solid conclusions.

Conflict of interest statement

The authors have no potential conflicts of interest.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

For this type of study, informed consent is not required.

Data availability statement

The data underlying this article are available in the article and in its online supplementary material.

References

1. Kennedy NI, Wijdicks CA, Goldsmith MT, et al. Kinematic analysis of the posterior cruciate ligament, part 1: the individual and collective function of the anterolateral and posteromedial bundles. Am J Sports Med 2013;41:2828–38.
2. Fanelli GC, Beck JD, Edson CJ. Current concepts review: the posterior cruciate ligament. J Knee Surg 2010;23:61–72.
3. Fanelli GC, Edson CJ. Posterior cruciate ligament injuries in trauma patients: part II. Arthroscopy 1995;11:526–9.
4. Jacobi M, Reischl N, Wahl P, et al. Acute isolated injury of the posterior cruciate ligament treated by a dynamic anterior drawer brace: a preliminary report. J Bone Joint Surg Br 2010;92:1381–4.
5. Tewes DP, Fritts HM, Fields RD, et al. Chronically injured posterior cruciate ligament: magnetic resonance imaging. Clin Orthop Relat Res 1997;335:224–32.
6. Patel DV, Allen AA, Warren RF, et al. The nonoperative treatment of acute, isolated (partial or complete) posterior cruciate ligament-deficient knees: an
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intermediate-term follow-up study. *HSS J* 2007;3:137–46.

7. Shelbourne KD, Clark M, Gray T. Minimum 10-year follow-up of patients after an acute, isolated posterior cruciate ligament injury treated nonoperatively. *Am J Sports Med* 2013;41:1526–33.

8. Berg EE. Posterior cruciate ligament tibial inlay reconstruction. *Arthroscopy* 1995;11:69–76.

9. Hermans S, Corten K, Bellemans J. Long-term results of isolated anterolateral bundle reconstructions of the posterior cruciate ligament: a 6- to 12-year follow-up study. *Am J Sports Med* 2009;37:1499–507.

10. Panchal HB, Sekiya JK. Open tibial inlay versus arthroscopic transtibial posterior cruciate ligament reconstructions. *Arthroscopy* 2011;27:1289–95.

11. Wijdicks CA, Kennedy NI, Goldsmith MT, et al. Kinematic analysis of the posterior cruciate ligament, part 2: a comparison of anatomic single- versus double-bundle reconstruction. *Am J Sports Med* 2013;41:2839–48.

12. Lin YC, Chen SK, Liu TH, et al. Arthroscopic transtibial single-bundle posterior cruciate ligament reconstruction using patellar tendon graft compared with hamstring tendon graft. *Arch Orthop Trauma Surg* 2013;133:523–30.

13. Deie M, Adachi N, Nakamae A, et al. Evaluation of single-bundle versus double-bundle PCL reconstructions with more than 10-year follow-up. *Sci World J* 2015;2015:751465.

14. Wang R, Xu B, Wu L, et al. Long-term outcomes after arthroscopic single-bundle reconstruction of the posterior cruciate ligament: a 7-year follow-up study. *J Int Med Res* 2018;46:865–72.

15. Chan YS, Yang SC, Chang CH, et al. Arthroscopic reconstruction of the posterior cruciate ligament with use of a quadruple hamstring tendon graft with 3- to 5-year follow-up. *Arthroscopy* 2006;22:762–70.

16. Curry RP, Castro Filho RN, Sadatsune DA, et al. Double-bundle PCL reconstruction using autologous hamstring tendons: outcome with a minimum 2-year follow-up. *Rev Bras Ortop* 2017;52:203–9.

17. Papageorgiou CD, Ma CB, Abramowitch SD, et al. A multidisciplinary study of the healing of an intraarticular anterior cruciate ligament graft in a goat model. *Am J Sports Med* 2001;29:620–6.

18. Xie X, Liu X, Chen Z, et al. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. *Knee* 2015;22:100–10.

19. Mohtadi NG, Chan DS, Dainty KN, et al. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. *Cochrane Database Syst Rev* 2011;9:CD005960.

20. Zayni R, Hager JP, Archbold P, et al. Activity level recovery after arthroscopic PCL reconstruction: a series of 21 patients with a mean follow-up of 29 months. *Knee* 2011;18:392–5.

21. Aglietti P, Buzzi R, Lazzara D. Posterior cruciate ligament reconstruction with the quadriceps tendon in chronic injuries. *Knee Surg Sports Traumatol Arthrosc* 2002;10:266–73.

22. Chen CH, Chen WJ, Shih CH, et al. Arthroscopic posterior cruciate ligament reconstruction with quadriceps tendon autograft: minimal 3 years follow-up. *Am J Sports Med* 2004;32:361–8.

23. Setyawan R, Soekarno NR, Asikin AIZ, et al. Posterior cruciate ligament reconstruction using patellar tendon graft compared with peroneus longus tendon graft: 2-Years follow-up. *Ann Med Surg (Lond)* 2019;43:38–43.

24. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ* 2009;339:b2700.

25. Coleman BD, Khan KM, Maffulli N, et al. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. *Victorian Institute of Sport Tendon Study Group. Scand J Med Sci Sports* 2000;10:2–11.

26. Shang X, Chen J, Chen S. A meta-analysis comparing tenotomy and tenodesis for treating rotator cuff tears combined with long head of the biceps tendon lesions. *PLoS One* 2017;12:e0185788.

27. Eberbach H, Hohloch L, Feucht MJ, et al. Operative versus conservative treatment of apophyseal avulsion fractures of the pelvis in the adolescents: a systematic review with meta-analysis of clinical outcome and return to sports. *BMC Musculoskelet Disord* 2017;18:162.

28. Hohloch L, Eberbach H, Wagner FC, et al. Age- and severity-adjusted treatment of proximal humerus fractures in children and adolescents—a systematical review and meta-analysis. *PLoS One* 2017;12:e0183157.

29. Cooper DE, Stewart D. Posterior cruciate ligament reconstruction using single-bundle patella tendon graft with tibial inlay fixation: 2- to 10-year follow-up. *Am J Sports Med* 2004;32:346–60.

30. Ahn JH, Yoo JC, Wang JH. Posterior cruciate ligament reconstruction: double-loop hamstring tendon autograft versus Achilles tendon allograft—clinical results of a minimum 2-year follow-up. *Arthroscopy* 2005;21:965–9.
31. Boutefnouchet T, Bentayeb M, Qadri Q, et al. Long-term outcomes following single-bundle transtibial arthroscopic posterior cruciate ligament reconstruction. *Int Orthop* 2013;37:337–43.

32. Chen CH, Chen WJ, Shih CH. Arthroscopic reconstruction of the posterior cruciate ligament with quadruple hamstring tendon graft: a double fixation method. *J Trauma* 2002;52:938–45.

33. Chen CH, Chuang TY, Wang KC, et al. Arthroscopic posterior cruciate ligament reconstruction with hamstring tendon autograft: results with a minimum 4-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2006;14:1045–54.

34. Deehan DJ, Salmon LJ, Russell VJ, et al. Endoscopic single-bundle posterior cruciate ligament reconstruction: results at minimum 2-year follow-up. *Arthroscopy* 2003;19:955–62.

35. Ochiai S, Hagino T, Senga S, et al. Treatment outcome of reconstruction for isolated posterior cruciate injury: subjective and objective evaluations. *J Knee Surg* 2019;32:506–12.

36. Jackson WF, van der Tempel WM, Salmon LJ, et al. Endoscopically-assisted single-bundle posterior cruciate ligament reconstruction: results at minimum ten-year follow-up. *J Bone Joint Surg Br* 2008;90:1328–33.

37. Jain V, Goyal A, Mohindra M, et al. A comparative analysis of arthroscopic double-bundle versus single-bundle posterior cruciate ligament reconstruction using hamstring tendon autograft. *Arch Orthop Trauma Surg* 2016;136:1555–61.

38. Li B, Wang JS, He M, et al. Comparison of hamstring tendon autograft and tibialis anterior allograft in arthroscopic transtibial single-bundle posterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3077–84.

39. Li B, Wen Y, Wu H, et al. Arthroscopic single-bundle posterior cruciate ligament reconstruction: retrospective review of hamstring tendon graft versus LARS artificial ligament. *Int Orthop* 2009;33:991–6.

40. Xu M, Zhang Q, Dai S, et al. Double bundle versus single bundle reconstruction in the treatment of posterior cruciate ligament injury: a prospective comparative study. *Indian J Orthop* 2019;53:297–303.

41. Mestriner MB, Cury RPL, Dos Santos NA, et al. Double-bundle posterior cruciate ligament reconstruction: no differences between two types of autografts in isolated or combined lesions. *Knee* 2020;27:140–50.

42. Norbaksh ST, Zafarani Z, Najafi A, et al. Arthroscopic posterior cruciate ligament reconstruction by using hamstring tendon autograft and transosseous screw fixation: minimal 3 years follow-up. *Arch Orthop Trauma Surg* 2014;134:1723–30.

43. Rhatomy S, Abadi MBT, Setyawan R, et al. Posterior cruciate ligament reconstruction with peroneus longus tendon versus hamstring tendon: a comparison of functional outcome and donor site morbidity. *Knee Surg Sports Traumatol Arthrosc* 2021;29:1045–51.

44. Saragaglia D, Franconi F, Gaillot J, et al. Posterior cruciate ligament reconstruction for chronic lesions: clinical experience with hamstring versus ligament advanced reinforcement system as graft. *Int Orthop* 2020;44:179–85.

45. Sun X, Zhang J, Qu X, et al. Arthroscopic posterior cruciate ligament reconstruction with allograft versus autograft. *Arch Med Sci* 2015;11:395–401.

46. Tornese D, Bandia M, Volpi P, et al. Patellar tendon vs. Semitendinosus and Gracilis graft for posterior cruciate ligament reconstruction: an isokinetic and functional study one year after the operation. *Isokinetics Exercise Sci* 2008;16:133–7.

47. Xu X, Huang T, Liu Z, et al. Hamstring tendon autograft versus LARS artificial ligament for arthroscopic posterior cruciate ligament reconstruction in a long-term follow-up. *Arch Orthop Trauma Surg* 2014;134:1753–9.

48. Zhao J, Huangfu X. Arthroscopic single-bundle posterior cruciate ligament reconstruction: retrospective review of 4- versus 7-strand hamstring tendon graft. *Knee* 2007;14:301–5.

49. Chen CH, Chen WJ, Shih CH. Arthroscopic posterior cruciate ligament reconstruction with quadriceps tendon-patellar bone autograft. *Arch Orthop Trauma Surg* 1999;119:86–8.

50. Wu CH, Chen AC, Yuan LJ, et al. Arthroscopic reconstruction of the posterior cruciate ligament by using a quadriceps tendon autograft: a minimum 5-year follow-up. *Arthroscopy* 2007;23:420–7.

51. Chen CH, Chen WJ, Shih CH. Arthroscopic reconstruction of the posterior cruciate ligament: a comparison of quadriceps tendon autograft and quadruple hamstring tendon graft. *Arthroscopy* 2002;18:603–12.

52. Aglietti P, Buzzi R, Zaccherotti G, et al. Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. *Am J Sports Med* 1994;22:211–7 discussion 217-8.

53. Karlson JA, Steiner ME, Brown CH, et al. Anterior cruciate ligament reconstruction using gracilis and semitendinosus tendons. Comparison of through-the-condyle and over-the-top graft placements. *Am J Sports Med* 1994;22:659–66.
54. Thomas AC, Villwock M, Wojtys EM, et al. Lower extremity muscle strength after anterior cruciate ligament injury and reconstruction. *J Athl Train* 2013;48:610–20.

55. Vinagre G, Kennedy NI, Chahla J, et al. Hamstring graft preparation techniques for anterior cruciate ligament reconstruction. *Arthrosc Tech* 2017;6:e2079–84.

56. Murawski CD, van Eck CF, Irrgang JJ, et al. Operative treatment of primary anterior cruciate ligament rupture in adults. *J Bone Joint Surg Am* 2014;96:685–94.

57. Oakes DA, Markolf KL, McWilliams J, et al. Biomechanical comparison of tibial inlay and tibial tunnel techniques for reconstruction of the posterior cruciate ligament. Analysis of graft forces. *J Bone Joint Surg Am* 2002;84:938–44.

58. Hiraga Y, Ishibashi Y, Tsuda E, et al. Biomechanical comparison of posterior cruciate ligament reconstruction techniques using cyclic loading tests. *Knee Surg Sports Traumatol Arthrosc* 1996;4:100–10.

59. Staubli HU, Schatzmann L, Brunner P, et al. Quadriceps tendon and patellar ligament: cryosectional anatomy and structural properties in young adults. *Knee Surg Sports Traumatol Arthrosc* 1996;4:100–10.

60. Brand J Jr, Hamilton D, Selby J, et al. Biomechanical comparison of quadriceps tendon fixation with patellar tendon bone plug interference fixation in cruciate ligament reconstruction. *Arthroscopy* 2000;16:805–12.

61. Shi FD, Hess DE, Zuo JZ, et al. Peroneus longus tendon autograft is a safe and effective alternative for anterior cruciate ligament reconstruction. *J Knee Surg* 2019;32:804–11.

62. Rhatomy S, Abadi MBT, Setyawan R, et al. Posterior cruciate ligament reconstruction with peroneus longus tendon versus hamstring tendon: a comparison of functional outcome and donor site morbidity. *Knee Surg Sports Traumatol Arthrosc* 2020;29:1045–1051.

63. Wang CJ, Chan YS, Weng LH, et al. Comparison of autogenous and allogeneous posterior cruciate ligament reconstructions of the knee. *Injury* 2004;35:1279–85.

64. Razi M, Ghaffari S, Askari A, et al. An evaluation of posterior cruciate ligament reconstruction surgery. *BMC Musculoskelet Disord* 2020;21:526.

65. Kim SJ, Kim HK, Kim HJ. Arthroscopic posterior cruciate ligament reconstruction using a one-incision technique. *Clin Orthop Relat Res* 1999;359:156–66.

66. MacGillivray JD, Stein BE, Park M, et al. Comparison of tibial inlay versus transtibial techniques for isolated posterior cruciate ligament reconstruction: minimum 2-year follow-up. *Arthroscopy* 2006;22:320–8.

67. Sun K, Zhang J, Wang Y, et al. Arthroscopic anterior cruciate ligament reconstruction with at least 2.5 years’ follow-up comparing hamstring tendon autograft and irradiated allograft. *Arthroscopy* 2011;27:1195–202.

68. Chiang LY, Lee CH, Tong KM, et al. Posterior cruciate ligament reconstruction implemented by the Ligament Advanced Reinforcement System over a minimum follow-up of 10 years. *Knee* 2020;27:165–72.

69. Shen G, Xu Y, Dong Q, et al. Arthroscopic posterior cruciate ligament reconstruction using LARS artificial ligament: a retrospective study. *J Surg Res* 2012;173:75–82.

70. Huang JM, Wang Q, Shen F, et al. Cruciate ligament reconstruction using LARS artificial ligament under arthroscopy: 81 cases report. *Chin Med J (Engl)* 2010;123:160–4.

71. Chen CP, Lin YM, Chiu YC, et al. Outcomes of arthroscopic double-bundle PCL reconstruction using the LARS artificial ligament. *Orthopedics* 2012;35:e800–6.