Journal: British Medical Bulletin
Article doi: ldx014
Article title: Management of combined injuries of the posterior cruciate ligament and posterolateral corner of the knee: a systematic review
First Author: Stefano Petrillo
Corr. Author: Nicola Maffulli

INSTRUCTIONS

We encourage you to use Adobe's editing tools (please see the next page for instructions). If this is not possible, please print out the proof, mark your corrections clearly in black ink, scan it, and email it to BRIMED_OUP@adi-mps.com. Please do not send corrections as track changed Word documents.

Changes should be corrections of typographical errors only. Changes that contradict journal style will not be made.

These proofs are for checking purposes only. They should not be considered as final publication format. The proof must not be used for any other purpose. In particular we request that you: do not post them on your personal/ institutional web site, and do not print and distribute multiple copies (please use the attached offprint order form). Neither excerpts nor all of the article should be included in other publications written or edited by yourself until the final version has been published and the full citation details are available. You will be sent these when the article is published.

1. **Licence to Publish:** If you have not already done so, please also complete and return the Licence to Publish form by fax or email attachment. Please also send a hard copy by mail.

2. **Permissions:** Permission to reproduce any third party material in your paper should have been obtained prior to acceptance. If your paper contains figures or text that require permission to reproduce, please inform me immediately by email.

3. **Author groups:** Please check that all names have been spelled correctly and appear in the correct order. Please also check that all initials are present. Please check that the author surnames (family name) have been correctly identified by a pink background. If this is incorrect, please identify the full surname of the relevant authors. Occasionally, the distinction between surnames and forenames can be ambiguous, and this is to ensure that the authors' full surnames and forenames are tagged correctly, for accurate indexing online. Please also check all author affiliations.

4. **Figures:** If applicable, figures have been placed as close as possible to their first citation. Please check that they are complete and that the correct figure legend is present. Figures in the proof are low resolution versions that will be replaced with high resolution versions when the journal is printed.

5. **Colour reproduction:** These figures are currently intended to appear online in colour and black and white in print. Please reword the legend/text to avoid using reference to colour. Alternatively, please let us know if you wish to pay for print colour reproduction or to have both versions in black and white. The standard charge for colour reproduction in print is £350/€525/$600 per figure. Please check the black and white versions at the end of the paper and contact us if you have any concerns.

6. **Missing elements:** Please check that the text is complete and that all figures, tables and their legends are included.

7. **Special characters:** Please check that special characters, equations, dosages and units, if applicable, have been reproduced accurately.

8. **Funding:** If applicable, any funding used while completing this work should be highlighted in a separate Funding section. Please ensure that you use the full official name of the funding body.

AUTHOR QUERIES - TO BE ANSWERED BY THE CORRESPONDING AUTHOR

Please respond to all queries and send any additional proof corrections. Failure to do so could result in delayed publication.

Query No.	Query
No Query	

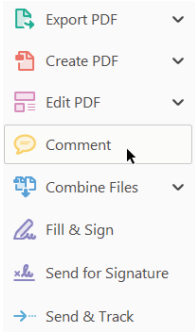
MAKING CORRECTIONS TO YOUR PROOF

These instructions show you how to mark changes or add notes to your proofs using Adobe Acrobat Professional versions 7 and onwards, or Adobe Reader DC. To check what version you are using go to **Help** then **About**. The latest version of Adobe Reader is available for free from get.adobe.com/reader.

DISPLAYING THE TOOLBARS

Adobe Reader DC

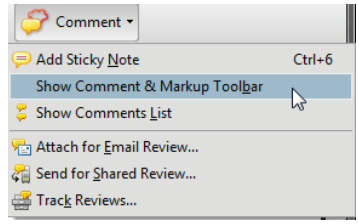
In Adobe Reader DC, the Comment toolbar can be found by clicking 'Comment' in the menu on the right-hand side of the page (shown below).



The toolbar shown below will then display along the top.

Acrobat Professional 7, 8, and 9

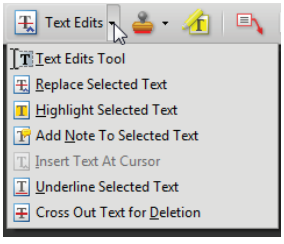
In Adobe Professional, the Comment toolbar can be found by clicking 'Comment(s)' in the top toolbar, and then clicking 'Show Comment & Markup Toolbar' (shown below).



The toolbar shown below will then be displayed along the top.

USING TEXT EDITS AND COMMENTS IN ACROBAT

This is the quickest, simplest and easiest method both to make corrections, and for your corrections to be transferred and checked.



1. Click **Text Edits**
2. Select the text to be annotated or place your cursor at the insertion point and start typing.
3. Click the **Text Edits** drop down arrow and select the required action.

You can also right click on selected text for a range of commenting options, or add sticky notes.

SAVING COMMENTS

In order to save your comments and notes, you need to save the file (**File, Save**) when you close the document.

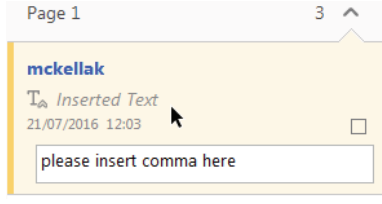
USING COMMENTING TOOLS IN ADOBE READER

All commenting tools are displayed in the toolbar. You cannot use text edits, however you can still use highlighter, sticky notes, and a variety of insert/replace text options.

POP-UP NOTES

In both Reader and Acrobat, when you insert or edit text a pop-up box will appear. In **Acrobat** it looks like this:

In **Reader** it looks like this, and will appear in the right-hand pane:



DO NOT MAKE ANY EDITS DIRECTLY INTO THE TEXT, USE COMMENTING TOOLS ONLY.

British Medical Bulletin, 2017, 1–11
doi: 10.1093/bmb/ldx014

Invited Review

Management of combined injuries of the posterior cruciate ligament and posterolateral corner of the knee: a systematic review

Stefano Petrillo[†], Piero Volpi[‡], Rocco Papalia[†], Nicola Maffulli[§,¶,*], and Vincenzo Denaro[†]

[†]Department of Orthopaedic and Trauma Surgery, Campus Bio-Medico University, Via Alvaro del Portillo 200, 00128 Trigoria, Rome, Italy, [‡]Department of Knee Surgery and Sports Traumatology, Humanitas Research Hospital, Via Manzoni 56, 20089 Rozzano, Milan, Italy, [§]Department of Musculoskeletal Disorders, University of Salerno School of Medicine and Surgery, Salerno, Italy, and [¶]Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK

*Correspondence address. Department of Musculoskeletal Disorders, University of Salerno School of Medicine and Surgery, Salerno, Italy. E-mail: n.maffulli@qmul.ac.uk

Editorial Decision 3 April 2017; Accepted 24 April 2017

Abstract

Background: Approximately 60% of posterior cruciate ligament (PCL) injury are associated with a posterolateral corner (PLC) tear.

Sources of data: We performed a systematic review of the literature according to the PRISMA guidelines. The following key words were searched on Medline, Cochrane, EMBASE, Google Scholar, and Ovid: 'posterior cruciate ligament' or 'PCL' with 'posterolateral corner' or 'PLC' and 'chronic'; 'injury'; 'management'; 'reconstruction'; 'outcomes'; 'complications'.

Areas of agreement: There was a statistically significant improvement of all clinical scores after surgery regardless of the procedure performed to reconstruct both PCL and PLC.

Areas of controversy: No randomized control trials were identified on the topic. Standardized methods of functional outcomes assessment are necessary to improve communication on the functional results of the management of PC–PLC.

Growing points: Single stage surgical reconstruction of PCL and PLC is recommended in patients with posterolateral rotatory instability of the knee.

Areas timely for developing research: Adequately powered randomized trials with appropriate subjective and objective outcome measures are necessary to reach definitive conclusions.

Key words: posterior cruciate ligament, posterolateral corner, knee, surgery, outcomes, complications

Introduction

The management of combined posterior cruciate ligament (PCL) posterolateral corner (PLC) injuries is a major challenge, especially in young, high demand athletic patients.

Approximately 60% of PCL injuries are associated with tears of the PLC structures, including the lateral collateral ligament (LCL), coronary ligament, popliteo-fibular ligament (PFL), popliteus tendon (PT) and arcuate ligament.[1] Isolated lesions of the PLC structures are uncommon and account for 1.6–8% of acute ligamentous knee injuries.[2,3] The anatomy of the PLC is complex, and the principal contributors to the static stability of the knee are the LCL, PFL and PT.[4,5]

From a biomechanical viewpoint, in PCL-deficient knees the rotational axis shifts towards the posteromedial compartment at 90 degrees of flexion. In patients with combined injury of PCL and PLC (PC–PLC), this shift is greater, even at lower degrees of knee flexion.[5,6] Accordingly, patients develop posterolateral rotatory instability (PLRI), and inability to practice sport, and early femorotibial and patellofemoral osteoarthritis.[4,7,8]

When conservative management fails, PCL injuries are managed with arthroscopic-assisted single bundle reconstruction with autograft or allograft,[6,9,10] but several studies have reported excellent results of the double-bundle technique.[11–13] On the other hand, different surgical options have been described for the management of PLC tears. Non-anatomical techniques were initially used.[14–17] However, recent studies recommend anatomical and isometric reconstruction of the PLC.[18–21]

The present systematic review reports the clinical outcomes and complications of different surgical procedures performed for the management of chronic PC–PLC.

Materials and methods

We performed a systematic review of the literature according to the PRISMA guidelines with a PRISMA checklist (Fig. 1) and flow diagram (Fig. 2). Two independent reviewers (S.P. and R.P.) conducted the search separately. The search was performed on September 21, 2016. The following databases were screened: Medline, Cochrane, EMBASE, Google Scholar and Ovid. Only articles in English were included. The key words used for the search were 'posterior cruciate ligament' or 'PCL' with 'posterolateral corner' or 'PLC' and 'chronic'; 'injury'; 'management'; 'reconstruction'; 'outcomes'; 'complications'.

Inclusion and exclusion criteria are listed in Table 1. Only articles published in peer review journals were considered. Articles were initially evaluated by title and abstract. Full-text articles were obtained if the abstract did not allow the investigators to assess whether a given article could definitely be included or excluded at this stage. Each abstract and article was reviewed by two investigators separately, and a cross-reference search of the selected articles was performed to identify other relevant studies.

All articles reporting preoperative and postoperative clinical outcomes, as well as complications of single-stage surgical procedures performed for the management of chronic PC–PLC, were included.

Statistical analysis

All the statistical evaluations were performed using SPSS for Mac (IBM SPSS Statistics Desktop verion 22.0; Chicago-Illinois). The comparison between preoperative and postoperative clinical scores was performed using the Wilcoxon–Mann–Whitney test. *P* values lower than 0.05 were considered statistically significant. The categorical variables were reported as frequency with percentage. Continuous

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	5
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	5

Fig. 1 PRISMA checklist.

Section/topic	#	Checklist item	Reported on page #
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig. 2
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6–8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	-
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	6–8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	-
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	-
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9–11
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	11–12
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	12
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	-

Fig. 1 *Continued*

variables data were reported as mean ± standard deviation and range as minimum and maximum values. In all studies, *P* values less than 0.5 were considered statistically significant.

Results

The literature search and cross-referencing identified eight articles[22–29] eligible for the present systematic review. No randomized prospective control trials were found.

Demographics

Overall, 259 knees in 259 patients with PC–PLC injury were included. There were 210 (81%) male and 49 (19%) female patients, a male/female ratio of 4.2/1.

The mean age of the patients at the time of surgery was 32.1 ± 4.1 years (range 22–65 years). All patients had a chronic PC–PLC lesion and underwent surgery at least one month after the index trauma. The mechanism of injury was reported in 189 patients (73%): it was road traffic accident in 92 (48.6%) patients, contact sport trauma in 57 (30.2%) patients and non-contact sport trauma in other 40 (21.2%) patients. This information was not reported in the remaining 70 (27%) patients. The mean follow-up period was 41.6 ± 12.2 months (range 12–110 months) after surgery.

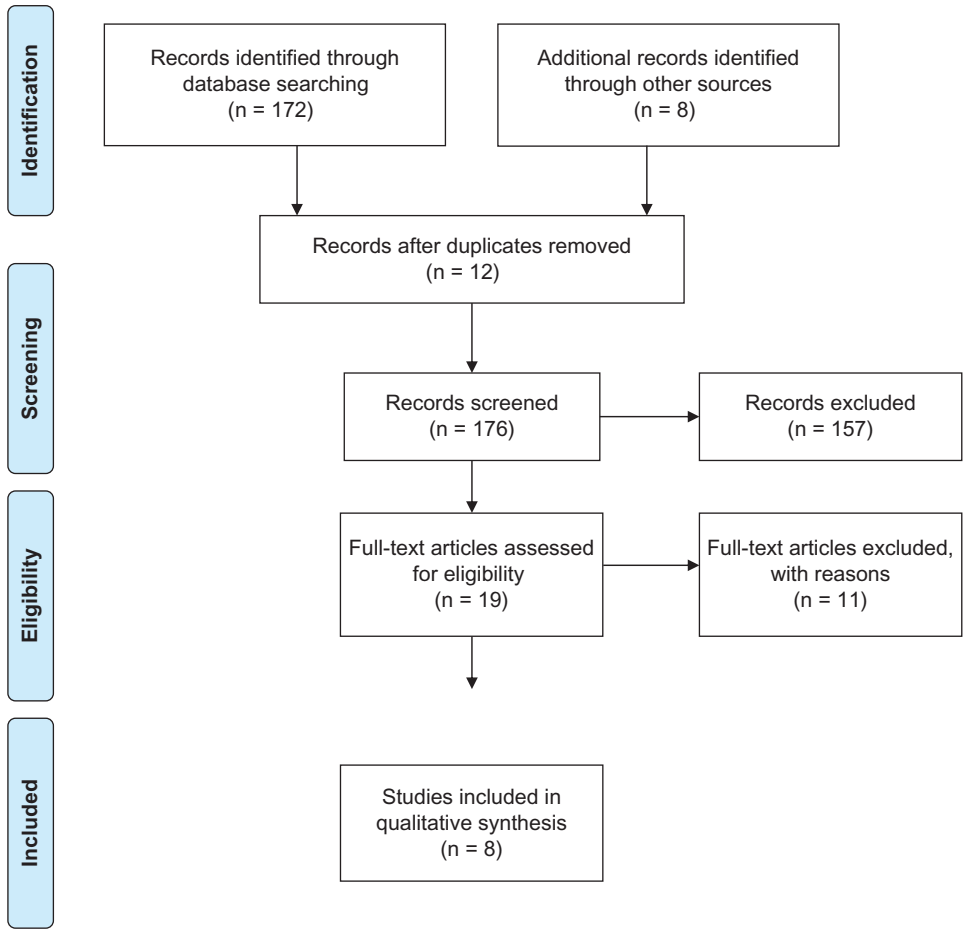


Fig. 2 PRISMA flow diagram.

Surgical procedures

PCL reconstruction

The PCL lesion was managed with arthroscopically-assisted single-bundle anterolateral reconstruction with an allograft in 82 (31.6%) patients,[22,24,25,27] and with an autograft in 112 (43.2%) patients.[27–29] Another 19 (7.3%) patients received a double-bundle PCL reconstruction with an allograft,[25] and 21 (8.1%) patients with an autograft.[23] In the remaining 25 (9.8%) patients, the PCL lesion was managed with a modified endoscopic single-incision technique.[26,30]

PLC reconstruction

The PLC lesion was managed with a reconstruction of both LCL and PT with an allograft in 66 (25.4%) patients.[24,25] 108 (41.6%) patients were managed with Larson's technique.[22,27,28] Of these, 38 (35.2%) received an allograft,[22,27] and 70 (64.8%) an autograft.[28] A popliteal bypass associated with Larson's technique was performed in 21 (8.1%) patients.[23] Albright's technique with allograft and autograft was used in 4 (1.4%) and 15 (5.7%) patients, respectively,[29] while 25 patients (9.8%) were treated with a modified biceps rerouting technique.[26] The remaining 20 (8%) patients where managed with the McGuire and Wolchok technique. Of these, two (10%) received an allograft, while 18 (90%) of them an autograft.[29]

PC–PLC reconstruction

The PC–PLC was managed with arthroscopically-assisted single-bundle anterolateral reconstruction of the PCL associated with Larson's technique in

Table 1 Inclusion/exclusion criteria

Inclusion criteria	
Databases	Medline, EMBASE, Google Scholar and Ovid
Source date/pubdate	September 21, 2016/2000–2016
Key words	'Posterior cruciate ligament' or 'PCL' with 'posterolateral corner' or 'PLC' and 'chronic'; 'injury'; 'management'; 'reconstruction'; 'outcomes'; 'complications'
Article's language	English, French, Spanish, German, Italian
Level of evidence	Oxford centre of EBM, Level I, II, III, IV
Diagnosis	PC–PLC
Type of surgery	Combined reconstruction of both PCL and PLC in a single-stage procedure
Outcomes assessment	Clinical: clinical questionnaires, clinical scores
Minimum follow-up time	12 months
Exclusion criteria	
Type of study	Literature reviews, case reports, case series, conference abstracts, committee posters, studies on animals, on cadavers, biomechanical reports, tumoral studies, technical notes, letters to editors, instructional course.
Diagnosis	No clinical assessment of the PC–PLC. No description of the tests performed to assess the PC–PLC.
Management	Conservative, non-operative management, operative management performed in two-stage procedure.
Outcomes measures	No information on preoperative diagnosis, follow-up, preoperative clinical examination, clinical postoperative outcomes, clinical scores, clinical questionnaires, statistical analysis of the relative outcomes.

108 (41.6%) patients,[22,27,28] while it was associated with anatomical reconstruction of both LCL and PT in 47 (18.1%) patients.[24,31] Arthroscopically-assisted single-bundle anterolateral reconstruction of the PCL associated with the Albright's technique or McGuire's technique was performed in 19 (7.7%) and 20 (8%) patients, respectively.[29]

Double-bundle PCL reconstruction was associated with combined poplieteal bypass and Larson's technique in 21 (8.1%) patients.[23] Another 19 (7.7%) patients with PC–PLC were managed with double-bundle PCL reconstruction associated with an anatomical reconstruction of both LCL and PT.[25] The remaining 25 (8.8%) patients were managed with a modified endoscopic single incision single-bundle technique for the treatment of the PCL lesion, associated with an anatomical reconstruction of both LCL and PT.[26,30]

Outcomes assessment

Clinical outcomes were assessed using the International Knee Documentation Committee (IKDC) objective score[32] both preoperatively and postoperatively in 215 (83%) patients, and only postoperatively in 25 (9.6%) patients. The IKDC subjective score was administered both preoperatively and postoperatively in 115 patients (44.4%), while it was administered only postoperatively in 58 (22.4%) patients. The Orthopädishe Arbeitsgruppe Knie (OAK) score[33] was administered both preoperatively and postoperatively in 109 (42.1%) patients.

The Lysholm score[34] was used both preoperatively and postoperatively in 66 (25.5%) patients, and only postoperatively in 25 (9.6%) patients. The Tegner score[34] was used both preoperatively and postoperatively in 38 (14.7%) patients. The HHS and VAS were administered postoperatively in 25 (9.6%) patients, respectively.[26]

Clinical outcomes

A statistically significant improvement of all clinical scores was found comparing the preoperative with the postoperative value (Table 2).

Table 2 Outcome scores

Outcome score	*n* (%) patients	Preoperative	Postoperative	*P* value
IKDC objective score[32]	215 (83%)			
Grade A		0 (0%)	69 (32%)	
Grade B		0 (0%)	110 (51%)	
Grade C		109 (51%)	32 (15%)	
Grade D		106 (49%)	4 (2%)	
IKDC subjective score[32]	115 (44.4%)	48.2 ± 7.8	78.5 ± 8.5	<0.05
OAK score[33]	109 (42.1%)	63.4 ± 0.9	89.1 ± 1.4	<0.05
Lysholm score[34]	66 (25.5%)	54.7 ± 9.1	83.2 ± 4.9	<0.05
Tegner score[34]	38 (14.7%)	2.3 ± 0.4	6.2 ± 0.3	<0.05

IKDC: International Knee Documentation Committee; OAK: Orthopädishe Arbeitsgruppe Knie score.

According to the preoperative IKDC objective score, 109 (51%) and 106 (49%) patients were classified as Grade C and Grade D, respectively. According to the postoperative IKDC objective score, 69 (32%) patients were Grade A, 110 (51%) were Grade B, 32 (15%) patients were Grade C, and four (2%) patients were Grade D.

Complications

Complications were reported in all studies. Overall, 19 (7.3%) patients developed a complication. The different types of complications and their management are listed in Table 3.

Table 3 Complications and treatment

n (%) patients	Complication	Management
9 (3.5%)	Uncomfortable tibial screw	Tibial screw removal
3 (1.3%)	Cortical breakage of the fibular head	Not necessary
2 (0.7%)	Peroneal nerve palsy	Spontaneous recovery
2 (0.7%)	Postoperative stifness	Manipulation under anaesthesia
2 (0.7%)	Superficial infection	Antibiotic theraphy
1 (0.4%)	Biceps tendon rupture	Reconstruction with allograft

Discussion

Single state surgical reconstruction of chronic PC–PLC injuries is safe and effective to manage PLRI of the knee. A high percentage of satisfactory outcomes, good knee stability and a low complication rate were reported in the literature. Regardless of the procedure performed to reconstruct simultaneously both PCL and PLC lesions, there was a statistically significant improvement of all clinical scores when comparing the preoperative with the postoperative value. According to postoperative IKDC subjective score, 32% patients had Grade A, 51% had Grade B, 15% patients had Grade C and 2% patients had Grade D. Complications were found in 7.3% of patients. The most frequent was intolerance to the tibial fixation screw, easily resolved with its removal.

The PCL prevents posterior translation of the tibia, while the PLC is the most important restraint to varus stress, acting also as a secondary restraint to posterior tibial translation on the lateral tibiofemoral compartment.[35] Moreover, the PCL and PLC are the main restraints to external rotation of the tibia: the PLC is the primary restraint at low flexion angles, while both the PCL and PLC are the main restraints at high flexion angles.[36,37] In PLC lesions, the PCL is placed under high loading conditions, and it is thus more prone to injury.[38]

Despite its synovial coverage and high potential for spontaneous healing,[39] surgery should be considered in patients with Grade II and III PCL lesions.[40] Arthroscopically assisted single bundle PCL

reconstruction provides excellent results. Tensioning of the remnant fibres and augmentation of the anterolateral bundle of PCL improve knee stability.[41] The mechanoreceptors in PCL-injured knees act as knee stabilizers.[41] Accordingly, if the remnant of the PCL is tensioned surgically, there would be an advantage of preserving the proprioceptive function of the ligaments mechanoreceptor.

Double-bundle PCL reconstruction better restores the normal biomechanics of the knee when compared with single-bundle procedure.[42–44] On the other hand, other studies reported no differences between double-bundle and single-bundle grafts using a transtibial technique or an inlay technique in PCL reconstruction.[45] The anterolateral bundle of the PCL is taut in knee flexion, and slackens close to full extension of the knee. On the other hand, the posteromedial bundle of the PCL is normally taut in knee extension.[46] Therefore, insufficiency of the posteromedial bundle of PCL could result in knee instability near extension.[46] However, all these studies did not evaluate PLC deficiency. Biomechanically, single-bundle PCL reconstruction associated with Larson's technique is effective to manage PLRI.[42] Double-bundle PCL reconstruction combined with posterolateral corner reconstruction did not show advantages over single-bundle PCL reconstruction in terms of clinical outcomes and knee stability.[25]

At present, anatomic isometric reconstruction of the PLC is recommended. The first reports on PLC reconstructions were on non-anatomical procedures. Clancy and Sutherland described the biceps femoris tendon tenodesis,[47] whereby the tendon of biceps femoris was tenodesed to the lateral femoral epicondyle and fixed with screws. Of 39 patients with PC–PLC injury, 77% returned to activity with no limitations, and 54% returned to preinjury level of sports practice. However, their technique does not reproduce the PFL and PT, which are fundamental stabilizers of the knee.

In the posterolateral sling procedure,[48] the central slip of the iliotibial band or an Achilles tendon allograft is passed through a tibial tunnel, and fixed on the femur near the LCL insertion. Complete resolution of PLRI was reported in 87% of patients, although this technique did not reconstruct the LCL and PFL. The reconstruction of LCL and PT associated with arcuate advancement was proposed by Noyes and Barber-Westin.[49] They had 76% of good to excellent functional results and 10% of failure rate at 42 months of follow-up. Arciero *et al.*[50] reconstructed PFL, LCL and popliteal complex using two separate limbs of the soft tissue graft. They used this technique in 14 patients with PC–PLC or combined injury of the anterior cruciate ligament and PLC, reporting complete restoration of varus stability and decreased abnormal external rotation of the tibia in all their patients.

When considering the results of the present study, good to excellent clinical outcomes were found in 83% of patients who underwent PCL and PLC reconstruction in a single-stage surgery. Khanduja *et al.*[27] and Zorzi *et al.*[22] found that single-bundle PCL reconstruction combined with Larson's technique provided excellent clinical outcomes, but did not restore the normal laxity of the knee. Both studies reported abnormalities in range of motion, posterior drawer and rotational laxity of the knee. Lee *et al.*[28] used a similar technique reporting excellent results and decreased posterior laxity. Wajsfisz *et al.*[23] performed a double-bundle PCL reconstruction associated with popliteal bypass and Larson's technique in 21 patients. They found a significant improvement of clinical and radiographic results after surgery. However, rotational stability and subjective results were not improved after surgery. Furthermore, all patients recoverd sufficient function of the knee for daily life activities, but not for sports practice.

Kim *et al.*[24] compared the clinical outcomes of PLC surgery using anatomical reconstruction of both LCL and PT with or without simultaneous PCL reconstruction in PCL injuries with mild posterior translation. They found a statistically significant improvement on posterior stress radiography, IKDC subjective score and IKDC objective score in patients underwent combined PCL and PLC surgery.

The major strength of the present systematic review is that it was performed according to PRISMA guidelines. Therefore, the risk of selection bias and data extraction errors is substantially reduced. Another important strength is that all studies were

screened in a blind fashion by two independent reviewers who extracted all the relevant data from the articles. Moreover, the strict inclusion and exclusion criteria of the present systematic review allowed us to evaluate only studies conducted in a strict scientific fashion, reporting preoperative and postoperative clinical outcomes of chronic PC–PLC.

The main limitation of our study is represented by the lack of Level I studies included in our analysis. This prevented us from performing a metanalysis. We decided to combine the results from all the eight studies to have a better insight in the clinical outcomes of PC–PLC. However, we are aware that the included studies have marked difference in the levels of evidence. Secondly, the results that we report should be considered with caution, taking into account the nature of the present study. Thirdly, we have included in the qualitative synthesis only information about outcome scores and complications, without considering functional results. However, we found a lack of homogeneity to evaluate this information in the selected studies, and it was not possible to statistically compare the different results. Finally, we identified only eight studies reporting the outcome of combined PCL–PLC injuries in 259 patients (259 knees). Therefore, this sample of patients is not sufficient to consider our results as univocal.

In conclusion, single stage surgical reconstruction of PCL and PLC is recommended in patients with PC–PLC to tackle PLRI of the knee. Regardless of the surgical procedure used to reconstruct both PCL and PLC, good and excellent clinical outcomes were reported in 32% and 52% patients, respectively. However, surgery did not restore normal laxity of the affected knee, especially regarding range of motion, posterior drawer and rotational laxity.

Level I studies are necessary to understand which is the best treatment option for the management of chronic PC–PLC, and standardized methods of functional outcomes assessment are necessary to improve the knowledge about functional results of single-stage PCL and PLC reconstruction.

Conflict of interest statement

The authors have no potential conflicts of interest.

References

1. Sekiya JK, Haemmerle MJ, Stabile KJ, et al. Biomechanical analysis of a combined double-bundle posterior cruciate ligament and posterolateral corner reconstruction. *Am J Sports Med* 2005;33:360–9.
2. Larsen MW, Toth A. Examination of posterolateral corner injuries. *J Knee Surg* 2005;18:146–50.
3. Arthur A, LaPrade RF, Agel J. Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee: a prospective clinical study. *Am J Sports Med* 2007;35:1844–50.
4. Thaunat M, Pioger C, Chatellard R, et al. The arcuate ligament revisited: role of the posterolateral structures in providing static stability in the knee joint. *Knee Surg Sports Traumatol Arthrosc* 2014;22:2121–7.
5. Pasque C, Noyes FR, Gibbons M, et al. The role of the popliteofibular ligament and the tendon of popliteus in providing stability in the human knee. *J Bone Joint Surg Br* 2003;85:292–8.
6. Papalia R, Osti L, Del Buono A, et al. Tibial inlay for posterior cruciate ligament reconstruction: a systematic review. *Knee* 2010;17:264–9.
7. Flandry F, Sinco SM. Surgical treatment of chronic posterolateral rotatory instability of the knee using capsular procedures. *Sports Med Arthrosc* 2006;14:44–50.
8. Yong CK. Chronic posterolateral rotatory instability of the knee. *Med J Malaysia* 2006;61:27–31.
9. Kong Y, Zhang Y, Zhao X. Effectiveness of arthroscopic single-bundle posterior cruciate ligament reconstruction with remnant preservation and quadrupled hamstring tendons. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 2013;27:1037–40.
10. Hammoud S, Reinhardt KR, Marx RG. Outcomes of posterior cruciate ligament treatment: a review of the evidence. *Sports Med Arthrosc* 2010;18:280–91.
11. Markolf KL, Feeley BT, Jackson SR, et al. Biomechanical studies of double-bundle posterior cruciate ligament reconstructions. *J Bone Joint Surg Am* 2006;88:1788–94.
12. Garofalo R, Jolles BM, Moretti B, et al. Double-bundle transtibial posterior cruciate ligament reconstruction with a tendon-patellar bone-semitendinosus tendon autograft: clinical results with a minimum of 2 years' follow-up. *Arthroscopy* 2006;22:1331–8.e1.
13. Nyland J, Hester P, Caborn DN. Double-bundle posterior cruciate ligament reconstruction with allograft tissue: 2-year postoperative outcomes. *Knee Surg Sports Traumatol Arthrosc* 2002;10:274–9.
14. McGuire DA, Wolchok JC. Posterolateral corner reconstruction. *Arthroscopy* 2003;19:790–3.

15. Veltri DM, Warren RF. Anatomy, biomechanics, and physical findings in posterolateral knee instability. *Clin Sports Med* 1994;13:599–614.
16. Veltri DM, Warren RF. Operative treatment of posterolateral instability of the knee. *Clin Sports Med* 1994;13:615–27.
17. Fanelli GC. Surgical treatment of lateral posterolateral instability of the knee using biceps tendon procedures. *Sports Med Arthrosc* 2006;14:37–43.
18. Fanelli GC, Larson RV. Practical management of posterolateral instability of the knee. *Arthroscopy* 2002;18:1–8.
19. Chang CB, Seong SC, Lee S, et al. Novel methods for diagnosis and treatment of posterolateral rotatory instability of the knee. *J Bone Joint Surg Am* 2007;89:2–14.
20. Miyatake S, Kondo E, Tsai TY, et al. Biomechanical comparisons between 4-strand and modified Larson 2-strand procedures for reconstruction of the posterolateral corner of the knee. *Am J Sports Med* 2011;39:1462–9.
21. LaPrade RF, Johansen S, Wentorf FA, et al. An analysis of an anatomical posterolateral knee reconstruction: an in vitro biomechanical study and development of a surgical technique. *Am J Sports Med* 2004;32:1405–14.
22. Zorzi C, Alam M, Iacono V, et al. Combined PCL and PLC reconstruction in chronic posterolateral instability. *Knee Surg Sports Traumatol Arthrosc* 2013;21:1036–42.
23. Wajsfisz A, Christel P, Djian P. Does combined posterior cruciate ligament and posterolateral corner reconstruction for chronic posterior and posterolateral instability restore normal knee function? *Orthop Traumatol Surg Res* 2010;96:394–9.
24. Kim SJ, Lee SK, Kim SH, et al. Clinical outcomes for reconstruction of the posterolateral corner and posterior cruciate ligament in injuries with mild grade 2 or less posterior translation: comparison with isolated posterolateral corner reconstruction. *Am J Sports Med* 2013;41:1613–20.
25. Kim SJ, Jung M, Moon HK, et al. Anterolateral transtibial posterior cruciate ligament reconstruction combined with anatomical reconstruction of posterolateral corner insufficiency: comparison of single-bundle versus double-bundle posterior cruciate ligament reconstruction over a 2- to 6-year follow-up. *Am J Sports Med* 2011;39:481–9.
26. Kim SJ, Shin SJ, Jeong JH. Posterolateral rotatory instability treated by a modified biceps rerouting technique: technical considerations and results in cases with and without posterior cruciate ligament insufficiency. *Arthroscopy* 2003;19:493–9.
27. Khanduja V, Somayaji HS, Harnett P, et al. Combined reconstruction of chronic posterior cruciate ligament and posterolateral corner deficiency. A two- to nine-year follow-up study. *J Bone Joint Surg Br* 2006;88:1169–72.
28. Lee KH, Jung YB, Jung HJ, et al. Combined posterolateral corner reconstruction with remnant tensioning and augmentation in chronic posterior cruciate ligament injuries: minimum 2-year follow-up. *Arthroscopy* 2011;27:507–15.
29. Jung YB, Jung HJ, Kim SJ, et al. Posterolateral corner reconstruction for posterolateral rotatory instability combined with posterior cruciate ligament injuries: comparison between fibular tunnel and tibial tunnel techniques. *Knee Surg Sports Traumatol Arthrosc* 2008;16:239–48.
30. Kim SJ, Kim HK, Kim HJ. Arthroscopic posterior cruciate ligament reconstruction using a one-incision technique. *Clin Orthop Relat Res* 1999;156–66.
31. Kim SJ, Kim TW, Kim SG, et al. Clinical comparisons of the anatomical reconstruction and modified biceps rerouting technique for chronic posterolateral instability combined with posterior cruciate ligament reconstruction. *J Bone Joint Surg Am* 2011;93:809–18.
32. Hefti F, Müller W. Current state of evaluation of knee ligament lesions. The new IKDC knee evaluation form. *Orthopade* 1993;22:351–62.
33. Müller W, Biedert R, Hefti F, et al. OAK knee evaluation. A new way to assess knee ligament injuries. *Clin Orthop Relat Res* 1988;37–50.
34. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 1985;43–9.
35. Apsingi S, Nguyen T, Bull AM, et al. The role of PCL reconstruction in knees with combined PCL and posterolateral corner deficiency. *Knee Surg Sports Traumatol Arthrosc* 2008;16:104–11.
36. Covey DC. Injuries of the posterolateral corner of the knee. *J Bone Joint Surg Am* 2001;83-A:106–18.
37. Csintalan RP, Ehsan A, McGarry MH, et al. Biomechanical and anatomical effects of an external rotational torque applied to the knee: a cadaveric study. *Am J Sports Med* 2006;34:1623–9.
38. Chen G, Fu WL, Tang X, et al. Clinical epidemiological analysis on posterior cruciate ligament injuries. *Zhongguo Gu Shang* 2015;28:638–42.
39. Del Buono A, Radmilovic J, Gargano G, et al. Augmentation or reconstruction of PCL? A quantitative review. *Knee Surg Sports Traumatol Arthrosc* 2013;21:1050–63.
40. Chan TW, Kong CC, Del Buono A, et al. Acute augmentation for interstitial insufficiency of the posterior

cruciate ligament. A two to five year clinical and radiographic study. *Muscles Ligaments Tendons J* 2016;6:58–63.
41. Lee SH, Jung YB, Lee HJ, et al. Remnant preservation is helpful to obtain good clinical results in posterior cruciate ligament reconstruction: comparison of clinical results of three techniques. *Clin Orthop Surg* 2013;5:278–86.
42. Apsingi S, Nguyen T, Bull AM, et al. Control of laxity in knees with combined posterior cruciate ligament and posterolateral corner deficiency: comparison of single-bundle versus double-bundle posterior cruciate ligament reconstruction combined with modified Larson posterolateral corner reconstruction. *Am J Sports Med* 2008;36:487–94.
43. Mauro CS, Sekiya JK, Stabile KJ, et al. Double-bundle PCL and posterolateral corner reconstruction components are codominant. *Clin Orthop Relat Res* 2008;466:2247–54.
44. Zehms CT, Whiddon DR, Miller MD, et al. Comparison of a double bundle arthroscopic inlay and open inlay posterior cruciate ligament reconstruction using clinically relevant tools: a cadaveric study. *Arthroscopy* 2008;24:472–80.
45. Bergfeld JA, Graham SM, Parker RD, et al. A biomechanical comparison of posterior cruciate ligament reconstructions using single- and double-bundle tibial inlay techniques. *Am J Sports Med* 2005;33:976–81.
46. Girgis FG, Marshall JL, Monajem A. The cruciate ligaments of the knee joint. Anatomical, functional and experimental analysis. *Clin Orthop Relat Res* 1975;216–31.
47. Clancy WG, Sutherland TB. Combined posterior cruciate ligament injuries. *Clin Sports Med* 1994;13:629–47.
48. Albright JP, Brown AW. Management of chronic posterolateral rotatory instability of the knee: surgical technique for the posterolateral corner sling procedure. *Instr Course Lect* 1998;47:369–78.
49. Noyes FR, Barber-Westin SD. Surgical restoration to treat chronic deficiency of the posterolateral complex and cruciate ligaments of the knee joint. *Am J Sports Med* 1996;24:415–26.
50. Arciero RA. Anatomic posterolateral corner knee reconstruction. *Arthroscopy* 2005;21:1147.