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The use of allograft tissue in posterior cruciate, collateral and multi-ligament knee reconstruction

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Abstract

Purpose Currently both autograft and allograft tissues are available for reconstruction of posterior cruciate, collateral and multi-ligament knee injuries. Decision-making is based on a complex interplay between anatomical structures, functional bundles and varying biomechanical requirements. Despite theoretically better biological healing and reduced risk of disease transmission autografts are associated with donor site morbidity as well as being limited by size and quantity. The use of allografts eliminates donor-site morbidity but raises cost and issues of clinical effectiveness. The purpose of this paper is to review current concepts and evidence for the use of allografts in primary posterior cruciate, collateral and multi-ligament reconstructions.

Methods A narrative review of the relevant literature was conducted for PCL, collateral ligament and multi-ligament knee reconstruction. Studies were identified using a targeted and systematic search with focus on recent comparative studies and all clinical systematic reviews and meta-analyses. The rationale and principles of management underpinning the role of allograft tissue were identified and the clinical and functional outcomes were analysed. Finally, the position of postoperative physiotherapy and rehabilitation was identified.

Results The review demonstrated paucity in high quality and up-to-date results addressing the issue especially on collaterals and multi-ligament reconstructions. There was no significant evidence of superiority of a graft type over another for PCL reconstruction. Contemporary principles in the management of posterolateral corner, MCL and multi-ligament injuries support the use of allograft tissue.

Conclusion The present review demonstrates equivalent clinical results with the use of autografts or allografts. It remains, however, difficult to generate a conclusive evidence-based approach due to the paucity of high-level research. When confronted by the need for combined reconstructions with multiple grafts, preservation of synergistic muscles, and adapted postoperative rehabilitation; the current evidence does offer support for the use of allograft tissue.

Level of evidence IV.

Keywords Posterior cruciate ligament reconstruction · Collateral ligaments · Multiligaments · Allografts · Graft choice · Decision-making · Autografts

Introduction

Knee ligament injuries are common injuries in the young and active population. Arguments for anterior cruciate ligament (ACL) reconstruction advocate restoration of normal kinematics and laxity, as well as return to normal function and sports, ultimately allowing joint preservation by preventing secondary meniscal lesions and degenerative changes, which can result from abnormal joint contact stresses [57, 86, 112]. The use of allograft or autograft tissue for ACL

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reconstruction has been analysed in depth [50, 124]. In contrast, posterior cruciate ligament (PCL) tears are less frequent than ACL tears with a reported incidence of 3% of all knee ligamentous injuries [26, 27, 90]. These figures are echoed in a report from the Danish ligament registry, where PCL reconstruction accounts for 2.6% of all knee ligament reconstructions [77]. The majority of PCL tears result from contact sports or trauma associated with a direct AP impact on the knee [38, 77, 92]. The rationale for the operative management of isolated high-grade PCL injury is becoming more established. An isolated PCL injury can lead to abnormal articular contact pressures leading to a higher risk of meniscus tear, OA and subsequent total knee arthroplasty (TKA) [98, 124].

The literature addressing graft choice in collateral ligaments reconstruction generally falls under the broader category of multi-ligament knee injury [10, 23]. Multi-ligament knee injuries (MLKIs) are uncommon but potentially devastating injuries and represent less than 0.02% of all orthopaedic injuries [69, 103]. By definition, multi-ligament knee injuries (MLKIs) involve two or more of the four primary knee stabilisers: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posteromedial corner (PMC) and posterolateral corner (PLC) [29]. However, MLKIs caused by knee dislocations usually involve tears of both cruciate ligaments (ACL/PCL), with or without injuries to one or both collateral ligaments. These injuries are often also associated with other injuries including vascular trauma (30%) and common peroneal nerve injury (20–30%) [29, 88] and are, therefore, a cause of morbidity and economic burden to both patients and health care systems. The surgical management of multiple ligaments injuries has been reported to yield superior clinical and functional outcomes when compared to non-operative treatment. Furthermore, a number of studies have favoured multiple ligament reconstruction as opposed to repair which consequently increases the demand for more graft material. While autografts are associated with donor-site morbidity and potentially longer rehabilitation, allografts do also carry their own battery of potential complications. Allografts are not readily available in all areas of the world, they are expensive and have been associated with higher failure rates with intra-articular use in young patients. These factors have created a degree of sceptecism in relation to allograft tissue selection for knee ligament reconstruction.

Numerous studies have compared the clinical outcomes of autograft versus allograft in primary ACL reconstruction (ACLR), demonstrating clinically significant differences and advantages to each graft type. Over time the evidence to help decision-making has evolved. Greater complication rates were reported with autograft utilisation [30] and higher rerupture rates were reported with allograft utilisation [111]. A meta-analysis in 2007 favoured autograft in relation to graft failure and objective stability evaluation [99]. Subsequently, variation in outcomes according to graft sources for ACLR could not be identified [12, 30]. Previous authors have highlighted the effect of allograft preparation on outcomes and graft rupture [56]. Indeed recent literature shifted attention towards graft processing and patients selection instead [81, 119]. The question remains whether similar findings are echoed in the context of PCL reconstruction and multi-ligament knee injuries.

In the present review, the current data on the use and outcomes of allografts for knee ligament reconstruction with a principal focus on PCL in addition to collateral ligaments and multi-ligament reconstruction are discussed. The authors followed a systematic approach to addressing factors related to graft selection, reviewing current understanding of the functional anatomy, as well as clinical and functional outcomes. For each area the evidence and factors for decision-making are summarised, to identify the role, where possible, of the use of allograft tissue in the surgical armamentarium for PCL, collateral ligament and multi-ligament reconstruction.

Posterior cruciate ligament reconstruction

Rationale and principles of allograft posterior cruciate ligament reconstruction

The posterior cruciate ligament (PCL) plays a key role in antero-posterior tibio-femoral stability. Pache et al. recently reiterated that PCL is comprised of two functional bundles, a larger anterolateral bundle (ALB) and a smaller posteromedial bundle (PMB) [94]. The anterolateral bundle acts as the main constraint to posterior translation and the greatest effect occurs at 90° of knee flexion [11, 17, 31, 35, 84]. The smaller posteromedial bundle provides posterior stability as the knee approaches full extension in addition to secondary constraint to external rotation [83, 107, 108]. Allografts are commonly used for PCL reconstruction, and this is in part because PCL rupture is often combined with a multi-ligament injury where multiple grafts are required, and in part because of the volume of graft required when performing double-bundle reconstruction.

An in-depth discussion on the surgical indications for isolated PCL tears is beyond the scope of the present article. However, most symptomatic grade III and combined PCL and other ligament tears or medial meniscal posterior root tear are treated surgically. Injury results in objective instability and pain from increased articular contact pressure in the medial and patello-femoral compartments [38, 85, 100], and are associated with an increased long-term risk of osteoarthritis [49, 87, 102, 122]. Some authors have reported poorer outcomes for patients with increased time between initial injury and surgical treatment [15, 41]. The long-term outcomes following the surgical reconstruction of symptomatic PCL tears have remained variable. The KOOS improvement from preoperative to 1-year follow-up for both isolated PCL reconstructions and multi-ligament PCL reconstructions do not reach the levels of those recorded in ACL reconstructions [77]. This is potentially attributable to a lack of reconstruction of both functional bundles of the PCL, patient selection, postoperative rehabilitation regime or graft choice [67, 85]. In vitro studies and biomechanical analyses comparing single-bundle (SB) and double-bundle (DB) PCL reconstructions remain inconclusive [6, 39, 66]. The present review recognises the limitations of such investigation due to artificial loading conditions and the absence of normal dynamic stabilisers. Nevertheless, a single-bundle PCL reconstruction addresses the AL bundle only and in theory, especially in chronic PCL deficiency, can result in residual knee laxity [66, 67, 85, 107, 131]. A systematic review by Chahla et al. analysed data from 441 patients in 11 studies comprising results from three RCTs and eight case control studies [13]. Results of double- and single-bundle reconstruction both improved knee stability and patient outcomes, but double bundle provided better posterior stability and IKDC scores [13]. Garofalo et al. reported amelioration of clinical and subjective scores following grade III isolated chronic PCL tears reconstruction using double-bundle bone-patellar tendon-bone and semitendinosus tendon autograft at a minimum 2-year follow-up [33]. In contrast, Spiridonov et al. demonstrated significant improvement of outcome scores and objective knee stability with double-bundle allograft tissue PCL reconstruction [113]. In the latter study, 32 out of 39 cases were combined PCL and other ligament reconstructions, hence revealing the possible need for allograft tissue.

Clinical outcomes of allograft posterior cruciate ligament reconstruction

Hudgens et al. published a systematic review in 2013 on the variety of available PCL reconstruction techniques [45]. The authors included 19 studies, of which 5 were on allografts, 12 on autografts and 2 simply comparing graft choice and concluded that there was a paucity of comparative outcomes and that both grafts resulted in satisfactory clinical and functional outcomes [45]. The review provided a valuable outline of the advantages of allografts, listing shorter operation time, avoidance of donor site morbidity, and a better graft length plus thickness. Disadvantages included deleterious effects on graft strength from sterilisation methods, costs and availability, as well as a theoretical risk of disease transmission. Disadvantages of autografts included graft size limitations, prolonged operative time, and graft donor-site morbidity [45].

More recent work consisted of a meta-analysis comparing autograft to allografts in PCL reconstruction [120]. The authors only included five studies, one RCT and four non-randomised studies. Due to the limited quality of data in the available literature, the authors concluded that there is currently insufficient evidence to indicate that allograft tendons were significantly better than autograft tendons for PCL reconstruction [120]. Finally, Belk et al. recently published an updated systematic review comparing the use of allograft with autograft in PCL reconstruction [4]. The authors included five studies; three of the studies overlapped with the previous reviews and concluded that primary PCLR with either autograft or allograft leads to improvement in clinical outcomes, and that using pooled estimates from the original studies, allografts had a clinically insignificant 0.7 mm greater AP laxity [4].

The current literature also contains other studies, which were too methodologically weak to include neither in the above discussion nor the outline of clinical outcomes below. Kim et al. reported results of BPTB PCL reconstruction a small subgroup of patients received allograft BPTB tissue [53]. There was a lack of detailed reporting on allograft results and the primary aim of this study was to compare arthroscopic versus open technique [53]. In another study, Jung et al. compared clinical outcomes following PCL reconstruction among male and female patients. Although allograft tissue was used in a subset of patients the reported results were not stratified by graft type [48]. Finally, Khakha et al. reported the result of physeal sparing, all-inside PCL reconstruction using parental donation allograft [51]. Apart from this single case report there are no other published data on the use of related live donor allograft.

Current review of PCL allograft outcomes

Clinical studies reporting PCL allograft reconstruction

Detailed review of the original studies from the above systematic review and meta-analysis was conducted. There was an overlap in the original articles included and there have been no further studies since the latest review. A total of 12 studies were identified and study characteristics and baseline characteristics of the participants are summarised in Tables 1 and 2. There was a range of study designs, with three prospective randomised studies, five retrospective comparative studies and four single arm before and after studies. The risk of selection bias in the randomised studies was unclear and was high in the comparative studies. The non-randomised studies had marked methodological limitations limiting usefulness of the data. Allograft selection was subjective and largely due to either surgeon or patient preferences. Sample sizes in the included studies ranged from 18 to 90 cases, with an overall total of 549, which comprised

Table 1 Methodological parameters of studies reporting clinical outcomes of allograft PCL reconstruction

Study	Design	Sample Size	Baseline demographics Mean age (SD) % male	Follow-up, mean (SD)	Surgical Indications	Concomitant procedures	Graft selection, number of cases		Operative time, mean (SD) min
							Allograft	Autograft	
Li et al. 2016 [74]	Prospective, randomised	90	Allograft 32.2 % male 55 Autograft 31.3 % male 56	60 months	Isolated PCL tear > grade II + persistent instability and nonresponse to physiotherapy > 3 months	Autograft 65% meniscal repair or partial excision Allograft 62% meniscal repair or partial excision Hybrid graft 66% meniscal repair or partial excision	27	26	NR
Sun et al. 2015 [117]	Retrospective clinical series	71	Allograft 33.4 (SD, 6.4) % male 73 Autograft 31.1 (SD, 5.7) % male 75	Autograft 3.2 (0.2) years Allograft 3.3 (0.6) years	Grade III PCL tears excluded all combined ACL or grade III collateral injury	48% meniscal repair or partial excision	35	36	Autograft 93.2 (10.3) Allograft 83.6 (8.1)
Li et al. 2015 [73]	Retrospective clinical series	37	Autograft 31.3 (6.8) Allograft 32.5 (7.4) % male autograft 72% allograft 63%	Allograft 2.4 years Autograft 2.3 years	Isolated PCL tears, all grade III and chronic grade II or grade II with persistent symptoms for > 3 months	Meniscal lesions treated by partial excision Allograft 52% Autograft 61%	19	18	NR
Li et al. 2014 [75]	Prospective, randomised	50 (SB 25, DB 25)	SB 25.1 (SD 2.6); DB 23.5 (SD 5.2) % male: SB 68.2; DB 75.0	SB 28.7 (3.0); DB 30.4 (5.1) months	Isolated posterior knee instability grade II to III	NR	50	0	SB 76.7 (10) DB 91.4 (7.3)
Yoon et al. 2011 [133]	Prospective, randomised	60 (SB 30, DB 30)	SB 28.5 (17–47); DB 27.4 (18–46) % male: SB 80.0; DB 89.3	SB 31 months (range 24–42); DB 33 months (range 24–43)	Isolated PCL tears	NR	53	0	NR
Min et al. 2011 [89]	Case series	21	35.6 (18–54) % male: 90.5	51.7 months (range, 25–73 months)	Isolated grade III PCL injury with > 10 mm side-to-side difference	19% Partial meniscetomy	21	NA	NR

Table 1 (continued)

Study	Design	Sample Size	Baseline demographics Mean age (SD) % male	Follow-up, mean (SD)	Surgical Indications	Concomitant procedures	Graft selection, number of cases		Operative time, mean (SD) min
							Allograft	Autograft	
Spiridonov et al. 2011 [113]	Retrospective comparative clinical series	39	33 (15–62) % male: 84.6	2.5 (2.0–4.3) years	Grade-III isolated or combined PCL tears. Chronic combined injury of the PCL and PLC or MCL and/or PML	10.3% initial proximal tibial biplane osteotomy. 82% combined procedures (PCL with + MCL, PLC, ACL)	39	NA	NR
Lim et al. 2010 [76]	Case series	22	36 (18–59) % male: 86.4	33 (24–60) months	PCL injury > 8 mm side-to-side laxity Failed non-operative treatment > 6 months	NR	22	NA	NR
Yoon et al. 2005 [134]	Case series	27	27.9 (17–43) % male: 73.1	25 months (range 12–48)	Combined PCL injury	35% combined ACL using Tibialis anterior allograft, 57.7% meniscal repair or partial excision	27	NA	NR
Ahn et al. 2005 [1]	Case Control (Historic comparison)	36	Allograft 31 (17–60) Autograft 30 (16–58)	Minimum 24 months	Isolated symptomatic PCL tears	NR	18	18	NR
Wang et al. 2004 [123]	Prospective comparative series	55	Allograft 30 (SD 12); autograft 29 (SD12) % Male: allograft 69.6; autograft 78.1	Mean 34 months (10) (range 24–71)	Pain and instability due to PCL injury + failure of conservative treatments at 3 months	50% meniscal repair or partial excision	23	32	NR
Cooper and Stewart, 2004 [16]	Retrospective comparative clinical series	41	28 76% male	39 months, minimum 24 months	Severe laxity in isolated PCL or combined PCL multi-ligaments injury	85% other ligaments repair	25	16	NR

SB single bundle; *DB* double bundle; *NA* not available; *NR* not reported; *SD* standard deviation

Table 2 PCL allograft selection, graft choice and allograft preparation

Study	Country	Graft selection	Graft Choice		Allograft Preparation
			Allograft	Autograft	
Li et al. 2016 [74]	China	Randomised allocation: allograft or autograft	Tibialis anterior	Semitendinosus and gracillis	Washing, irradiation 2.5 mrad sterilisation, deep freezing
Sun et al. 2015 [117]	China	Subjective selection: patient preference	NR	Semitendinosus and gracillis	Irradiation 2.5 mrad. Physiological saline + gentamicin wash
Li et al. 2015 [73]	China	Subjective selection: Patient preference	Tibialis anterior	Semitendinosus and gracillis	Washing, radiation 2.5 mrad sterilisation, deep freezing
Li et al. 2014 [75]	China	Randomised allocation: single bundle or double bundle	Tibialis anterior	NA	NR
Yoon et al. 2011 [133]	Korea	Randomised allocation: single bundle or double bundle	Achilles tendon	NA	NR
Min et al. 2011 [89]	Korea	Single-arm study	Tibialis anterior	NA	NR
Spiridonov et al. 2011 [113]	USA	Single-arm study	Achilles tendon and Semitendinosus	NA	NR
Lim et al. 2010 [76]	Korea	Single-arm study	Achilles tendon	NA	NR
Yoon et al. 2005 [134]	Korea	Single-arm study	Achilles tendon	NA	NR
Ahn et al. 2005 [1]	Korea	Not described	Achilles tendon	Semitendinosus and gracillis	NR
Wang et al. 2004 [123]	Taiwan	Graft availability and surgeon's choice	Achilles tendon	Quadriceps tendon or Semitendinosus and gracillis	NR
Cooper and Stewart, 2004 [16]	USA	All combined ligaments injury received allograft tissue	Allograft BPTB	Autologous BPTB	Low-dose irradiation < 1.8 mrad

SB single bundle, *DB* double bundle, *NA* not available, *NR* not reported, *SD* standard deviation, *BPTB* bone-patellar tendon-bone

359 allografts. Mean length of follow-up ranged from 1 to 5 years. Five studies were undertaken in South Korea, four in China, two in the USA and one in Taiwan. Eligibility criteria or indication for the allograft differed between the studies. The rate of combined procedure reported in the studies was also highly variable between 10% and 85%. The mean ages of patients included ranged between 23 and 36 years and males represented between 55% and 90.5% of patients. Clinical and demographic parameters of the studies are outlined in Table 1; the interventional parameters are outlined in Table 2.

Two studies investigated the outcomes following isolated PCL reconstruction using single bundle either four strands hamstring autograft or a four strands Achilles tendon allograft [1, 116] and reported equivalent clinical outcomes. There were two prospective randomised studies comparing single versus double-bundle allograft tendon. Li et al. used Tibialis anterior allograft and Yoon et al. used Achilles tendon allograft [75, 133] and both studies favoured double-bundle reconstruction. In a further prospective randomised study with five years follow-up, Li et al. compared results of primary PCL reconstruction with autograft (gracilis and semitendinosus tendons), hybrid graft (tibialis anterior tendon allograft and semitendinosus tendon autograft), or γ-irradiated allograft tibialis anterior tendons and showed no significant difference in clinical or functional outcomes [74]. There were three non-randomised comparative studies. Li B et al. retrospectively analysed two groups, tibialis anterior allograft and four strands hamstring autograft, reporting similar results between both groups but evidence of residual laxity in both groups when compared with the normal contralateral side [73]. Wang et al. who conducted an age and gender matched retrospective analysis of isolated PCL reconstruction using single-bundle autograft compared to allograft tendons [123], and reported similar results across both groups. Cooper et al. prospectively compared cases following isolated or combined PCL reconstruction using the direct tibial inlay fixation with BPTB graft comprising of 16 autografts and 25 allografts [16]. Intergroup comparisons showed equivalent results in terms of stability but a statistically significant difference in IKDC in favour of allograft. There were four single-arm and single-centre retrospective clinical case series, which have all reported improvement in outcome scores and objective knee stability. Spiridonov et al. Lim et al. and Yoon et al. reported the results of double-bundle PCL reconstruction using Achilles tendon allograft [76, 113, 134]. Min et al. published results following transtibial double-bundle PCL reconstruction using a tibialis anterior allograft [89].

Clinical and functional outcomes

The clinical and functional outcomes among the 12 studies investigating allograft PCL reconstruction were reviewed and are presented in Table 3. Four studies only [74, 75, 117, 133] reported mean Lysholm scores, Tegner activity scores and IKDC subjective scores with baseline and endpoint values for comparison. Three studies [73, 76, 123] reported only Lysholm scores and Tegner activity scores with baseline and endpoint values. Three studies [1, 89, 134] reported Lysholm scores only, and two studies [16, 113] reported IKDC scores only.

For Lysholm scores, five clinical case series demonstrated a statistically significant improvement in scores at endpoint [75, 76, 89, 133, 134]. There was no statistically significant difference between the allograft group and the autograft group at endpoint in four studies [1, 74, 117, 123].

For Tegner activity scores similar results were reported. Three clinical case series demonstrated a statistically significant improvement at endpoint [75, 76, 133] and there was no statistically significant difference between the allograft group and the autograft group at endpoint for Tegner activity scores [74, 117, 123].

Analysis of subjective IKDC score showed that there was no statistically significant difference in two prospective randomised studies [74, 117], In contrast, a statistically significant improvement in subjective IKDC was reported in allograft reconstruction in two studies [113, 133]. All statistically significant results in clinical and functional outcome scores were also clinically significant based on the minimal clinically important difference (MCID) of the outcome measures utilised [96]. In relation to objective measures of clinical outcomes three studies [113, 133, 134] reported baseline and endpoint values, showing improvements among allograft PCL reconstructions both in terms of standalone values and side-to-side differences. In addition, seven of the studies reported on instrumented measurement of AP laxity showing improvement in standalone values and side-to-side differences. The intergroup difference according to graft choice was minimal and we question its clinical significance. Results of objective measures of clinical outcomes with stress radiographs and instrumented AP laxity measurements are outlined in Table 3.

Secondary clinical outcomes and complications

Detailed review shows paucity in the reporting of secondary clinical outcome measures among the studies investigating allograft PCL reconstruction. Li et al. reported an 11% (2/18) with autograft and 5% (1/19) with allograft rates of grade I radiographic osteoarthritic changes [73]. No other studies reported long-term effect on progression to secondary osteoarthrosis and no studies reported health-related quality of life outcome measures. None of the studies reported allograft failure rates (neither anatomical nor functional) or survival of the allograft. Spiridonov et al. [113] reported an increase of 4 mm in posterior translation in one case after reconstruction. The reported rates of complications or adverse events were mostly very low figures with the most recent studies [74, 117] reporting no case of major neurovascular, infection, deep vein thrombosis or wound complications. Sun et al. reported double the incidence of paraesthesia and dysaesthesia around the wound, 61% with autograft versus 29% with allograft [117] and attributed this to autologous hamstring tendon harvest. Yoon et al. reported postoperative limited range of motion in 4% and 7% of participants in the single-bundle allograft and double-bundle allograft groups respectively [133]. Two other studies reported no major neurologic, vascular, or wound complications no intraoperative neurovascular injuries, deep vein thrombosis or infections [76, 113]. Wang et al. reported one complication (4.3%, organism isolated from wound but no clinical infection) occurring in the allograft group and seven (21.9%; two infections, four donor site pain) in the autograft group [123]. Arthrofibrosis was reported in 4.8% and screw removal was required in 19% of allograft procedures [89].

Subgroup analysis

Analysis of subgroup difference was not possible among the vast majority of the studies reviewed. Methodological quality in all of the above studies was limited by marked heterogeneity in addition to the fact that none of the studies were adequately powered to detect differences associated with results stratification. Li et al. among a relatively small sample study reported meniscal lesions treated by partial excision with allograft 52% versus autograft 61% [73]. The study also showed double the incidence of osteoarthritic radiographic changes among autografts [73]. Spiridonov et al. reported subgroups for cases having isolated procedures ($n = 7$) and those having combined procedures ($n = 32$). Statistically significant improvements but no significant differences were identified in both groups on the modified Cincinnati score and IKDC subjective score [113]. Cooper and Stewart reported equivalent results in subgroup analysis according to graft choice with a tendency to favour allograft on IKDC scores. The authors, however, reported

Table 3 Clinical and functional outcomes among studies investigating allograft PCL reconstruction

Study	Study groups	Lysholm mean (SD)/(range)			Tegner mean (SD)/(range)			IKDC subjective (SD)/(range)			Stress radiography mean (SD), mm		Arthrometry mean (SD), mm	
		Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	Baseline value	Endpoint value
Li et al. 2016 [74]	Allograft Hybrid graft[b] Autograft	64.1 (10.8) 62.3 (12.9) 63.8 (11.2)	85.2 (3.9) 86.9 (4.3) 87.8 (3.6)	n.s n.s –	2.6 (1.1) 2.9 (1.3) 2.7 (1.2)	6.2 (1.7) 6.5 (1.8) 6.8 (1.1)	n.s n.s –	65.9 (9.3) 65.5 (11.5) 66.5 (10.1)	80.2 (6.8) 82.8 (5.7) 83.5 (6.3)	n.s n.s –	–	–	11.3 (1.9) 11.5 (2.0) 10.7 (1.8)	3.5 (1.1) 2.6 (1.2) 2.1 (1.0)
Sun et al. 2015 [117]	Allograft Autograft	56.3 (1.4) 57.5 (2.1)	84 (8) 82 (9)	n.s n.s	3.7 (1.4) 3.9 (2.1)	7.1 (1.6) 7.7 (1.2)	n.s n.s	57.7 (6.4) 58.9 (7.3)	80 (10) 81 (9)	n.s n.s	–	–	– –	4.8 (1.7) 3.8 (1.5)
Li et al. 2015 [73]	Allograft Autograft	66 (27–96) 64 (28–98)	85 (38–100) 84 (36–100)	–	2 (1–5) 2 (1–5)	6 (1–9) 6 (1–9)	–	–	–	–	–	–	11.9 (1.7) 11.7 (1.9)	3.3 (1.8) 4.1 (1.7)
Li et al. 2014 [75]	Allograft SB Allograft DB	63.1 (3.8) 64.4 (4.3)	88.0 (4.2) 89.8 (3.8)	< 0.05 < 0.05	3.1 (0.6) 3.3 (1.0)	6.2 (0.9) 6.8 (1.2)	< 0.05 < 0.05	–	65.5 (7.8) 71.6 (6.7)	–	–	–	9.6 (0.9) 9.6 (1.5)	4.1 (1.3) 2.2 (1.3)
Yoon et al. 2011 [133]	Allograft SB Allograft DB	64 (41–73) 62 (43–71)	89 (71–99) 91 (76–100)	< 0.001 < 0.001	2 (1–3) 2 (1–3)	6 (4–7) 6 (4–7)	< 0.01 < 0.01	40.2 (27.6–46.0) 39.1 (27.6–48.3)	79.3 (59.8–88.5) 81.7 (65.5–88.5)	< 0.01 < 0.01	10.0 11.4	2.0 1.5	12 (2) 12.2 (3.2)	4.5 (2.3) 3.1 (2.4)
Min et al. 2011 [89]	Allograft	52.2 (42–66)	78 (56–92)	< 0.001	–	–	–	–	–	–	–	–	13.5 (1.2)	3.4 (0.8)
Spiridonov et al. 2011 [113]	Allograft	–	–	–	–	–	–	47.1 (16.2)	71.8 (24)	< 0.001	15 (4.1)	0.9 (2)	–	–
Lim et al. 2010 [76]	Allograft	64 (50–75)	88 (82–96)	< 0.001	3 (2–5)	6 (3–9)	< 0.01	–	–	–	11 (8–14) SSD	3 (1–7) SSD	11 (8–13) SSD	3 (1–6) SSD
Yoon et al. 2005 [134]	Allograft	59.5	91.8	< 0.05	–	–	–	–	–	–	12.7 (10–26) SSD	2.4 (0–8) SSD	–	–
Ahn et al. 2005 [1]	Allograft Autograft	68.6 (54–79) 68.2 (54–78)	85.8 90.5	n.s	–	–	–	–	–	–	–	–	13.8 (2.8) 14.3 (3.2)	2.9 (1.9) 2.2 (1.8)
Wang et al. 2004 [123]	Allograft Autograft	–	92.3 (6.8) 87.8 (9.6)	n.s	–	4.70 (1.66) 4.73 (1.66)	n.s	–	–	–	–	–	–	2.83 (1.7) SSD 3.16 (2.6) SSD

Table 3 (continued)

Study	Study groups	Lysholm mean (SD)/(range)			Tegner mean (SD)/(range)			IKDC subjective (SD)/(range)			Stress radiography mean (SD), mm		Arthrometry mean (SD), mm	
		Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	*P* value	Baseline value	Endpoint value	Baseline value	Endpoint value
Cooper and Stewart, 2004 [16]	Allograft and autograft subgroups (no subgroup outcomes)	–	–	–	–	–	–	–	75 (20–100)	–	–	4.11 (− 2 to 10) SSD	–	–

SB single bundle, *DB* double bundle, *SD* standard deviation, *SSD* side-to-side difference, (-) results not reported by study authors

[a]Reported median value and range

[b]Hybrid graft: irradiated Tibialis anterior plus autogenous semitendinosus tendon

that laxity was better after primary PCL reconstruction when compared with revision cases ($n = 6$ revisions) [16]. The same study had the highest rate of other ligaments combined instability (85%).

Physiotherapy and rehabilitation following allograft posterior cruciate ligament reconstruction

Regardless of graft choice, postoperative management and rehabilitation protocols play a crucial role in the efficacy of treatment and long-term outcomes. There is paucity in research addressing the relationship between allograft utilisation and the current approach to postoperative rehabilitation. A protective as well as adapted physiotherapy and rehabilitation programme is recommended following allograft PCL reconstruction [25, 38, 63]. Relative to the ACL, tendon graft to bone healing and ligamentisation take longer for PCL [5]. The early objectives from day 1 are to provide comfort and help reduce postoperative swelling. Post op bracing provides posterior stability during the early healing phase [42, 47]. As pain allows early quadriceps muscle strengthening is introduced [98]. The current concept focuses on an initial 2-week period with static posterior stabilising brace followed by the early implementation of a dynamic PCL brace. The initial period avoids hamstrings activation, which leads to increased stress on the PCL graft [63]. From weeks 2–6 the emphasis is on early quadriceps muscle activation with prone knee flexion from 0° to 90° of flexion. At 6 weeks, weight-bearing exercises are commenced alongside low resistance exercise on the stationary bike.

At approximately 12 weeks following surgery, patients who are advancing at the expected rate can commence progressing into low-impact exercises as tolerated. The dynamic brace is maintained until the sixth month following surgery at which stage patients can discontinue the brace and can initiate a jogging program, side-to-side work and proprioceptive exercises. This stage is a key milestone for clinical assessment and subjective evaluation with several authors advocating the kneeling posterior stress radiographs [32, 46]. From 9 to 12 months, and prior to return to full activities, functional testing is performed to guide a phased return and some authors advocate continued use a functional PCL brace for the first year of return to sports especially for high-end athletes [98].

Summary of evidence for use of allografts in posterior cruciate ligament reconstruction

Despite the highlight of low methodological quality nearly a decade ago, clinical studies on PCL tears remain burdened with a weak design [126]. The available current evidence does not show any significant difference in clinical effectiveness between autografts and allografts. However, there are clearly situations where an allograft might be preferred. Overall, the stratified outcomes highlighted above, despite being affected by methodological limitations, suggest a more favourable outcome for allograft choice particularly in cases of combined, double bundle, or revision PCL reconstruction.

Posterolateral corner

Rationale and principles of allograft posterolateral corner reconstruction

Injuries to the posterolateral aspect of the knee comprise a complex interplay of trauma to a number of structures including the fibular collateral ligament, popliteal components, mid-third lateral capsular ligament and posterior arcuate ligament [34, 64]. Clinical identification of rupture of the fibula collateral represents the tip of the iceberg and isolated injury only occurs in 23% of cases according to LaPrade et al. indicating the complexity of the region when faced with PLC injuries [64]. Correct diagnosis and treatment of PLC injuries are important and instability due to an untreated injury has been reported to increase graft forces on ACL and PCL [34, 64, 80]. Despite this, there is no consensus about the best surgical treatment for these injuries [115]. Finally, a recent qualitative research was conducted to develop consensus statements on the diagnosis, classification, treatment, and rehabilitation concepts of PLC injuries [14]. A panel of 27 experts agreed that prompt diagnosis and management are crucial for patients with PLC injuries. There was agreement that the primary components of the posterolateral corner (the fibula collateral ligament, the popliteus tendon and the popliteo-fibular ligament) should be reconstructed rather than repaired. An anatomy-based biomechanically validated PLC reconstruction was recommended but there was no conclusion in the paper regarding allograft choice or specific techniques [14].

Clinical outcomes of allograft posterolateral corner reconstruction

Recent studies have showed a greater failure rate among repairs compared to reconstruction such that reconstruction is advocated over repair [69, 115]. Furthermore, the PLC repair technique is limited by the fact that it could only be performed at an acute stage with adequate tissue quality of the torn structures [115]. A systematic review investigating the surgical techniques for reconstruction of PLC injuries broadly divided these into either biceps tendon transfer, fibular-based sling techniques or anatomic-based reconstruction of the LCL, popliteus tendon and popliteo-fibular ligament [34]. When performing a complete reconstruction of the PLC, the use of allograft tissue is often advised [40, 80] and the allograft choices most frequently described in the literature are the Achilles tendon with bone plug, tibialis anterior or tibialis posterior tendons [59, 60].

The most established methods of posterolateral corner reconstruction are outlined in Fig. 1. LaPrade et al. have described an anatomic reconstruction using Achilles tendon allograft [60]. Two tunnels are created in the femur for the bone end of the graft, and the LCL limb passes from epicondyle through fibular head to the back of tibia and through the tibia while the Popliteus limb passes directly to the tibial tunnel. This technique was primarily evaluated in a cadaver study and was shown to successfully restore varus

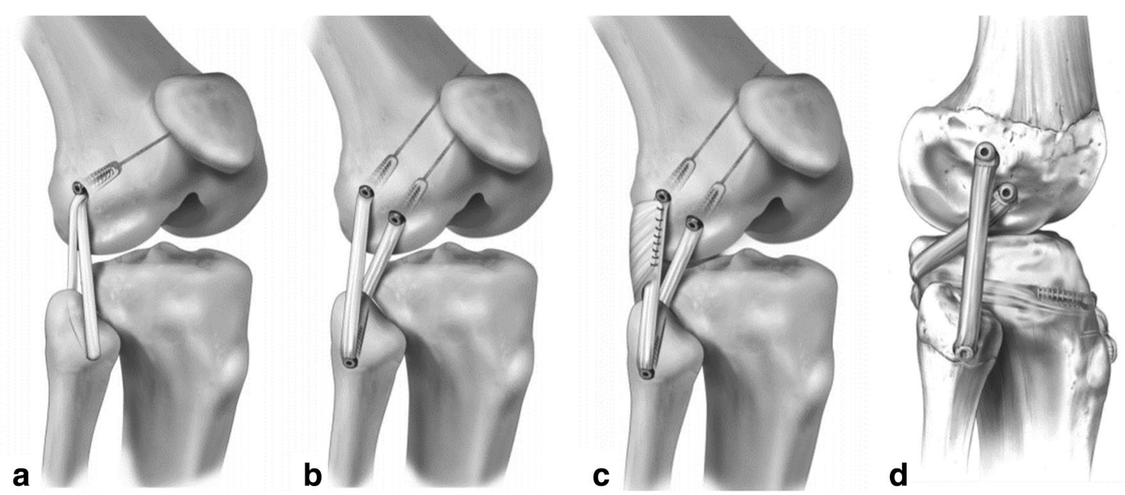

Fig. 1 Posterolateral corner reconstruction techniques. **A** Single femoral tunnel fibular sling technique, **B** Double femoral tunnel sling technique, **C** Similar technique to **B** with addition of Posterolateral capsular shift, attaching posterolateral capsule to increase rotational stability, **D** Anatomic-based reconstruction with 2 grafts re-creating the fibular collateral ligament, popliteus tendon, and popliteofibular ligament. (Reproduced with permission from [93])

and external rotary stability [60]. Subsequently, a clinical study of 64 patients presenting with chronic PLC instability and pain was conducted [59]. A significant improvement in clinical outcomes and objective stability was seen, and there was no difference in outcome between isolated PLC injuries and patients with multi-ligament injuries [59].

A less complex technique for reconstruction of the PLC with Achilles tendon allograft, which does not require creation of a tibial tunnel, was described by Arciero in 2005 and results of this have been described by Schechinger et al. [2, 105]. Two tunnels are created in the femur and one in the fibular head and Achilles tendon is used to reconstruct the LCL, the popliteus tendon, and the PFL. In the technique from Schechinger et al. an additional posterolateral capsular shift is performed. Their small study of 13 patients reported that this technique successfully restored stability and presented good functional outcome in patients with two-ligament and multi-ligament PLC-based reconstructions [105]. Furthermore, the outcome results were comparable to the previous studies of other techniques [105].

Another surgical technique commonly described is the modified two-tail fibular sling reconstruction utilising a tibialis anterior or tibialis posterior tendon allograft [34, 93, 115]. In this technique a single tunnel is drilled in the femur and fibular head and the graft is passed through the fibular head with both tails fixed in the femur. Outcome in terms of physical examination with additional knee stability and PROMs have been reported sufficient at short term follow-up [115]. The two-tailed technique with tibialis allograft is believed to restore better anatomical PLC reconstruction compared to most other reconstruction techniques [34, 93, 95, 115]. It also provides a quality of tissue and fixation that allows for early motion of the knee, thereby minimising the risk of arthrofibrosis. According to the literature, PLC reconstruction with concurrent reconstruction of cruciate ligament injuries have a mean 9% failure rate, while repair of the lateral structures with later cruciate ligament reconstruction results in a much higher failure rate (38%) [34].

Physiotherapy and rehabilitation following allograft posterolateral corner reconstruction

Current concepts dictate that all rehabilitation protocols after PLC and multi-ligament reconstructions involve restricted mobilisation of the knee. However, there are some variations in recommended time of immobilisation and also timing and restriction of weight bearing during the rehabilitation period [40, 52, 68]. The rehabilitation protocols for PLC reconstruction may be modified due to concurrent knee ligament injury, but the principles are mainly similar [80]. Progression is delayed for return to full activity if multi-ligament reconstructions have been performed [59]. In the recent consensus study, a sequential staged rehabilitation (range of motion, muscular endurance, strength, and finally power) was considered important for a successful outcome but there was disagreement regarding the weight-bearing status following reconstruction [14]. The degree of injury and type of surgical treatment performed, therefore, is key when formulating postoperative rehabilitation strategies.

Summary of evidence for use of allografts in posterolateral corner reconstruction

There is paucity of outcome data to guide the surgical treatment of acute grade III posterolateral corner (PLC) knee. Moreover, the available data from combined reconstructions in the context of multi-ligaments injury remain significantly heterogeneous. The substantially higher postoperative PLC failure rate associated with acute PLC repair and staged cruciate reconstruction remains an area of concern, which needs to be addressed. Because none of the studies have been adequately powered to detect differences between groups according the graft choice, it is difficult to make conclusive statements on the role of allograft tissue. Nevertheless, the current evidence tends to favour reconstruction of all torn structures, by virtue of graft quantity and availability of tissue the paradigm logically shifts in favour of allograft.

Medial collateral ligament

Rationale and principles of allograft medial collateral ligament reconstruction

Isolated medial collateral ligament (MCL) injuries usually result in satisfactory clinical and functional outcomes with non-operative treatment alone [18, 131]. However, in the context of multiple ligaments knee injuries, reconstruction of the MCL as the primary medial stabiliser is advocated [29, 37, 58, 78, 121]. For surgical decision-making, two key arguments should be considered. First, the impact of autogenous hamstring tendons harvest on medial dynamic stability is an important consideration [43]. In a recent study using a robotic universal force moment analysis of knee kinematics in ten fresh frozen knees Herbort et al. demonstrated that preservation of hamstring tendons significantly reduced valgus moments in the MCL deficient status [43]. Similar findings were noted by Kremen et al. when associated with ACL deficient and ACL reconstructed scenarios [55]. Second, the need for sufficient graft material to achieve an anatomic reconstruction which incorporates the superficial MCL (s-MCL) and the posterior oblique structures should be considered [58].

The main structures of the medial aspect of the knee are the proximal and distal divisions of the superficial medial collateral ligament, the meniscofemoral and menisco-tibial divisions of the deep medial collateral ligament, and the posterior oblique ligament [129]. With the aim of restoring the native load-sharing relationships among these medial knee structures, so-called anatomic reconstruction of both s-MCL and posterior oblique ligament have been advocated [36, 97, 130]. Bonasia et al. and Dold et al. published very well illustrated reviews based on current understanding of the anatomy and kinematic features of the medial and posteromedial aspect of the knee. Both concluded that though controversies still exist regarding the most reliable surgical technique, reconstruction of the s-MCL and POL as well as isometricity of the repair remain the essential components in obtaining favourable results [9, 21]. Similar observations were echoed in the systematic review conducted by DeLong et al. [19].

MCL injuries can be viewed as a part of a large spectrum ranging from isolated low-grade to combined multi-ligament injuries. Management of the middle group of combined grade II and III lesions of the MCL with anterior cruciate ligament (ACL) in the acute phase has remained controversial [9, 21, 109]. A comprehensive evaluation of this issue is beyond the scope of the present review. However, analysis of the biomechanical role of MCL in ACL load suggests that further attention to the clinically relevant concomitant medial injuries is required [3]. Surgical strategies will depend on objective clinical assessment, severity and timing of injury [8]. Ultimately, however, the use of allograft tissue for medial reconstruction can help with graft availability in a combined ACL–MCL scenario [104, 135].

Clinical outcomes of allograft medial collateral ligament reconstruction

The overwhelming majority of studies dealing with the question of MCL reconstruction especially when combined with cruciate reconstructions have focused on the chronic MCL-deficient knee [19]. Some authors have advocated secondary repair of the MCL by advancement of the ligament and augmentation with a tendon autograft, such as the semitendinosus. Given the challenges of preserving dynamic stabilisers and availability of graft material, different allograft techniques have been described. Allograft reconstruction of the MCL involves tissue augmentation of the ligament with attachment using fixation devices or through drill sockets both the tibial and femoral insertion sites.

In a recent systematic review, 39% of the reported series performed MCL reconstructions with allografts [19]. Different soft-tissue grafts and bone-tendon grafts were used. Interestingly, only two out of 12 series performed anatomic reconstructions with the remainder performing either non-anatomic medial knee reconstruction or non-anatomic tendon transfer medial knee reconstructions. Clinical outcomes showed no evidence of superiority of one graft choice over the other. An in-depth analysis of individual case series revealed marked heterogeneity and numerous confounding factors, which impact on the interpretation of these results [19]. Furthermore, comparisons can be limited due to variation in the processing and storage method of each type of graft type, graft requirements for concomitant procedures, surgical techniques, types of fixation and finally level of patients' activity and rehabilitation protocols. Ultimately the current level of evidence supports the utilisation of allograft for the reconstruction of the MCL based on the argument for the preservation of native hamstring tendons, and the more abundant availability of graft material to permit an anatomic reconstruction.

Physiotherapy and rehabilitation following allograft medial collateral ligament reconstruction

Early motion is important to ensure that no intra-articular adhesions develop. To avoid elongation of the reconstruction, postoperative bracing is recommended. However, it differs slightly between studies concerning allowed movements in the brace and timing of restricted weight bearing. LaPrade et al. and Wijdicks et al. recommended a brace in full extension and non-weight bearing for 6 weeks [65, 130]. Liu et al. also used a brace locked in extension and non-weight bearing, but only for 4 weeks postoperatively [79]. This differs somewhat from the study of Zhang et al. where they used a brace with 0°–60° the first 2 weeks, and then until 6 weeks 0°–90° with full weight bearing [136]. Dong et al. following allograft MCL reconstruction used a brace allowing 30°–90° of motion with non-weight bearing for 2 weeks. From weeks 3–6, weight bearing to the patients comfort was allowed. Patients were gradually weaned-off the brace from 3 month postoperatively [22].

Summary of evidence for use of allografts in medial collateral ligament reconstruction

In vitro cadaveric biomechanical studies have given us a better understanding of ligament deficiency on the medial and posteromedial aspect of the knee joint. In cases of isolated MCL injury, chronic medial knee instability is rare due to the intrinsic capability of the medial ligamentous structures to heal. However, with concomitant anterior cruciate ligament deficiency and/or injuries to the posteromedial structures of the knee the resulting anterior, valgus, and rotatory laxity can be detrimental. A variety of operative techniques have been described, including repair, augmentation, and reconstruction. Surgeons are encouraged to remain cautious when reading favourable outcomes especially from small series reporting non-consecutive cases. Choice of graft should be based on injury pattern, tissue availability and preservation of synergistic muscles; with the ultimate goal of achieving valgus as well as antero-medial rotatory stability.

Multi-ligament knee injuries

Rationale and principles of allograft multi-ligament knee reconstruction

Multi-ligament knee injuries (MLKIs) are defined as involving two or more of the four primary knee stabilisers: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posteromedial corner (PMC) and posterolateral corner (PLC) [69, 106, 110]. The infrequent and diverse nature of this injury severely limits the opportunity for collecting prospective data for high-level randomised controlled trials and this leads to profound controversies on many aspects of timing, risks of arthrofibrosis, the benefit of reconstruction over repair and staged or combination treatment plans for MLKIs.

Surgery performed in the first 3 weeks after the injury is considered acute, while it is chronic if performed beyond 4 weeks [40, 121]. Some authors are in favour of delayed and staged surgeries to lower the risk for arthrofibrosis, however, several studies report improved functional and clinical outcomes with acute surgeries without this influencing the final range of motion (ROM) [40, 69, 78, 125]. A recent paper by Hanley et al. investigated factors associated with knee stiffness after surgical management of MLKIs. On 121 MLKIs, 26 suffered postoperative knee stiffness. Factors such as the injury involving three or more ligaments treated and knee dislocation type of injury were correlated with postoperative stiffness. This was not noted for surgical timing (acute versus chronic) [37].

Clinical outcomes of allograft multi-ligament knee reconstruction

The benefit or reconstruction over repair is debated and few studies directly compared those two techniques [70, 82, 114, 115]. The majority of the recent studies have shown a higher failure rate with repair rather than reconstruction. However, in the study by Mariani et al. the authors noted a greater loss of flexion, greater PCL instability and lower rate of return to preinjury activity level with reconstruction [82]. A recent study compared medial collateral ligament (MCL) repair versus reconstruction in MLKI patients, and the authors found patients undergoing repair had higher patient reported outcomes than those undergoing reconstruction at a mean 6 years of follow-up [37].

Surgical treatment can be performed as a single or a staged procedure. Again, there is a lack of evidence-based consensus on this choice. Some authors propose a two-stage surgery, in which the MCL and/or LCL are repaired within 8–10 days of injury followed by reconstruction of the ACL and/or PCL after 6–8 weeks [7, 20, 28, 132]. Stannard and Bauer advocate a staged procedure for a KDIII M (type III knee dislocation, medial) according to Schenk classification, having an acute reconstruction of PCL and PMC and a delayed ACL reconstruction following 6 weeks from first stage [106, 114]. The advantage of staged surgeries is regaining adequate ROM in between surgeries. If this is not achieved, manipulation under anaesthesia and lysis of adhesions can be performed at the time of the second stage. However, other authors warn against staged procedures because of the potential risk for altering joint kinematics and increased risk of graft failure [61, 62, 127]. Overall surgical timing is dictated by the general condition of the patient and by the soft tissues status about the knee. Emergency treatment is necessary in case of vascular injury, compartment syndrome, open knee dislocation or irreducible knee dislocation. Indications to external fixation are open dislocation, vascular repair or the inhabitability to maintain joint reduction in a brace [69, 70]. If emergency treatment is not required, acute surgery is advised especially when there are displaced meniscal tears limiting range of motion and/or in case of bony avulsion ligament injuries [71, 101].

The present review highlights the fact that in the context of multi-ligaments knee injury several grafts are often required. This in turn creates an issue when allografts are not readily accessible. The gold standard approach according to current evidence and level of understanding is that of anatomic ligament reconstruction of functional bundles, which are biomechanically and clinically validated. Nevertheless, there is a clear lack of research addressing optimal reconstructions in the setting where allografts are not available. Of note here, certain groups have opted for the use of synthetic material as an alternative approach [44]. A comprehensive review of synthetic alternatives to soft-tissue graft is beyond the scope of the present article. The authors, however, note that single-arm retrospective case series can report satisfactory long-term results [118]. Talbot et al. reported the results of reconstruction using synthetic ligaments for 21 knee dislocations [118]. At follow-up between 3 and 6 years, Lysholm score was 71.7 (18); and the mean (SD) radiologic laxity evaluated for the ACL and PCL was 6.1 (5.7) mm and 7.3 (4.5) mm, respectively [118]. In a similar scenario, Geeslin et al. reviewed the results of concurrent cruciates and grade III PLC injuries, which comprised 73% of the cohort [34]. Posterolateral knee injuries required acute repair of avulsed structures, reconstruction of mid-substance tears in addition to cruciate ligament reconstruction. Graft choice appeared to be guided by extent of available tissue and did not correlate with the reported outcome measures. Engebretsen et al. reported improved patient outcomes at follow-up of 2–9 years with a mean Lysholm of 83, median Tegner activity score of 5 and mean IKDC subjective score of 64. Nevertheless, they also reported that 87% of cases developed radiological features of osteoarthritis in the injured side [24]. The authors used Achilles or quadriceps tendon allograft for

ACL and PCL reconstruction in the pre 1998 procedures, and used hamstring autograft and BPTB in the post 1998 procedures. Subgroups comparison and report in the latter study considered the severity of injury but not graft choice [24]. Equally, poor outcomes have been correlated with a number of factors including high-energy trauma, repair of medial side injury, age > 30 years, concomitant cartilage injury, combined medial and lateral meniscal tears; but not graft choices [54, 72, 91].

Physiotherapy and rehabilitation following allograft multi-ligament knee reconstruction

Multi-ligament injuries comprise inherently a heterogeneous cohort of patients. Consequently, the recommended postoperative physiotherapy and rehabilitation should be adaptive and take into account the full extent of concomitant injuries at the level of and distant from the knee joint. This situation also explains the relative absence of objective data on MLKI physiotherapy and rehabilitation. The authors recognise that the continuous passive motion device (CPM), which was popular in the 1990s and early 2000s, was discontinued and passive motion is obtained with daily flexion exercises in prone position without a brace [24]. The patients are often kept in a brace for the initial 8 weeks to allow the PCL to begin healing without being stretched. The overall aim of the early rehabilitative phase is to prevent stiffness while protecting the repaired structures with a target of 90° knee flexion by 4 weeks following surgery. In addition, patients are typically allowed protected partial weight bearing only with the assistance of crutches. It remains important, however, to maintain quadriceps activity with protected isometric exercises including in-brace straight leg raise. Full active free range of motion exercise can typically commence at week 8 following surgery after removal of the brace. A less restrictive regime can be introduced at that point including progression to full weight bearing, strengthening exercises for quadriceps, hamstrings and calf muscles. Similarly, return to full activity is adapted to the extent of reconstructions, severity of initial injury and resulting muscle strength compared to the uninjured limb, as well as full knee range of motion. In case of allograft multi-ligament reconstruction this is re-introduced between 9 and 12 months after surgery depending on the above conditions.

Summary of evidence for use of allografts in multi-ligament reconstruction

Studies reporting results of multi-ligament knee injuries present, on the whole, small numbers of cases and limited follow-up. All in all, satisfactory outcomes have been presented above and are reported in the short to medium terms after surgical treatment. Several combinations of graft sources can be used in reconstruction ranging from all autografts to part allografts and all allograft sources. Allograft use is appealing in MLKI because of the need for multiple grafts to be available, the poor condition of the autograft tissues and the attempt to limit further damage to the patient by harvesting autografts [128]. Such practical issues may in fact outweigh clinical evidence.

Conclusions

This up-to-date review of current literature has not demonstrated conclusive differences in clinical outcomes, surgical procedures, complications and rehabilitation issues in relation to the choice of autograft versus allograft. The messages from available studies have been attenuated by poor methodological quality, but this criticism can be mitigated by marked heterogeneity especially in terms of patients' selection and historic comparisons. All in all, further clinical research including cost-effectiveness analysis is required to help formulate an evidence-based approach. The present review on the role of allograft tissue in posterior cruciate, collateral and multi-ligament knee reconstruction concludes that there is insufficient evidence on graft choice. Nevertheless, the results presented from clinical studies should at this stage eliminate the prevailing level of scepticism on equivalence of outcomes for allograft tissue. Achieving an anatomic reconstruction of functional bundles while preserving synergistic muscular function is the principal target of all surgical strategies. Coupled with the current concept of improved allograft processing, better patients selection and adapted rehabilitation regime; the use of allograft, therefore, constitutes an essential component in the management of PCL, collaterals and multi-ligament knee injuries.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

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