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Original Article

Graft Choice for Child and Adolescent Medial Patellofemoral Ligament Reconstruction: A Systematic Review

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Abstract

Background: Medial patellofemoral ligament (MPFL) reconstruction is a common procedure for child and adolescent patellofemoral instability. Graft choice remains debated, with hamstring autograft being most frequent. This systematic review aimed to assess the safety and clinical effectiveness of isolated MPFL reconstruction in children and adolescents based on graft choice, to guide clinical decision-making. **Methods:** MEDLINE and EMBASE were searched from 1946 to June 21, 2023, for randomized controlled trials, cohort studies, case–control studies, and case series of patients ≤18 years old undergoing MPFL reconstruction. Risk of bias was assessed using the Cochrane tool for RCTs and Joanna Briggs Institute checklists for observational studies. Random-effects meta-analysis was planned where possible. **Results:** Twenty-six studies (19 case series, 6 cohort studies, and 1 case–control study) with 844 procedures were included. No RCTs were identified. Case series had a mean JBI critical appraisal score of 7.6/10, while cohort studies scored 8.5/11. Redislocation rates ranged from 4 to 10% across graft types (gracilis 7%, semitendinosus 10%, quadriceps 8%, augmented tape 6%, and mixed 9%). The median postoperative Kujala scores ranged from 88.6 to 92.2. **Discussion:** Short-term data suggest that isolated MPFL reconstruction has good outcomes regardless of graft choice. However, evidence was limited by lack of RCTs, short follow-up, and under-reporting of risk factors. Most studies provided Centre for Evidence-Based Medicine Level 3–4 (case series) evidence. Better comparative studies are needed with risk stratification to allow the comparison of techniques for this procedure. Levels of evidence: CEBM Levels 3–4.

Keywords: Graft choice, medial patellofemoral ligament, patella dislocation, patella instability

Introduction

The many risk factors that predispose to recurrent patella instability have led to an evolving spectrum of operative choices. Factors such as coronal malalignment,[1] trochlea dysplasia, periarticular extensor mechanism malalignment,[2] patella height, and tibial/femoral torsion all play a role in surgical decision-making. Despite these risk factors, medial patellofemoral ligament (MPFL) reconstruction remains the commonest procedure for child and adolescent patellofemoral instability.[3]

Management in children and adolescents poses challenges similar to those in adult populations but with distinct differences. Young age is a well-described risk factor for recurrent instability.[4] Both trochleoplasty and tibial tubercle osteotomies may cause growth. disturbance in the child with residual growth. The technique of MPFL reconstruction needs to be considered in view of open growth plates to prevent growth disturbance.[5] Rehabilitation after knee surgery in children is more difficult to carry out and takes greater time in order to minimize risks and failure rates in comparison to adults.[6] Contemporary operative techniques often translate more slowly into pediatric practice due to these concerns and procedures that are largely abandoned in adult patient populations often persist in the care of the younger age group.[7]

Isolated MPFL reconstruction can be considered a good option with satisfactory reported outcomes,[8,9] although longer follow-up may suggest high failure rates[10] in a quarter of

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treated cases. In children, it remains an important surgical technique and identifying the best way to perform this procedure is therefore essential.

Graft choice in improving outcomes is debated extensively[11] for anterior cruciate ligament surgery but less so in patellofemoral instability surgery. Here, the technique of reconstruction is often considered, but the procedure of choice is often chosen based on technique as opposed to the graft itself. Hamstring autograft tendon is the most popular choice for reconstruction although the use of quadriceps tendon can also be considered,as can the use of allograft.[12] The use of synthetic grafts has a paucity of published data in adults, and at present, the role in children is not well described,[13] although hybrid techniques do exist.[14,15]

The aim of this review is to systematically review clinical studies assessing the safety and clinical effectiveness of isolated MPFL reconstruction for children and adolescents based on the choice of graft.

Methods

This systematic review was registered with Prospero (CRD42023464274) with the protocol being published-Hind, Nicolaou (2023). Graft choice for Child and Adolescent MPFL Reconstruction: Protocol for a Systematic Review and Meta-analysis. The University of Sheffield. Workflow. https://doi.org/10.15131/shef.data.24190260.v1.

We searched MEDLINE and EMBASE from 1946 to June 21, 2023. We searched trial registers without contacting any of the study authors and followed the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements.

Randomized controlled trials, cohort comparisons, case–control studies, and case series that had patients aged 18 years or younger (the legal definition of pediatric), having undergone an MPFL reconstruction to address patellar instability, were included. Studies with a mixed age population were included if data specifically regarding the 18 and under population were explicit. The intervention was the use of a graft in order to reconstruct the MPFL. The different types of grafts that were included were hamstring tendon (semitendinosus or gracilis), quadriceps tendon, synthetic tape or hamstring/quadriceps tendon augmented with tape. Grafts could be autografts or allografts. We used nonoperative management and other surgical procedures for patellofemoral instability as comparators. Studies were checked to ensure no duplication of the same patients.

The specific outcome measures we assessed were redislocation rates, recurrent instability, need for revision surgery, non-MPFL reoperation, and other validated outcome measures. The validated outcome measures included International Knee Documentation Committee Score, the Knee Injury and Osteoarthritis Outcome Score, return to sport, Kujala score, Lysholm score, Tegner score, Visual Analogue Score, Banff Patellofemoral Instability Instrument, the Hospital for Special Surgery Pediatric Functional Activity Scale (HSS-FABS), and the Norwich Patellar Instability Index. This systematic review focused on studies published in the English language that have been published in or after the year 2000. The reference lists of eligible citations were also checked for further studies [Appendix 1].

Selection process

All abstracts obtained were screened against the eligibility criteria by 6 reviewers, blinded to each other's decisions. Once eligible abstracts were obtained, two reviewers went over the full texts in order to check their suitability for inclusion at the analysis stage, once again blinded to each other's decisions [Table 1]. Data from eligible studies were extracted from the full texts into a standardized Google sheet, with multiple copies of the data sheet being made to allow blind extraction. Different sheets were combined together in order to produce a complete master sheet, with all queries or disagreements resolved by the six reviewers' group and discourse with an experienced reviewer and surgeon.

Data items

The primary outcome was rates of redislocation within our population. The secondary outcomes included ongoing instability, revision surgery, non-MPFL reoperations, and other validated outcome measures.

Risk of bias assessment in individual studies

In our complete synthesis, risk of bias was assessed and then described. We used the Cochrane assessment tool for

Table 1: Search strategy

Number	Term
1	Joint Instability/(23454)
2	Patella/(10932)
3	Patellofemoral Joint/(1976)
4	2 or 3 (12337)
5	1 and 4 (1339)
6	((Patella or Patellofemoral) adj2 (alta or instability or Dislocat*)).tw. (1685)
7	Trochlear dysplasia.tw. (592)
8	Medial patellofemoral ligament.tw. (1211)
9	mpfl.tw. (925)
10	or/5–9 (3297)
11	exp Orthopedic Procedures/(359030)
12	reconstruction.tw. (247711)
13	(Medial adj2 (reefing augmentation or plication or imbrication)).tw. (90)
14	Quadricepsplasty.tw. (150)
15	Proximal realignment.tw. (63)
16	or/11–15 (575569)
17	10 and 16 (1865)
18	limit 17 to"all child (0 to 18 years)" (600)
19	(child* or adolesc* or teen* or juvenile* or infant* or pediatric* or paediatric* or skeletal* immatur*).tw. (2380612)
20	17 and 19 (293)
21	18 or 20 (716)

randomized controlled trials to assess the risk of bias. For case series and cohort studies, we applied to the Joanna Briggs Institute critical appraisal checklist.[16]

Synthesis

Where multiple studies existed which reported a comparable outcome, their results were presented descriptively using Forest plots to allow visual comparisons of the results. Where outcomes were binary, proportions were presented, and where outcomes were continuous, mean outcomes were presented. Where relevant, data reported as medians and interquartile range or range were converted to means. All results were shown with corresponding 95% confidence intervals. The results of the different studies were not combined into pooled estimates due to the heterogeneity of the studies in terms of study design (randomized and nonrandomized studies), age groups included, presence of risk factors (e.g., trochlea dysplasia), type of outcome measures reported, and variable length of follow-up.

Reporting bias assessment

Due to the surgical and niche nature of the population studied, there would likely be a small number of randomized clinical trials and a greater proportion of single-arm studies. Therefore instead of using the GRADE tool, we used the Centre for Evidence-Based Medicine tool, to appreciate the risk of bias across all studies. Additionally, if 10 or more studies on the same intervention reported the same outcome, we produced a funnel plot in order to identify small study effects and determine the risk of publication bias.

Results

Study selection

One thousand three hundred and twenty-nine abstracts were obtained with 200 duplicates leaving 1129 unique abstracts that fit our search criteria [Figure 1]. After the primary abstract screening stage, we deemed that 926 of the abstracts would not suit our eligibility criteria and hence were excluded. This left us with 203 full texts to retrieve, with us being successful in retrieving 191 of them in order to assess them at the full-text stage. From these 191 full texts, only 26 fit our eligibility criteria and reported at least one of our specified outcomes. The reasons for exclusion were ineligible population (99), unspecified or incorrect graft type (31), undesired or nonspecific outcome measures (21), a lack of detail in evaluation (10), and a study published in a language other than English (4).

Study characteristics

The studies included at full-text stage [Table 2] were published from 2001[17] and 2023[10,18,19] and were from 12 different

Table 2: Study characteristics

Study	Levels of evidence	Age range	Follow-up (months)	Population	Procedures	Graft	Country	Year published
Rueth *et al*.	IV	13–16	32	101	101	Gracilis	Germany	2022
Spang *et al*.	IV	10–18	24	25	27	Gracilis	USA	2017
Husen *et al*.	IV	8–17	24	69	79	Gracilis	USA	2023
Wegmann *et al*.	IV	14–17	50	6	7	Gracilis	Austria	2017
Schlumberger *et al*.	IV	11–15	48	49	54	Gracilis	Germany	2021
Bremond *et al*.	IV	12–18	24	54	54	Gracilis	France	2022
Hohn *et al*.	IV	14–18	24	22	25	Gracilis	USA	2016
Machado *et al*.	IV	14–17	44	35	35	Gracilis	Portugal	2017
Zampieri *et al*.	III	12–15	30	57	57	Gracilis	France	2022
Roger *et al*.	IV	8–17	43	18	20	Gracilis	France	2018
Matuszewski *et al*.	III	13–17	24	22	22	Gracilis	Poland	2018
Pemmaraju *et al*.	IV	16–18	31	8	8	Gracilis	UK	2016
Lind *et al*.	III	8–16	39	20	24	Gracilis	Denmark	2016
Leite *et al*.	III	10–17	60	29	29	Gracilis and quadriceps	USA	2023
Kumar *et al*. (autograft group)	III	13–17	49.2	23	23	Gracilis	USA	2018
Sadigurski *et al*.	IV	9–13	12	7	7	Semitendinosus	Brazil	2017
Kumahashi *et al*.	IV	11–15	27.8	5	5	Semitendinosus	Japan	2012
Drez *et al*.	IV	14–18	27.1	5	5	Semitendinosus	USA	2001
Abouelsoud *et al*.	IV	8–15	29.25	16	16	Quadriceps	Egypt	2015
Nelitz *et al*.	III	9–14	24	25	25	Quadriceps	Germany	2017
Nomura *et al*.	IV	8–17	133.2	11	11	Augmented tape	Japan	2007
Hobson *et al*.	IV	12–18	58.8	29	33	Augmented tape	USA	2022
Alm *et al*.	IV	11–17	25.6	28	30	Gracilis+semitendinosus	Germany	2017
Pesenti *et al*.	IV	11–16	41.1	25	27	Gracilis+semitendinosus	France	2018
Reddy *et al*.	III	7–16	6	57	76	Hamstring	UK	2022
Hannah *et al*.	IV	10–16	6	33	40	Hamstring	UK	2021

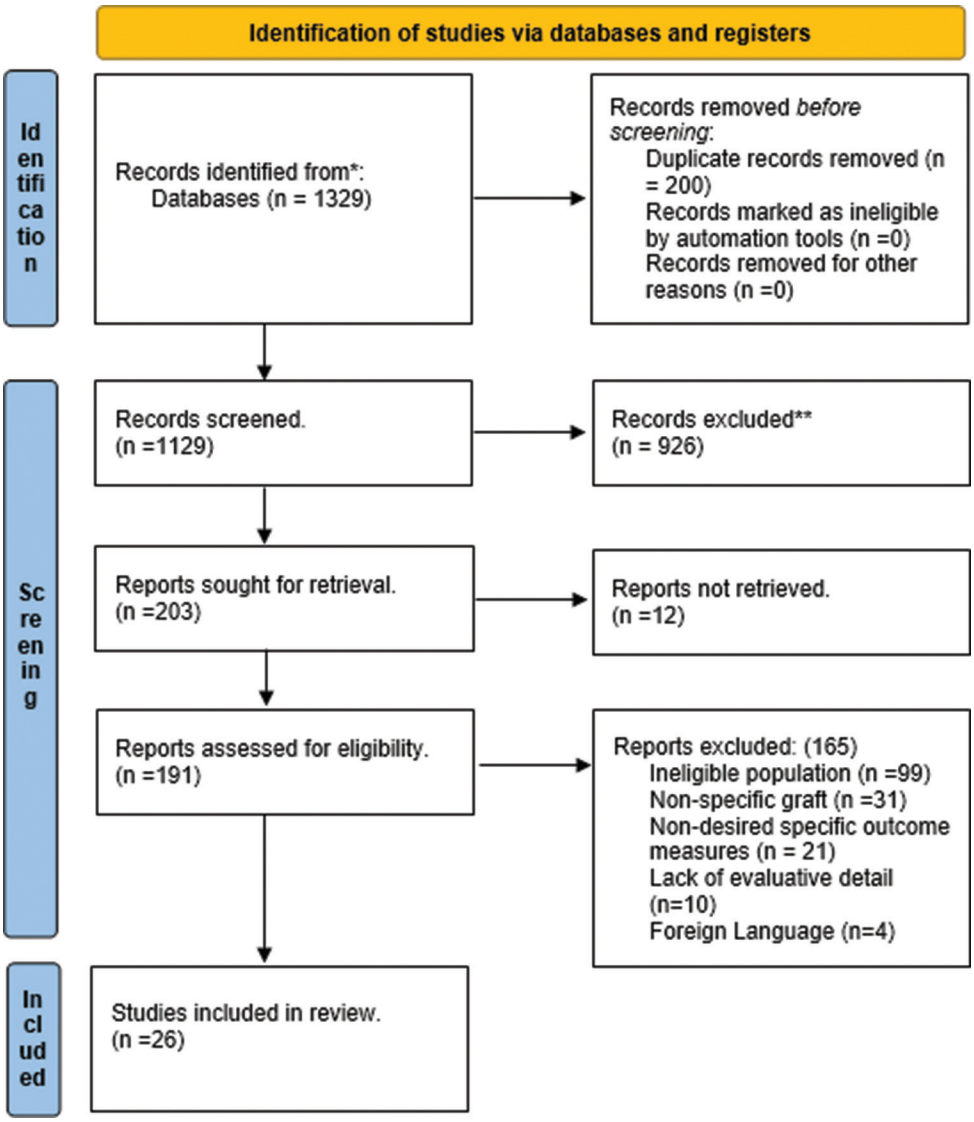

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart showing the identification, selection, eligibility, and inclusion of studies

countries. The included publications were from: the USA (7), Germany (4), France (4), the UK (3), Japan (2), and 6 other publications each from different countries. The range of ages for included patients was 7–18. The mean follow-up times for the different studies ranged from 6 months[20] to 133.2 months.[21] The different grafts used in the studies were gracilis (n = 15),[10,18,19,22-33] semitendinosus (n = 3),[17,34,35] quadriceps (n = 3),[10,36,37] augmented tape (n = 2),[15,21] and mixed semitendinosus and gracilis or generic hamstring graft (n = 4).[20,38-40] It is of note that the study by Leite *et al*.[10] contained discrete data that could be fit into two different graft types (gracilis and quadriceps).

Risk of bias in studies

Nineteen out of 26 studies included were case series [Table 3], where the range of scores for the Joanna Briggs Institute critical appraisal checklist[16] ranged from 5[26] to 10[19,40] with a mean score of 7.63. There were two items where all studies met the criteria being "Was the condition measured in a standard, reliable way for all participants included in the case series?" and "Were valid methods used for identification of the condition for all participants included in the case series?." The worst reported checklist criteria within the studies was "Did the case series have complete inclusion of participants?" which no case series in this study met.

We applied the same checklist to case–control studies, with only one being included at the data extraction stage.[32] For this, 6/10 items of the checklist were met, with the remaining 4/10 not meeting the criteria.

For the cohort studies that were included there was a range of 5 to 11/11 of items met within the checklist [Table 4]. The mean number of items that the studies met was 8.5/11. There were 4 items that were met across all studies (items 3, 8, 9, and 11). Item 6 "Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?" was

Table 3: Identified case series

Author	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Total
Rueth	Y	Y	Y	N	N	Y	Y	Y	N	Y	7
Hobson	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Spang	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9
Husen	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Pesenti	Y	Y	Y	U	U	Y	Y	Y	U	Y	7
Wegmann	N	Y	Y	Y	Y	Y	Y	Y	N	Y	8
Alm	Y	Y	Y	U	N	Y	Y	Y	N	Y	7
Hohn	Y	Y	Y	U	U	Y	U	Y	N	U	5
Schlumberger	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9
Bremond	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	9
Machado	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9
Sadigurski	Y	Y	Y	U	Y	N	Y	Y	U	Y	7
Roger	Y	Y	Y	U	U	Y	Y	Y	N	U	6
Pemmaraju	Y	Y	Y	Y	Y	N	Y	Y	U	N	7
Abouelsoud	Y	Y	Y	Y	U	N	Y	Y	Y	U	7
Kumahashi	Y	Y	Y	N	N	Y	Y	Y	N	Y	7
Nomura	N	Y	Y	N	N	Y	Y	Y	N	Y	6
Drez	Y	Y	Y	N	N	Y	Y	Y	Y	U	7
Hannah	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Total	17	19	19	9	6	16	18	18	9	14	N/A

Table 4: Cohort studies

Author	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total
Leite	N	N	Y	N	N	U	Y	Y	Y	U	Y	5
Kumar	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	10
Neilitz	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Zampieri	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Matuszewski	N	Y	Y	U	N	U	Y	Y	Y	U	Y	6
Reddy	Y	Y	Y	Y	N	N	U	Y	Y	Y	Y	8
Total	4	5	6	4	3	2	5	6	6	4	6	N/A

the least well reported with only two studies[28,37] meeting the requirements of this item.

Results of individual studies

Thirty-six out of 497 (7%) knees operated on within the gracilis graft group had a redislocation postreconstruction occur within their follow-up period [Figure 2]. Within the semitendinosus graft group, 1/10 (10%) knees had a postoperation dislocation, and in the quadriceps graft group, 4/51 (8%) had a redislocation. For the augmented tape graft group, 2/33 (6%) of knees also experienced a redislocation. Within the final graft group, the mixed gracilis and semitendinosus or generic hamstring group, 5/57 (9%) observed a redislocation post reconstructive surgery. 15 of 26 studies were focused on the skeletally immature of which 14 reported redislocation rates with a median of 5% (standard deviation [SD]: 4.38) and a range from 0% to 26%. 2 of 26 included only skeletally mature patients with a median redislocation rate of 3.45% (SD = 1.62), range = 0%–7%. The remaining studies consisted of mixed populations or unstated skeletal maturity.

When comparing gracilis autograft redislocation rate to allograft, 17 studies reported on autograft redislocation rates with a median of 4% (SD = 4.34), range 0%–26%, compared to 2 studies of allograft with a median of 14% (SD = 1.98) and range = 9%–19%.

The mean Kujala scores [Figure 3], within the Gracilis graft group, ranged from 80.3[10] to 97.9[24] with a median of 89.63.[31] For the semitendinosus group, the mean Kujala score ranged from 88.57[34] to 95.4,[35] with a median of 90.8.[17] There was a range of 86.2[10]–94[36] for mean Kujala scores within the quadriceps group and a mean of 90.1. In addition, there was a separate median reported in the quadriceps group of 89.[37] There was only one mean Kujala score reported for the augmented tape group of 93.6.[21] In the "mixed gracilis and semitendinosus or generic hamstring" graft choice, there was a mean Kujala score range of 89[20]–95.3[39] with a median mean of 92.2. There was once again a separate individual median Kujala score of 91.12[38] within this final group.

Tegner and Lysholm scores were reported for a smaller number of studies [Figures 4 and 5].

Ongoing instability was analyzed for each of the different groups [Figure 6]. Within the gracilis group, 14/271 knees (5%) experienced postoperative ongoing instability at

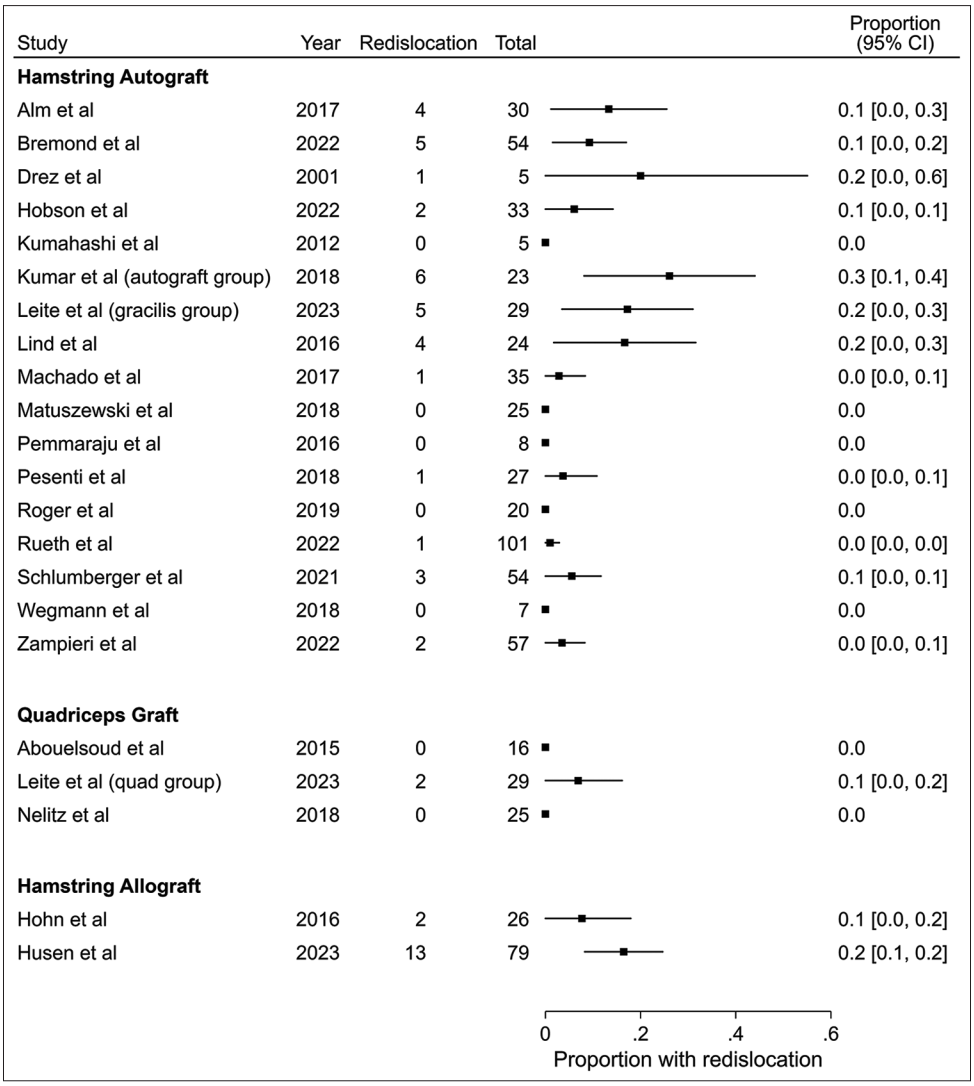

Figure 2: Forest plot of redislocation rates

a minimum follow-up time of 24 months.[19,25,26] There was no ongoing instability data within any of the semitendinosus graft group studies. 5/16 knees (31%) within the quadriceps graft choice group experienced ongoing instability, all patients coming from one study by Abouelsoud *et al*.[36] Within the augmented tape group and the mixed gracilis and semitendinosus or generic hamstring group, there were 2/33 (6%) and 11/103 (11%) cases of ongoing instability, respectively.

Revision surgeries [Figure 7] were reported in 27/403 (7%) knees within the gracilis graft group. None of the knees operated on within the semitendinosus group and the quadriceps graft group required revision surgery. For the augmented tape group, 2/33 knees (6%) required revision surgery, and 14/143 (10%) knees needed revision in the mixed gracilis and semitendinosus or generic hamstring group.

Only 3 of the 26 studies included information on participants with ligamentous laxity, 2 including patients with laxity and 1 excluding them. No studies included scoring of laxity.

Discussion

This systematic review was conducted in order to assess the suitability of different graft choices in pediatric MPFL reconstruction and identify outcomes to be relatively consistent across them for the selected outcome measures, although it lacked the data for a statistical analysis and therefore only acts as an indication of efficacy.

Twenty-six studies were included within this analysis from an original 1,129 individual articles. The pooled rate of postoperative redislocation was 4% (6%–10%) across the different graft groups, with occurrence most likely in the semitendinosus group and least likely in the augmented tape group. This confirms the successful role of isolated MPFL reconstruction in treatment of patellofemoral dislocation. Other outcome measures, such as ongoing instability and validated outcome measures, also did not differ across the different graft groups.

Follow-up was relatively short term in the majority of studies with a wide range. One of the concerns of isolated

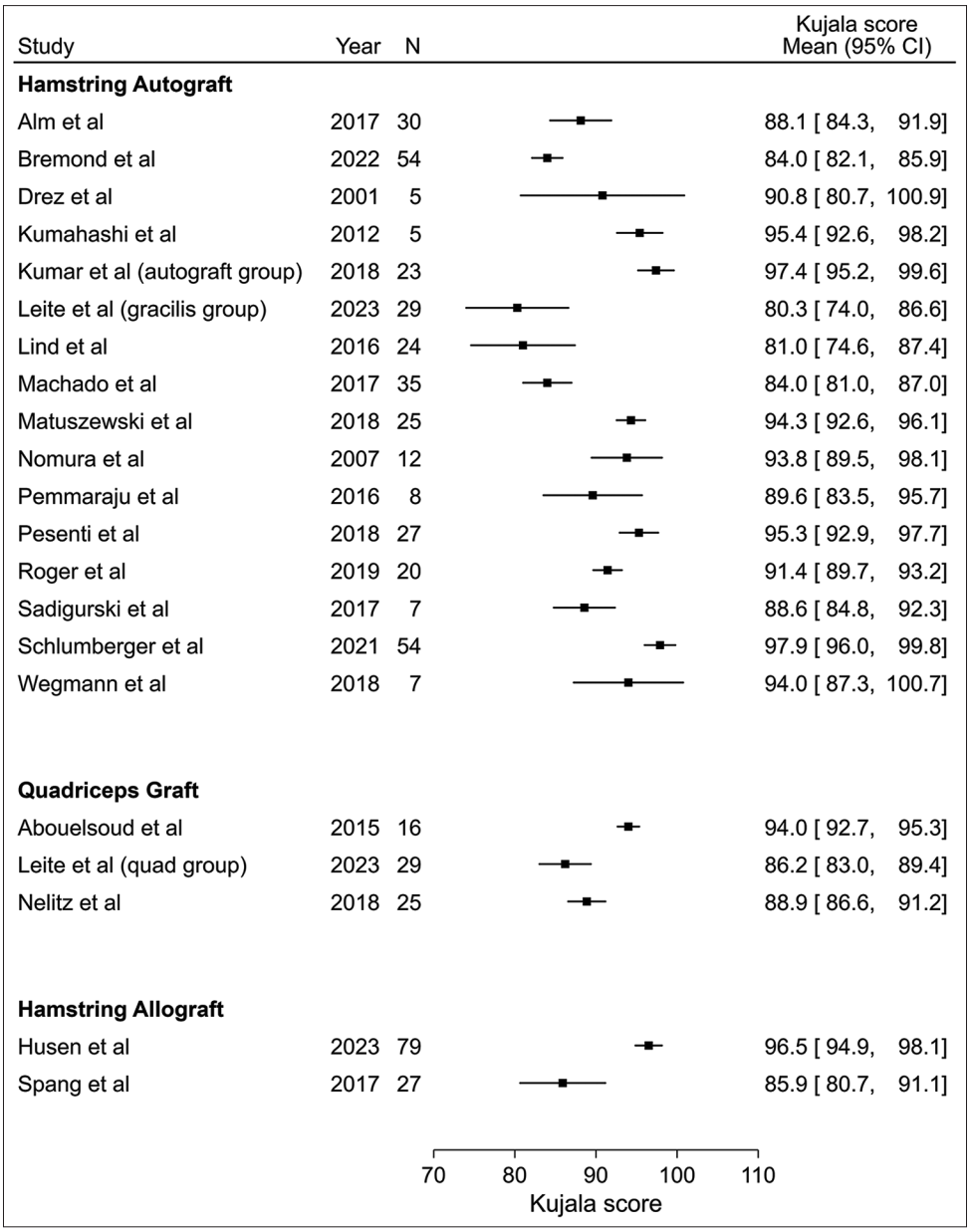

Figure 3: Forest plot of Kujala scores

MPFL reconstruction in the pediatric cohort is the presence of untreated anatomical risk factors increasing the risk of later dislocation, these factors playing a role in recurrence of instability with many studies not stratifying these risk factors. This is a recurring theme within the adult literature.[41] Well-established prognostic data were underreported across our included studies. Body mass index (BMI) and the tibial tuberosity to trochlear groove (TT-TG) distance are known factors in patella instability and therefore should be considered.[42,43] BMI was only reported in 5/26 included studies, with TT-TG distances only reported in 15/26. The TT-TG should be considered a composite figure, not a decision-making tool that allows understanding of periarticular rotational malalignment that is a complex measurement. The presence of ligamentous laxity was also not documented in the majority of studies. Revision surgery is also a difficult variable to standardize and indications differ and some cases may be missed that have functional problems postsurgery. The same is true for the reporting of ongoing instability.

The published data on graft groups are heavily weighted to populations treated with a gracilis graft, with the other graft groups under-represented. 31% of quadriceps grafts experienced ongoing instability. This could be due to this figure being derived from only one study of 16 patients. A small sample size could give a false indication of true outcome.[36] A greater number of patients in the non gracilis graft groups would be needed for a more accurate representation and therefore a more reliable analysis. The potential concerns of hamstring allograft seen with ACL reconstruction[44] may affect also the efficacy of MPFL reconstruction.

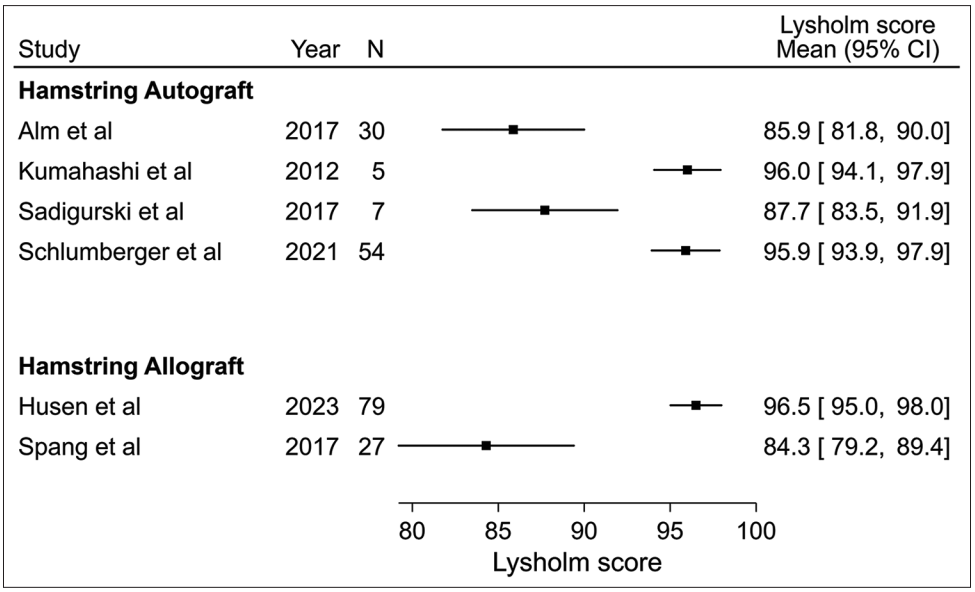

Figure 4: Forest plot of Lysolm scores

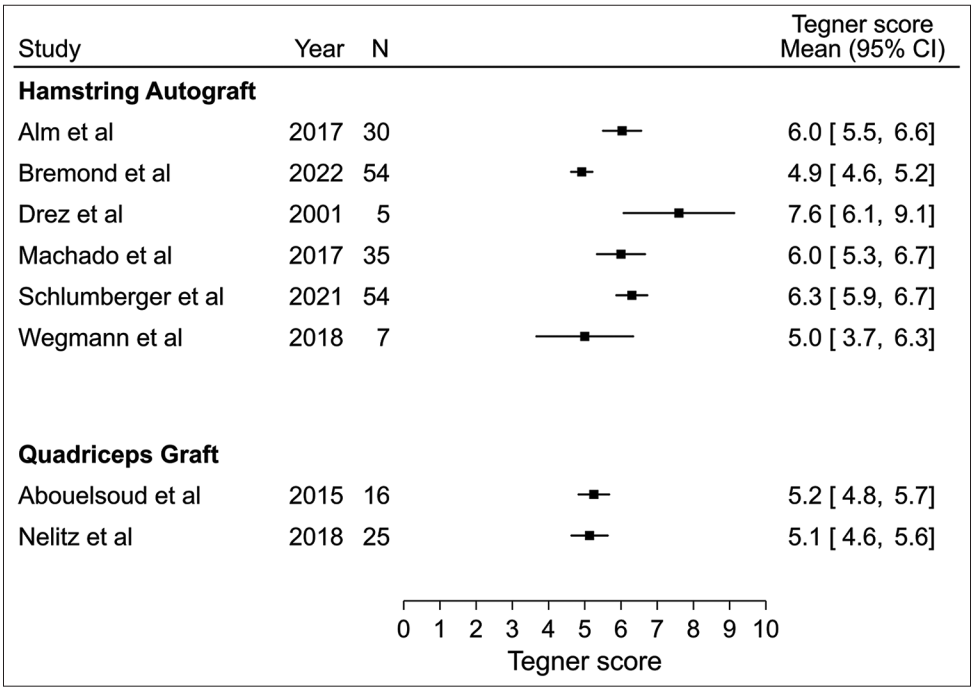

Figure 5: Forest plot of Tegner scores

In particular, although data are limited on quadriceps grafts, outcomes appear as effective as hamstring grafts in the limited period of follow-up and warrant further investigation based on low redislocation rates and the efficacy seen in adult MPFL reconstruction.[45-50]

Strengths and limitations

One key strength of this systematic review was the highly sensitive search strategy employed in order to retrieve potentially relevant articles. We were able to screen 1129 individual articles, allowing us to find 26 full-text studies that were eligible and therefore included in data extraction with two reviewers performing a critical appraisal of each article. This is in comparison to a recent review by Migliorini *et al*.[51] which was only able to identify 730 unique entries, due to their less sensitive search strategy and exclusion of allografts and less specific analysis of factors related to failure of the procedure. Our search allowed us to include 334 more procedures in our review (844 vs. 510).

Throughout our screening process, we also ensured the reliable inclusion of studies through multiple blinded reviewers being used. Six reviewers screened at the abstract stage, all blinded to each other's results. Any undecided

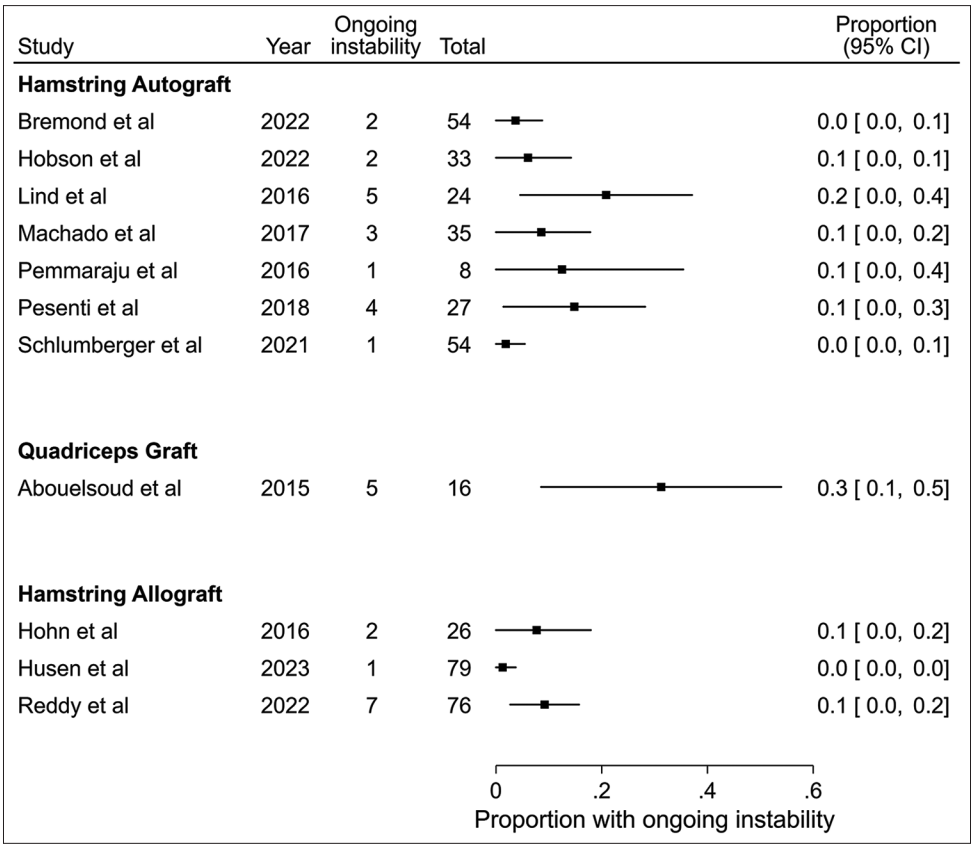

Figure 6: Forest plot of ongoing instability rates

decisions were brought up as a group and then settled, with input from an experienced reviewer and pediatric knee surgeon, and then at the full-text stage, 203 articles were split into pairs who assessed their eligibility, once again blind of each other.

In terms of weaknesses, our statistical synthesis was limited due to a lack of robust studies and therefore limited high quality evidence. The use of the GRADE tool was avoided in favor of the Centre for Evidence-Based Medicine tool due to the lack of randomized studies and could be considered a deviation from normal systematic review methods but a process we felt appropriate based on the number of case series. A number of clinical outcome scores used are not validated for patients under the age of 16 years such as the Kujala, Tegner, and Lysholm, but in the absence of core outcomes for pediatric knee surgery, their use by many within the study of the pediatric age bracket is understandable.

Although surgical variation such as graft fixation and technique of reconstruction with each graft can alter outcomes,[52] this was not considered in our analysis.Graft harvesting methods may differ in complications, a factor assessed in systematic reviews for ACL reconstruction[53,54] but not for MPFL. Contemporary reconstruction of other medial constraints such as the medial patellotibial ligament (MPTL) and medial quadriceps tendon femoral ligament were also not compared. These constraints are the subject of renewed interest and are often reconstructed simultaneously with the MPFL. They may play a future role in treatment of the paediatric cohort.[55-59]

Clinicians using any of these graft types can be confident that current evidence does not suggest one graft type is superior. As the practice of surgery for recurrent dislocation within the pediatric population continues to be dominated by isolated MPFL reconstruction, it suggests that better comparative studies of graft choice that takes in to account anatomical risk factors are needed. The TT-TG measurement, considered by many a composite and complicated figure, is still a measure of interest despite controversies on what it represents.

Conclusions

The data pooled across the studies suggest that isolated MPFL reconstruction had good outcomes for all graft types. Heterogeneity in both the participant groups, assessment of risk factors, outcome reporting, and methodology limits analysis of the published evidence of graft choice for MPFL reconstruction in children and adolescents. Further studies with careful risk stratification and core outcomes are needed to identify if there is a benefit to one particular type of procedure.

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Conflicts of interest

There are no conflicts of interest.

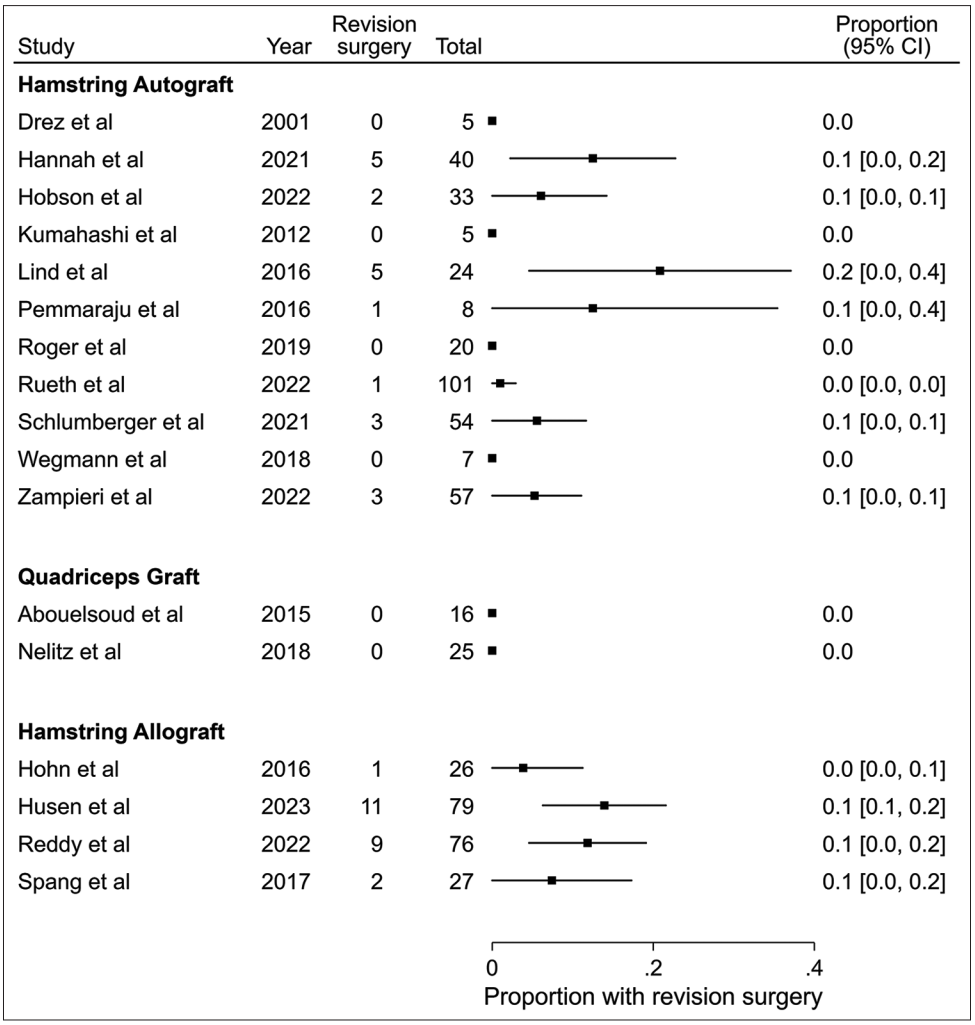

Figure 7: Forest plot of revision surgery

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