Early ACL reconstruction in children leads to less meniscal and articular cartilage damage when compared with conservative or delayed treatment

Peter D Fabricant,1 Nikita Lakomkin,2 Aristides I Cruz Jr,3 Elad Spitzer,1 J Todd R Lawrence,4 Robert G Marx1

ABSTRACT

Background Anterior cruciate ligament (ACL) tears are being seen and treated with increasing frequency in children and adolescent athletes. The superiority of treating ACL tears in children and adolescents with acute reconstruction, delayed reconstruction or non-operative treatment remains controversial.

Objectives To perform a systematic literature review to investigate for any associations between progressive intra-articular joint damage (increasing rates of meniscal and cartilage injury) with delayed or non-operative treatment of ACL tears in children and adolescents under age 18 when compared with acute ACL reconstruction (ACLR).

Data sources PubMed, EMBASE and Cochrane databases.

Study eligibility criteria Inclusion criteria: (1) paediatric patient population (defined as <18 years of age), (2) investigated association between operative or non-operative treatment and consequent meniscal/ chondral injury rates, (3) original research article, rather than a review, case report or meta-analysis. Exclusion criteria: (1) revision ACL cohort, (2) full-text article in a language other than English and (3) not a human clinical study.

Participants Youth aged <18 years with ACL tears.

Interventions Acute ACLR, delayed ACLR, non-operative management.

Synthesis methods Qualitative synthesis.

Results 17 studies were included in the final analysis, all of which reported on medial meniscal injuries, of which 8 (47%) favoured acute reconstruction. 10 of 17 reported on cartilage injuries, of which 4 (40%) favoured acute ACLR. No study concluded that delayed reconstruction or non-operative management was associated with fewer cartilage or meniscus injuries.

Limitations While the included studies provided patient age data, not all provided details about distribution of skeletal maturity. Furthermore, the majority of studies were retrospective and subject to selection bias, measurement bias and confounder bias (eg, surgical decision-making may have accounted for intra-articular pathology sustained at the time of injury).

Conclusions and implications of key findings On the basis of the available published literature which is largely retrospective, acute reconstruction for ACL tears appears to be associated with fewer medial meniscal injuries and articular cartilage lesions when compared with delayed or non-operative management. Several studies that were equivocal showed clinically relevant effect sizes but were underpowered to detect statistical differences between groups. Future prospective research in a large uniform cohort of skeletally immature patients with ACL tears may provide more answers to this important clinical question.

INTRODUCTION

Intrasubstance tears of the anterior cruciate ligament (ACL) were once considered a rare injury in children and adolescents; however, they are now observed with increasing frequency. This has been attributed to multiple factors including an increase in youth sports specialisation and competition, and increased awareness of ACL injuries in children. A recent epidemiological study revealed that the rate of ACL reconstruction (ACLR) in children under age 20 had increased nearly threefold over a 20-year period from 1990 to 2009, and indicated that adolescents and teenagers represent the largest per capita demographic of ACLRs.1

In light of the increasing frequency and awareness of ACL injuries in children, treatment strategies have evolved, catering to the unique anatomy of the skeletally immature patient. While non-operative or delayed surgical management until skeletal maturity was a historically ubiquitous treatment for complete ACL rupture due to the risk of physeal damage inherent to surgical treatment,2 newer surgical techniques and instrumentation have expanded the options for acute physeal-respecting ACLR and there are many techniques with an acceptable safety profile for patients with growth remaining.3–10 The superiority of treating ACL tears in children and adolescents with acute reconstruction, delayed reconstruction or non-operative treatment remains controversial in the orthopaedic literature.11–13 The potential for increased risk of further irreparable cartilage and/or meniscal damage in the unreconstructed knee is germane to the arguments for and against surgical reconstruction in children and adolescents.14 This is of particular concern in patients who do not modify their post-injury activity levels, as is often the case in active children and adolescents.

While recent quantitative synthesis of the available literature has been performed evaluating recurrent instability, pathological laxity and return to activity,15 no such study has been performed evaluating the effect of surgical delay on further intra-articular damage. The purpose of this study
was therefore to perform a systematic review of the orthopaedic surgery literature to investigate for any associations between progressive intra-articular joint damage (increasing rates of cartilage and meniscal injury) with delayed or non-operative treatment of ACL tears in children and adolescents under age 18 when compared with acute ACLR. We hypothesised that those patients who underwent initial non-operative management or experienced a surgical delay would have a greater risk of cartilage and meniscal injury than those who underwent acute ACLR.

**METHODS**

**Study design and search strategy**

The current study was registered with the International Prospective Register of Systematic Reviews (PROSPERO), registration number CRD42015027614. A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. An electronic search of the PubMed, EMBASE and Cochrane computerised databases was conducted by two independent reviewers (NL and ES) on 8 June 2015. The final sequence of the employed search terms is as follows: (‘ACL’ OR ‘Anterior Cruciate Ligament’) AND (‘delay’ OR ‘conservative’ OR ‘non-operative’) AND (‘pediatric’ OR ‘adolescent’ OR ‘physis’ OR ‘knee’) AND (‘cartilage’ OR ‘meniscus’ OR ‘meniscal’ OR ‘chondral’). A complete search strategy and results are presented in table 1. A filter was utilised in order to limit the search to studies that were published after 1 January 2000. The references of each unique full-text article were subsequently examined in order to identify additional articles that could potentially be relevant to the study. Since this study uses the existing literature and does not involve human subjects, Institutional Review Board (IRB) approval was not required.

**Study selection**

The titles and abstract sections of each of the unique studies identified via the electronic database and bibliography searches were then examined for relevance to the study question. A full-text review was subsequently performed for potentially relevant studies and final inclusion was determined on the basis of the following criteria: (1) paediatric patient population (defined as <18 years of age), (2) investigated association between operative or non-operative treatment and consequent meniscal/chondral injury rates and (3) original research article, rather than a review, case report or meta-analysis. Exclusion criteria included: (1) revision ACL cohort, (2) full-text article in a language other than English and (3) not a human clinical study.

**Data extraction**

Three authors (PDF, NL and AIC) independently extracted data from each of the studies that met the established inclusion/exclusion criteria, with discrepancies resolved unanimously through discussion of each included study. General information including the name of the first author, journal, year of publication, level of evidence and intervention was collected for each investigation. When available, the definition for delayed treatment, average follow-up time, and incidence of medial meniscal injury and cartilage lesions along with the corresponding comparative analyses and p values were recorded. Post hoc analyses were performed from original tabular study data, when possible, using χ² and Fisher’s exact tests as appropriate. A full list of the included articles along with the corresponding data is depicted in table 2.

**RESULTS**

**Study inclusion**

The original electronic database search yielded 91 unique articles, 7 of which were identified via a manual search of the references of those identified through electronic database search. Twenty-eight of these were deemed to be not relevant to the research topic based on title and abstract review, resulting in 63 full-text articles being assessed for inclusion/exclusion criteria. A total of 46 studies were excluded because they were: not examining outcome variables of interest (N=18), adult-focused (N=13), review articles (N=12), not clinical studies (N=2) or case reports (N=1). Seventeen studies were included in the final qualitative synthesis, as demonstrated in the PRISMA flow diagram (figure 1).

**General study characteristics**

Of the 17 included studies, 14 involved solely surgical reconstruction of the torn ACL while 3 incorporated non-operative treatment cohorts. Out of the investigations that included non-operative groups, two17 18 compared operative and non-operative approaches in the context of concomitant injury while one19 assessed the outcomes of conservative treatment alone. One of the studies that evaluated operative versus non-operative treatment provided the rates of both meniscal and chondral injury18 while the second only reported the incidence of medial meniscal damage for the two groups.17 Out of the studies comparing acute and delayed operative treatment, eight2 14 20–25 included data for both meniscal and chondral injury while six26–31 only reported information regarding meniscal damage. All studies reporting meniscal injury data examined the risk of medial meniscal tears while few examined lateral meniscal tears. Furthermore, since medial meniscal tears represent the majority of repetitive traumatic tears noted in unstable knees while lateral meniscal tears occur more commonly in the acute setting,22 medial meniscal injuries were investigated for this study. This analysis included 619 22 23 26 29–33 studies of level IV evidence and 1114 17 18 20–22 24 25 27 28 of level III evidence. Studies included in the final analysis along with corresponding characteristics and their comparative analyses are presented in table 2.

**Delayed versus acute ACLR**

A total of 14 studies examined the rates of concomitant injury following acute or delayed ACLR in children. Of these, five...
Table 2  Characteristics of studies comparing ACLR with non-operative treatment

<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Journal</th>
<th>LOE</th>
<th>Delayed treatment definition (weeks)</th>
<th>Intervention technique(s)</th>
<th>Follow-up (months)</th>
<th>Medial meniscal damage†</th>
<th>Chondral injuries</th>
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<tr>
<td>Newman et al[20]</td>
<td>272</td>
<td>AJSM</td>
<td>III</td>
<td>12</td>
<td>Unspecified ACLR techniques</td>
<td>12</td>
<td>12.3 44.4</td>
<td>10.3 48.1</td>
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<td>135</td>
<td>AJSM</td>
<td>III</td>
<td>12</td>
<td>AE</td>
<td>–</td>
<td>24 50</td>
<td>7 28</td>
</tr>
<tr>
<td>Funahashi et al[3]</td>
<td>71</td>
<td>AJSM</td>
<td>III</td>
<td>52 and 104</td>
<td>Unspecified ACLR</td>
<td>18</td>
<td>NR NR</td>
<td>NR NR</td>
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<td>CORR</td>
<td>IV</td>
<td>52</td>
<td>AE</td>
<td>12</td>
<td>15 45</td>
<td>10 45</td>
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<td>AJSM</td>
<td>III</td>
<td>12</td>
<td>AE</td>
<td>15</td>
<td>–</td>
<td>–</td>
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<td>III</td>
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<td>Non-operative vs TP</td>
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<td>31.3 33.3</td>
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<td>AJS</td>
<td>IV</td>
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<td>Non-operative only</td>
<td>46</td>
<td>– 28.5</td>
<td>– 7.1</td>
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<td>III</td>
<td>26</td>
<td>TP</td>
<td>–</td>
<td>8.7 30.8</td>
<td>6.8 11.5</td>
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<td>BJJ</td>
<td>III</td>
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<td>19.1 34.8</td>
<td>12.8 13</td>
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<td>PTP</td>
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<td>n/a</td>
<td>TP</td>
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<td>– 25</td>
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<td>IV</td>
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<td>TP</td>
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<td>21.1 71.4</td>
<td>5.3 28.6</td>
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<td>AJSM</td>
<td>IV</td>
<td>24</td>
<td>TP</td>
<td>127</td>
<td>25 71.4</td>
<td>–</td>
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</table>

Notes

- Newman et al[20] analysis performed to generate p values. Included patients represent a subcohort of patients under 14 years of age
- 27.7% of the general operative cohort had documented medial meniscal injuries
- 57.4% presented with chondral injury. (Study gave p values but no point estimate or distributional data)
- Follow-up is the time from injury to surgery (meniscal tears diagnosed at arthroscopy)
- Reported chondral injuries were all in the lateral compartment
- Meniscal injury rates calculated from tabular data, post hoc Fisher’s exact test performed to generate p value for meniscal injury. Operative group mean time to surgery 84 weeks
- Time from injury to final MRI follow-up. 19.5% eventually required surgery for meniscus injuries
- 32% eventually required ACLR
- Those with open physes were delayed until skeletal maturity
- Meniscal injury rates calculated from tabular data; post hoc χ² analyses performed to generate p values for meniscal injuries
- 3 of the 8 (37.5%) meniscal tears in the non-operative group required surgical treatment in the observation period
- New meniscal injury diagnosed at a mean of 6.9 weeks after injury
- Meniscal injury rates calculated from tabular data. Post hoc χ² analysis performed to generate p value for meniscal injuries
- Meniscal injury rates calculated from tabular data. Post hoc χ² analysis performed to generate p value for meniscal injuries. 1 (14%) patient in the delayed group had a lateral meniscal tear
- Meniscal injury rates calculated from tabular data. Post hoc Fisher’s exact test performed to generate p value for meniscal injuries. No differentiation was made between lateral and medial meniscus. 2 (7.4%) patients sustained chondral injury, but surgical timing was NR

Continued
studies demonstrated a statistically significant (p<0.05) association between delayed ACLR and the presence of new meniscal or chondral injuries at the time of surgery. 14 20–22 24 A large investigation performed by Dumont et al,24 which defined a treatment delay to be 21.4 weeks from the onset of injury, reported that 53.5% of children in the delayed cohort sustained medial meniscal injuries, compared with 37.8% of those treated acutely (p=0.014). Likewise, 76.7% of paediatric patients treated after 21.4 weeks presented with cartilage injuries, compared with 52.7% of their counterparts receiving acute reconstruction (p<0.001). However, two large studies reported no differences in the rates of chondral or medial meniscal injuries between patients treated acutely or with a delay.2 25 One of these investigations considered a delay to be 12 weeks following the initial injury while the second used 26 weeks as the definition for delay. The rest of the studies examining the outcomes of surgically treated ACL tears, which reported data regarding only meniscal damage, demonstrated that children who experience a delay to treatment develop medial meniscal injuries at significantly greater rates than those treated acutely (p<0.05).16–28

Operative versus non-operative treatment

Only two studies directly compared children whose ACL tears were treated via operative reconstruction with those who received conservative treatment. Streich et al17 retrospectively compared the outcomes of 16 paediatric patients who underwent transphyseal ACLR with 12 who were treated non-operatively. The authors reported rates of medial meniscal injury to be 31.3% and 33.3% (p>0.99; post hoc Fisher’s exact test) for the operative and non-operative cohorts, respectively. Similarly, Aichroth et al18 examined post-treatment differences between 47 children who underwent transphyseal reconstruction and 23 who received non-operative treatment. Calculations from the authors’ tabular data demonstrated medial meniscal injury rates to be 19.1% and 34.8% for the reconstruction and non-operative groups, respectively. While this difference appears to be clinically relevant, the study was most likely underpowered to detect a statistically significant difference between the two groups (p=0.26; post hoc χ² analysis). The Aichroth et al study noted similar rates of cartilage injury between groups (p>0.99; post hoc χ² analysis).

Non-operative treatment

One study examined the rates of meniscal and chondral injuries for patients whose ACL tears were treated non-operatively. Moksnes et al19 prospectively evaluated children with ACL tears who received non-operative therapy. The authors reported 28.5% of their conservatively treated patients developing medial meniscal damage and 7.1% sustaining a cartilage injury, suggesting that these injury rates are similar to those of other studies in which patients received operative treatment. However, 19.5% of their initial non-operative cohort sustained new meniscal pathology requiring surgery and 32% necessitated subsequent ACLR for symptomatic instability.

DISCUSSION

The superiority of treating ACL tears in children and adolescents with acute reconstruction, delayed reconstruction or non-operative treatment remains controversial in the orthopaedic literature.11–13 While some authors secondarily reported a positive effect between surgical delay and cartilage and meniscus damage in clinical reports investigating other primary outcomes, Millett et al22 and subsequently Lawrence et al22 directly
investigated the association between delayed ACLR and irreparable intra-articular joint damage in youth athletes. Subsequently, several studies have been performed to further investigate this topic. The large majority of studies support the notion of acute treatment of ACL tears in children and adolescents given the noted associations between delay or non-operative management and cartilage or meniscal pathology.

Of the 17 studies included in this review, all reported on medial meniscal injuries, of which 8 (47%) favoured acute ACLR. Ten of the 17 reported on cartilage injuries, of which 4 (40%) favoured acute reconstruction. For meniscal and cartilage injuries, those that did not favour acute treatment either showed no difference in outcomes or did not provide comparisons between groups. Despite the lack of study homogeneity and thus the inability to calculate weighted summary statistics in meta-analysis, these summary data seem to favour acute reconstruction of ACL injuries in patients aged under 18 years, as this was associated with a lower incidence of medial meniscal injury and global cartilage lesions.

One study strongly advocated a trial of non-operative management in skeletally immature children with ACL tears. It rigorously evaluated 40 skeletally immature patients with longitudinal MRI scans in order to determine new intra-articular pathology, and concluded that the risk of subsequent pathology was low. However, arthroscopy remains the gold standard for intra-articular evaluation, and MRI may be subject to false-negative reporting. In fact, non-contrast MRI techniques have been recently reported to have variable sensitivity, some as low as 42% for cartilage lesions and 62–78% for meniscus lesions, indicating that an MRI study of intra-articular pathology may underestimate the prevalence of disease through false-negative reporting. Furthermore, the clinical outcomes reported in the Moksnes et al study revealed that during the 4 years post-injury, one in three required ACLR for persistent instability and one in five required arthroscopy for newly sustained meniscal pathology. While this may suggest that universally performing ACL reconstructions in active skeletally immature patients may subject some to unnecessary surgery, it is up to treating surgeons and their patients and families to weigh the risks and benefits of acute ACLR versus controlled rehabilitation, understanding the significant risk of developing irreparable meniscal and/or chondral pathology as well as prolonged activity reduction due to a period of rehabilitation. Patients and families should also be aware that in one-third of patients initially treated non-operatively, surgery for persistent instability despite controlled rehabilitation may be necessary.

It is important to note the limitations inherent to this systematic review and its included investigations. First, the heterogeneity of ACLR techniques, definitions of surgical delay and variable length of follow-up precluded quantitative meta-analysis of the included studies. This is unfortunate because meta-analysis is able to combine similar study cohorts in order to gain statistical power and draw conclusions that may not have existed previously. Several studies evaluated in this review indicated statistical equivalence between surgical delay or non-operative treatment and intra-articular pathology, though it may have been underpowered to demonstrate an effect. For example, post hoc analysis of the adolescent subcohort in the Ralles et al study revealed a
difference in the incidence of medial meniscal tears of 10% between those who had surgery within 3 months and those who had delayed treatment, a finding that was not statistically significant. Gebhard et al. noted a twofold increase in meniscal pathology in the delayed cohort and Calvo et al. noted a threefold increase in meniscal pathology but neither demonstrated statistical significance, most likely because they were underpowered. The same may be true of the 5.4-times risk of cartilage injury in the delayed cohort in the Cohen et al. study which did not demonstrate statistical significance.

Second, one cannot infer causation from the associations between intra-articular injury and surgical delay noted by several studies. All comparative studies were retrospective and subject to selection bias, measurement bias and design bias. Specifically, surgical decision-making may have accounted for intra-articular pathology sustained at the time of injury. Furthermore, patients who were treated non-operatively and had subsequent surgery to address ACL, meniscus or cartilage pathology may have been more likely to be included in a retrospective study compared with asymptomatic patients who may not have returned for follow-up. Also, activity level during the interval between injury and surgery may have affected the rate of meniscal and/or cartilage damage noted at the time of arthroscopy, however, was not reported in the constituent studies.

Third, many studies provided aggregate patient age but did not specifically mention skeletal maturity. It is possible that parts of some cohorts included in this study are skeletally mature despite being in the paediatric/adolescent age range. Finally, while an association between surgical delay and the development of subsequent intra-articular pathology might best be studied using a randomised clinical design, this may not be feasible. In addition to the large amount of funding and healthcare resources required for any randomised control trial (RCT), the associations between surgical delay and intra-articular degenerative changes noted in the included studies eliminate clinical equipoise and may make a prospective experimental design ethically unfeasible.

In conclusion, while the majority of studies either provided sufficient data for post hoc analysis or directly reported significant associations between surgical delay and increased rates of intra-articular pathology, there still exists controversy in the orthopaedic literature regarding this effect. Future prospective research in a uniform cohort of skeletally immature patients with ACL tears may provide more answers to this question, as a randomised experimental design may be financially and ethically unfeasible.

Competing interests None declared.

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