



Operative Treatment of Isolated Meniscus Injuries in Adolescent Patients: A Meta-Analysis and Review

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Context: With the rise in sports participation and increased athleticism in the adolescent population, there is an ever-growing need to better understand adolescent meniscus pathology and treatment.

Objective: To better understand the operative management of meniscus tears in the adolescent population.

Data Sources: A systematic review of PubMed (MEDLINE) and Google Scholar was performed for all archived years.

Study Selection: Studies that reported on isolated meniscus tears in adolescent patients (age, 10-19 years) were included.

Study Design: Systematic review and meta-analysis.

Level of Evidence: Level 4.

Data Extraction: Two authors reviewed and extracted data from studies that fulfilled all inclusion criteria.

Results: Nine studies on isolated meniscus tears in adolescent patients were found, with level of evidence ranging from 3 to 4. These studies evaluated a total of 373 patients (248 males, 125 females) and 390 knees. Seven studies were published between 1979 and 2000, all of which discuss meniscectomy as the primary treatment. Two studies were published after 2000 and report on meniscus repair surgery. The mean patient age was 14.4 years. A total of 308 meniscectomies and 64 meniscus repairs were performed. Follow-up ranged from 1.8 to 30 years (mean, 10.8 years). A 37% retear rate was reported for patients undergoing meniscus repair. Different outcome measures were used for meniscectomy versus meniscus repair. Three studies evaluating meniscectomy reported Tapper-Hoover scores, showing 54 patients with an excellent result, 58 with good, 57 with fair, and 23 with poor results.

Conclusion: A shift in the management of isolated adolescent meniscal tears is reflected in the literature, with a recent increase in operative repair. This is likely secondary to poor outcomes after meniscectomy reflected in long-term follow-up studies. The current literature highlights the need for improved description of tear patterns, standardized reporting of outcome measures, and improved study methodologies to help guide orthopaedic surgeons on operative treatment of meniscal tears in adolescent patients.

Keywords: meniscus; adolescent; pediatric; operative

It is estimated that upward of 30 million children in the United States participate in organized sports programs, with the most commonly reported injuries stemming from this participation occurring in the knee joint.² Approximately 80% to 90% of adolescent meniscal injuries occur in the setting of athletic activity.^{4,7,27} Meniscal injuries in skeletally immature individuals can be secondary to congenital meniscal abnormalities, such as a discoid meniscus.^{4,7} In comparison, skeletally mature

adolescents more frequently acquire meniscal pathology as the result of acute trauma or during athletic activity and are more likely to have a concomitant ligamentous, chondral, or tibial injury.^{4,7,27} While many studies have focused on meniscal injuries in the context of anterior cruciate ligament (ACL) reconstruction, few studies have evaluated the outcomes of isolated meniscus treatment in the adolescent population.^{3,14,15,32,36}

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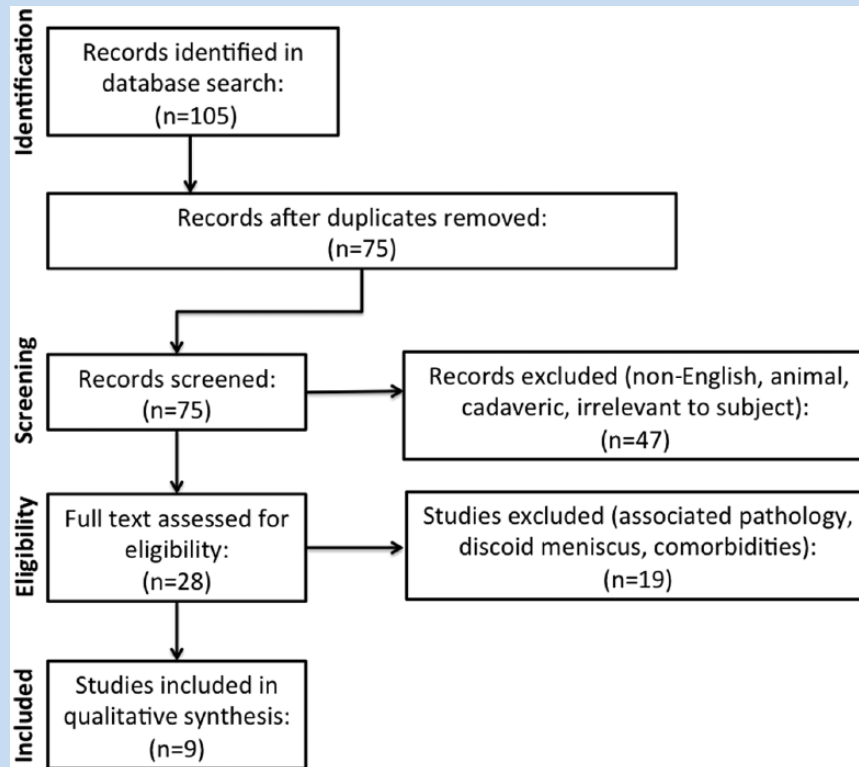


Figure 1. Search strategy according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Nine studies were identified for inclusion.

The purpose of this study was to evaluate the current body of orthopaedic literature to better understand the operative treatment practices for isolated, nondiscoid adolescent meniscus tears.

METHODS

Search Strategy

A comprehensive scientific literature review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines was performed (Figure 1).²⁵

A systematic review of PubMed (MEDLINE) and Google Scholar was performed to identify studies that reported on isolated meniscus tears in otherwise healthy pediatric or adolescent patients. The search criteria used were: “meniscus AND pediatric,” “meniscal repair AND pediatric,” “meniscectomy AND pediatric,” “meniscus AND adolescent,” “meniscal repair AND adolescent,” and “meniscectomy AND adolescent.” The search strategy was developed to include all study designs. English-language full-text manuscripts or abstracts were reviewed. After review of all relevant reports, the references of articles selected for review were further assessed to identify studies that were not captured in our initial database search.

Study Selection

Studies that reported on isolated pediatric or adolescent (patient age, <18 years) meniscus tears were included. Studies that

included meniscus tears with associated ACL tear or any other injury were excluded. Studies that reported on meniscus tears in patients with other congenital or acquired comorbidities were also excluded. Studies that did not evaluate the treatment or outcomes of isolated meniscus tears were also excluded. Finally, studies that were focused solely on discoid menisci were excluded.

Data Extraction

Two authors reviewed and extracted data from studies that fulfilled all inclusion criteria. The following variables were extracted from each study: year of study, type of study, level of evidence, demographic data, mechanism of injury, type of meniscus tear, laterality of meniscus tear, type of surgery, time to surgery, length of follow-up, Lysholm score,^{20,21} Tegner score,^{21,30} International Knee Documentation Committee (IKDC) score,^{16,17} Tapper-Hoover score,²⁹ Yocums score,³⁴ return-to-play data, retear rate, recurrence of symptoms, and reoperation rate.

Assessment of Level of Evidence and Methodological Quality of Studies

Level of evidence ratings were assigned to each study using the criteria set forth by Wright.³³ A quality assessment for each of the studies selected for final analysis was performed using the 12-point Methodological Index for Non-Randomized Studies (MINORS) criteria.²⁸

Table 1. Summary of included studies

Study	Intervention	Patients, n	Follow-up, mo	Level of Evidence	MINORS Score	Outcomes
Krych et al ¹⁸	Meniscal repair	44	69.6	4	13	Tegner, IKDC, retear rate
Lucas et al ¹⁹	Meniscal repair	17	22	4	14	Lysholm, Tegner, retear rate, reoperation rate
Manziona et al ²²	Meniscectomy	20	66	3	12	Yocums
McNicholas et al ²³	Meniscectomy	63	360	4	13	Tapper-Hoover
Abdon et al ¹	Meniscectomy	89	201.6	4	13	Tapper-Hoover
Medlar et al ²⁴	Meniscectomy	26	99.6	4	12	Authors' own scale, reoperation rate
Vahvanen and Aalto ³¹	Meniscectomy	41	67.2	4	11	Recurrence of symptoms
Dai et al ¹⁰	Meniscectomy	24	192	3	12	Tapper-Hoover, recurrence of symptoms
Zaman and Leonard ³⁵	Meniscectomy	49	90	4	11	Authors' own scale

IKDC, International Knee Documentation Committee; MINORS, Methodological Index for Non-Randomized Studies.

RESULTS

Methodological Quality

Nine studies on isolated meniscus tears in patients aged 18 years and younger were found, with level of evidence ranging from 3 to 4. Seven of the studies were published between 1979 and 2000 and discuss meniscectomy as the primary treatment for meniscus tear; 2 studies were published after 2000 and report on meniscus repair surgery, indicating a shift in the standard treatment for these injuries. The MINORS score of the studies ranged from 11 to 14 (out of 16 total points), with a mean score of 12.3 and a standard deviation of 1.0.

Patient and Lesion Characteristics

The 9 identified studies evaluate a total of 373 patients (248 males, 125 females) and 390 knees. The reported patient age ranged from 12.2 to 18.7 years, with a mean age of 14.4 years. Of the 390 injured knees, medial meniscal tear was reported in 187 knees and lateral meniscal tear in 193 knees. Combined medial and lateral tears were reported in 10 knees. Discoid menisci were reported in 41 knees. A total of 77 tears were characterized as bucket-handle meniscus tears.

Outcomes

A total of 308 meniscectomies and 64 meniscal repairs were performed. None of the identified articles evaluated

nonoperative treatment of meniscus tears. Follow-up ranged from 1.8 to 30 years (mean, 10.8 years). Different outcome measures were used in the various studies, including the Lysholm score (1 article¹⁹), Tegner score (2 articles^{18,19}), IKDC score (1 article¹⁸), Tapper-Hoover score (3 articles^{1,10,23}), Yocums score (1 article²²), as well as scoring systems developed and described by the authors (2 articles^{24,35}) (Table 1).

The variability of outcome reporting made the pooling of all data for meta-analysis impractical. However, 3 studies evaluating meniscectomy reported Tapper-Hoover scores, demonstrating 54 patients with excellent result, 58 with good, 57 with fair, and 23 with poor results (Table 2).^{1,10,23}

Given the variety of outcomes reported, the following is a brief synopsis of each study. Abdon et al¹ evaluated the long-term effects of single meniscectomy in 89 children at a mean 16.8 years after surgery and found that 52% of patients had excellent or satisfactory results on Tapper-Hoover score. A decrease in knee range of motion was found in 35.9% of patients.¹ There was increased anterior-posterior and rotatory instability after meniscectomy: 45% of patients with grade I instability and 15% with grade II to III.¹ Radiographic changes described as significant joint space narrowing were found in 89% of operated knees, compared with 13% of nonoperated knees.¹

Medlar et al²⁴ followed 26 patients for a mean 8.3 years after undergoing meniscectomy. The authors developed a

Table 2. Summary of outcome measures

Meniscus Repair	Lysholm	Tegner	IKDC	Retear Rate, %
Krych et al ¹⁸		8	89.4	38
Lucas et al ¹⁹	85.4	7.1		26
Combined		7.6		37
Meniscectomy	Excellent	Good	Fair	Poor
Manziona et al ^{22a}	5	3	11	1
Abdon et al ^{1b}	34	14	36	7
Dai et al ^{10b}	5	10	7	16
McNicholas et al ^{23b}	15	34	14	0
Combined Tapper-Hoover ^b	54	58	57	23
Medlar et al ^{24c}	4	7	12	3
Zaman and Leonard ^{35c}		25	11	23
Combined all scales ^c	63	93	91	50

IKDC, International Knee Documentation Committee.

^aYocums scale.

^bTapper-Hoover scale.

^cAuthors' own scale.

comprehensive 50-point grading scale that used patient questionnaires assessing level of activity, return to sport, and symptoms as well as objective measures of range of motion, thigh circumference, knee instability, and radiographic evaluation for osteophytes, flattening of femoral condyles, squaring of tibial margins, and joint space narrowing.²⁴ They found only 42% of patients demonstrated excellent or good results at final follow-up.²⁴

Vahvanen and Aalto³¹ evaluated 42 meniscectomies at a mean 5.6 years after surgery and found 71% of patients reported being asymptomatic with normal knee range of motion, stability, and radiographs at final follow-up. Twenty-nine percent of patients reported intermittent pain with activity, and 10% of patients demonstrated radiographic pathology at final follow-up.³¹

Dai et al¹⁰ followed 24 children for a mean 16.1 years after meniscectomy. Mean patient age at final follow-up was 29.4 years old.¹⁰ Of the 24 patients, 10 reported knee pain (9 with activity, 1 at rest), 2 had effusions, 8 had quadriceps wasting, 1 had knee instability, and 1 had decreased range of motion.¹⁰ A majority (20/23) of patients (87.5%) had more significant signs of degeneration in their operative knee compared with nonoperative (1 patient with bilateral meniscectomies not included in this analysis).¹⁰ Using the Tapper-Hoover score,

39.5% of patients demonstrated excellent or good results: 5 patients with excellent results, 10 with good, 7 with fair, and 16 with poor.¹⁰

Zaman and Leonard³⁵ assessed 49 children (59 knees) at a mean 7.5 years after meniscectomy. Only 27% of patients had normal radiographs at final follow-up,³⁵ and 19% demonstrated signs of early osteoarthritis.³⁵ The authors found that 25 patients (51%) were pain-free with all levels of activity, 11 (22.4%) were symptomatic with vigorous activity, and 23 (46.9%) reported pain with everyday activities.³⁵

Manziona et al²² evaluated 20 children and adolescents with isolated meniscus tears 5.5 years after they underwent meniscectomy and found that 60% had unsatisfactory results. The variables evaluated included pain, swelling or stiffness, return to primary sport, activity level, range of motion, quadriceps atrophy, and ligament instability.²² Sixteen of 20 patients (80%) demonstrated radiographic evidence of early osteoarthritis when preoperative and final follow-up radiographs were compared at approximately 5.5 years after surgery and specifically looking for joint space narrowing, femoral condylar flattening, tibial sclerosis, osteophyte formation, intercondylar spur formation, and patellofemoral narrowing.²²

McNicholas et al²³ performed a prospective longitudinal 30-year follow-up of 95 adolescents who underwent total meniscectomy and found that 74% reported decreased sporting activity at 30 years. They also found the incidence of narrowing of articular cartilage increased from 19% at the 17-year review to 36% at 30 years.²³ This is in comparison with an 11% incidence of joint space narrowing in the nonoperative knee at both time points.²³ One patient in the study required total knee arthroplasty at age 42 years, that is, 27 years after medial meniscectomy.²³ Retear rate was naturally not a reported outcome measure for any patients undergoing meniscectomy.

With a mean follow-up of 45.8 months, 2 studies evaluating meniscal repair demonstrated a mean 37% retear rate.^{18,19} Krych et al¹⁸ reported a mean time to retear of 17 months. A combined average Tegner score of 7.6 was demonstrated by these 2 studies. The clinical success rate of arthroscopic meniscal repair was 80% for simple tears, 68% for displaced bucket-handle tears, and 13% for complex tears. Seventeen menisci (38% overall) failed initial repair at a mean 17 months (range, 3–61 months) postoperatively and underwent repeat arthroscopic surgery (15 partial meniscectomies, 2 re-repair). The mean Tegner and IKDC scores were 8 (range, 5–9) and 89.4 (range, 79–99), respectively, at final follow-up. Risk factors for failure included complex tears and rim width greater than 3 mm.

Lucas et al¹⁹ retrospectively assessed 19 arthroscopic repair procedures performed in adolescents (mean age, 14 years) with documented stable knees having normal menisci prior to injury. The study demonstrated good outcomes in 12 of 17 patients (70%), with significant improvement in the mean Tegner score from 3.9 to 7.1 and mean Lysholm score from 55.9 to 85.4 between pre- and postoperative assessments at a mean follow-up of 22 months.¹⁹

DISCUSSION

The results of the meta-analysis demonstrate a significant shift in the management of isolated adolescent meniscus tears, with the current treatment being arthroscopic repair. Seven of the articles were instrumental in documenting the deleterious long-term effects of meniscectomy as the treatment choice for this population. Prior to the work done by these authors, it was theorized that meniscectomy in the adolescent population would be followed by regeneration of a fibrocartilaginous meniscus and that long-term morbidity would be minimal.¹¹ Collectively, these studies demonstrated unsatisfactory outcomes in terms of pain, stiffness, and range of motion, as well as a significantly increased rate of osteoarthritis.^{1,10,22–24,31,35}

This review of the literature found only 2 studies evaluating the postoperative outcomes of meniscus repair in adolescent patients. These 2 studies claim promising and good results at a mean follow-up of 45.8 months.^{18,19}

Given that most of our current principles of meniscus repair come from the adult literature, improved understanding of how adult and pediatric meniscus tears differ is needed. Francavilla et al¹³ sought to characterize how meniscus injuries in children

differ from adults and pointed out that by the age of 10 years, the structure and physiology of the meniscus is similar to that of the adult patient. The meniscus in young children is composed mostly of fibroblasts and is highly cellular.^{9,13} Over time, these fibroblasts lay down collagen, and by the age of 10 years, the menisci are composed mostly of circumferentially arranged collagen fibers, making them susceptible to injuries similar to those seen in the adult population.^{9,13} The vascularity of the menisci also changes over time, with the medial and lateral geniculate arteries vascularizing the menisci throughout their substance at birth.^{5,9,13} The vascularity of the menisci decreases centrally and reaches the adult pattern by 10 years of age.^{5,9,13} The peripheral 10% to 30%, or “red zone,” of the meniscus remains vascular while the inner 70% to 90%, or “white zone,” is considered avascular.^{5,13} Understanding the vascular anatomy is important in determining when and how to operatively intervene on a meniscal injury. Bloome et al⁸ describe a case report of meniscus repair in two 4-year-old patients, indicating the possibility of successful repair even in very young age groups. Currently, it is understood that young age is beneficial in healing meniscal tears, which is likely secondary to improved vascularity and tissue quality compared with the older population; however, it is not completely understood which pediatric or adolescent meniscal tears require repair versus debridement.

Given that the adolescent meniscus is similar in its structure and anatomical properties to that of the adult patient by age 10 years,¹³ one could argue that it is possible to make some inferences regarding the treatment of adolescent meniscus tears from what we have learned in the adult literature. It is reasonable to assume that the best candidate for surgical repair is a meniscus tear that is vertical and peripheral, in the red-red vascularized region in both adolescent patients and adults. Given the poor long-term results after childhood meniscectomy,^{1,10,22–24,31,35} attempt at repair should be the standard for all amenable meniscus tears in adolescent patients. Francavilla et al¹³ demonstrated that the vascular anatomy is that of an adult by age 10 years; however, there are other possible explanations as to why younger patients may have more robust healing potential, for instance, they may have higher levels of resident stem cells or a more advantageous inflammatory response.

The adult literature on the treatment of isolated meniscus tears shows that outcomes are overall good.^{6,12,26} In a recent systematic review of sport-related outcomes of adult isolated meniscus repairs, Eberbach et al¹² demonstrated that the mean preoperative Tegner score improved from 3.5 ± 0.3 to 6.2 ± 0.8 postoperatively, and the pooled retear rate was 21%.¹² The 2 studies from the adolescent literature found a combined postoperative mean Tegner score of 7.6 and a combined retear rate of 37%.^{18,19} Return to sports at the preinjury level was achieved in 89% of adult patients. Interestingly, the failure rate in the adult study was lower in professional athletes compared with mixed-level athletes (9% vs 22%), indicating that perhaps prior conditioning and/or postoperative protocols may influence

retear rates. Overall, the adult literature may serve as a surrogate in steering treatment algorithms for the adolescent population while waiting for studies to accrue more patient-specific information.

Limitations

There are limitations inherent to this meta-analysis, as it is subject to the cumulative weaknesses of the included studies. This review includes predominantly retrospective studies, none of which are comparative. Unfortunately, there is no sufficient body of evidence in the literature involving prospective studies and randomized controlled trials. These retrospective studies were included to amass sufficient data for comparison. Another limitation of this study is the significant amount of heterogeneity that exists in the included studies with regard to the type of meniscal repair performed. The indications for surgical intervention as well as the type of meniscal repair performed varied between studies. Finally, a significant limitation of this study is the inability to pool much of the aggregate data given the use of different outcome reporting methods by the included studies.

CONCLUSION

A shift in the management of isolated adolescent meniscus tears is reflected in the literature, with the current gold standard being operative repair as opposed to meniscectomy. This shift in treatment is largely secondary to the findings of increased osteoarthritis after meniscectomy reflected in the long-term follow-up studies.

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