

Meniscus Tear Patterns in Relation to Skeletal Immaturity

Children Versus Adolescents

Alvin Shieh,^{*} MS, Tracey Bastrom,[†] MA, Joanna Roocroft,[†] MA,
Eric W. Edmonds,^{*†} MD, and Andrew T. Pennock,^{*†‡} MD

Investigation performed at Rady Children's Hospital and Health Center, San Diego, California

Background: Meniscus tear patterns in the pediatric population have not been well described.

Purpose: To delineate the pattern of meniscus tears and the likelihood of repair at the time of surgery in both children and adolescents.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A retrospective review was performed on all patients between the ages of 10 and 19 years who underwent arthroscopic surgery for a meniscus injury at a single institution. Patients with open growth plates were classified as children, while those with closed growth plates were classified as adolescents. Demographic data were documented, including age, sex, body mass index (BMI), mechanism of injury, and time from injury to surgery. Operative reports and intraoperative photographs were used to assess the tear pattern (type, location, zone) as well as all concomitant procedures and injuries. Tears were classified as discoid, vertical, bucket-handle, radial, oblique, horizontal, fray, root detachment, or complex.

Results: Of the 293 patients reviewed, 197 (67%) had lateral meniscus tears, 65 (22%) had medial meniscus tears, and 31 (11%) had tears to both menisci. The cohort was separated into 119 (41%) children (mean age, 13.5 years) and 174 (59%) adolescents (mean age, 16.4 years). Children were more likely to have discoid meniscus tears, lower BMI, and meniscus injuries not associated with ligamentous injuries ($P < .05$). The rate of associated ligament injuries in children was 28% compared with 51% in adolescents. Overall, the most frequent tear pattern was complex (28%), followed by vertical (16%), discoid (14%), bucket-handle (14%), radial (10%), horizontal (8%), oblique (5%), fray (3%), and root detachment (2%). Complex tears were associated with boys (32% vs 20% in girls; $P < .03$) and greater mean BMI (27.4 vs 25.1 kg/m² in those with noncomplex tears; $P < .002$), even when taking sex into account. Surgical repair was performed in 47% of all cases (56% in those treated within 3 months of injury vs 42% in those treated after 6 months; $P < .03$), and there was no difference in the repair rate between the two age groups (49% in children vs 46% in adolescents; $P > .05$).

Conclusion: Adolescents and children sustain more complex meniscus injuries that are often less repairable than previously reported in the literature. Factors that are associated with greater tear complexity include male sex and obesity. Our findings also suggest that the earlier treatment of meniscus tears may increase the likelihood of repair in younger patients.

Keywords: knee; meniscus; meniscus tear; pediatric sports medicine; children; adolescents; repair

With the rise of youth participation in athletics, an increasing number of meniscus tears have been seen in the pediatric and adolescent age groups.^{5,28,32} An estimated 80% to 90% of meniscus injuries are associated with athletic

activity and are often seen in conjunction with other acute injuries such as anterior cruciate ligament (ACL) tears, chondral injuries, and tibial fractures.^{1,32}

The menisci are C-shaped fibrocartilaginous structures that are critical to shock absorption, load sharing, reduction of contact stresses, and stability within the knee joint.^{12,16,21,23,29} The importance of the menisci is apparent in complete or partial meniscectomies, where early osteoarthritic and degenerative changes are often seen.^{11,30,33} Anatomically, the meniscus is fully vascularized at birth, but the area of vascularity recedes toward the periphery with age, such that by the age of 10 years, only the peripheral 10% to 30% of the meniscus is vascularized, as is seen in the adult meniscus.^{19,20} The higher vascularity both in the young meniscus and in the periphery of the adult

[‡]Address correspondence to Andrew T. Pennock, MD, Rady Children's Hospital and Health Center, 3030 Children's Way, Suite 410, San Diego, CA 92123 (e-mail: apennock@rchsd.org).

^{*}University of California, San Diego, La Jolla, California.

[†]Rady Children's Hospital and Health Center, San Diego, California.

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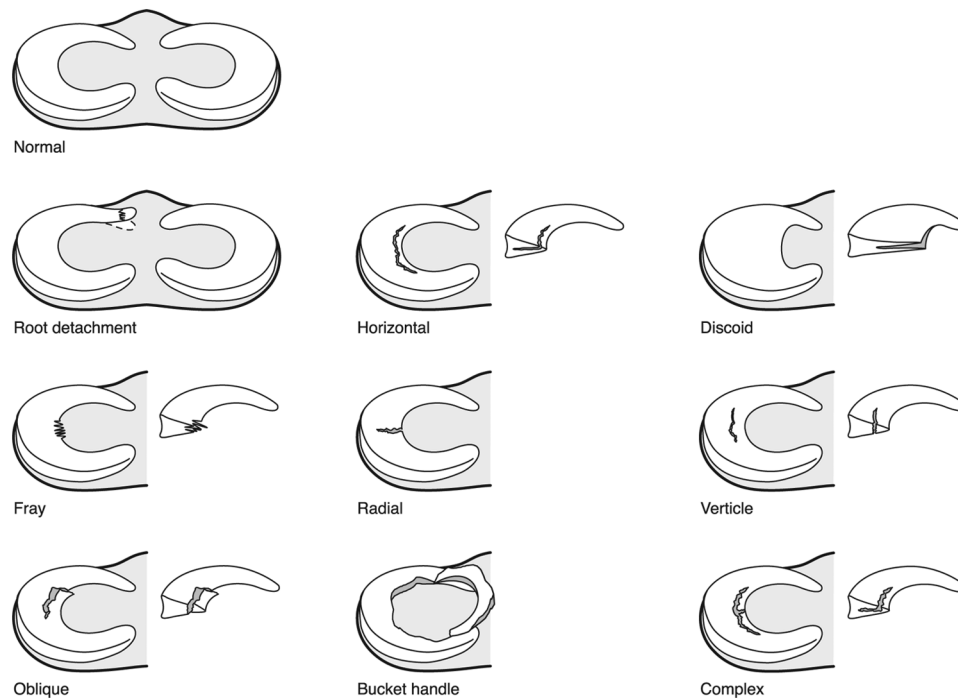


Figure 1. Meniscus tear classification.

meniscus has been shown to provide better healing outcomes to surgical repair.^{3,17}

Tear patterns may be classified according to their orientation relative to the plane of the meniscus and the direction of the collagen fibers.^{24,31} All tears occur in 1 of 2 ways: horizontal or vertical. Horizontal tears represent axial plane tears parallel to the articular joint surface. Vertical tears can occur in a longitudinal, transverse, or mixed fashion and as such are further divided into the following subcategories: longitudinal, radial, and oblique. Longer and complete tears are often displaceable and are commonly referred to as “bucket-handle” tears because of their resemblance in shape and ability to flip into the notch. Tears with multiple components are referred to as complex.

The surgical approach to meniscus tears is typically determined by the type of the tear in conjunction with the tear location, patient age, and chronicity of the tear. Longitudinal, vertical, and bucket-handle tears are often able to be repaired surgically with various suturing techniques, while radial, oblique, horizontal, and complex tears do not respond as well to surgical repair.⁶ Meniscus tear patterns have been well characterized in the adult population, but extensive studies have not been performed on the pediatric and adolescent populations. Previous studies have found that young patients typically present with longitudinal, vertical (50%-90%), and bucket-handle meniscus tears to the medial meniscus.^{2,13,15,19} However, differences in meniscus tears that occur in children who are skeletally immature and tears that occur in adolescent patients who are skeletally mature have not been previously elucidated. The purpose of this study was to describe meniscus tear patterns and to assess the incidence of repair during surgery in these 2 youthful groups.

MATERIALS AND METHODS

After institutional review board approval, a retrospective chart review of all pediatric and adolescent patients between the ages of 10 and 19 years who underwent arthroscopic knee surgery for a meniscus injury at our institution between October 2008 and July 2012 was performed. After imposing the exclusion criterion of a previous meniscus procedure, the patients were classified as a child or adolescent based on skeletal maturity as determined by radiographs and magnetic resonance imaging (MRI) scans taken when they first presented to the clinic. Those with open growth plates were classified as children, while those with closed growth plates were classified as adolescents. Demographic data were documented, including sex, age, and body mass index (BMI) at the time of surgery and duration from injury to surgery. Operative reports and intraoperative photographs were used to assess the tear pattern and location as well as all concomitant procedures and injuries. Tear patterns were classified into the following categories: discoid, vertical, bucket-handle, radial, oblique (parrot beak), horizontal, fray, root detachment, or complex (Figure 1). Patients who were treated within 3 months of injury were considered to have an acute injury, while those treated after 6 months were considered to have a chronic injury. To more accurately differentiate acute and chronic tears, those treated between 3 to 6 months from the injury were not included in either chronicity group because injury dates were often estimated by patients or family members. Ninety-three patients fell into this sub-acute group. Tears with no evidence of peripheral instability upon probing, that measured less than 1 cm, and/or that

TABLE 1
Patient Data^a

	Children		Adolescents		Total
No. of patients	119 (41)		174 (59)		293 (100)
Meniscus tears	126 (39)		198 (61)		324 (100)
Patients with associated ligament injury	33 (28)		89 (51)		122 (42)
Discoid tears	32 (25)		14 (7)		46 (14)
Complex tears	31 (25)		60 (30)		91 (28)
Meniscus repair rate	59 (49)		89 (46)		148 (47)

	Children		Adolescents		Total
	Boys	Girls	Boys	Girls	
Complex tears	27 (32)	4 (10)	40 (33)	20 (27)	91 (28)
Meniscus repair rate	41 (51)	18 (45)	49 (41)	40 (56)	148 (47)

	Children		Adolescents		Total
	Acute	Chronic	Acute	Chronic	
Complex tears	14 (29)	10 (21)	22 (29)	21 (36)	67 (29)
Meniscus repair rate	25 (53)	21 (46)	43 (58)	21 (37)	110 (49)

^aValues are expressed as n (%).

were incomplete were considered stable and were excluded from repair rate calculations. Analysis of variance (ANOVA) and χ^2 tests were performed with significance set at $P < .05$.

RESULTS

A total of 293 patients (186 boys and 107 girls) were included in the study: 153 had surgery on their left knee, while 140 had surgery on their right knee (52% vs 48%, respectively; $P < .45$). There were 197 patients (67%) with lesions of the lateral meniscus, 65 (22%) with lesions of the medial meniscus, and 31 (11%) with lesions of both menisci, giving a total of 324 torn menisci (Table 1).

Based on physal status (open vs closed), 119 (41%) were defined as children with open growth plates, while 174 (59%) were defined as adolescents with closed growth plates. Children had a lower mean age (13.5 vs 16.4 years, respectively; $P < .001$) and mean BMI (23.0 vs 27.5 kg/m², respectively; $P < .01$) than adolescents. Discoid tears accounted for 25% of all tears in children but only 7% of tears in adolescents ($P < .0001$). A concomitant ligament injury was observed in 51% of adolescents compared with 28% of children ($P < .0001$). The ACL was involved in 96% of all ligamentous injuries. One patient had an associated tibial spine fracture. There were no significant differences in meniscus tear complexity, location, zone, or surgeon-determined ability to repair the tear between the 2 groups.

However, when assessing the associated injuries within the children and adolescent groups, a few differences were identified. Among children, complex tears were associated with boys (32% vs 10% in girls; $P < .01$). Among the adolescent population, decreased repair rates were associated with boys (41% vs 56% in girls; $P < .04$) and chronic tears (37% vs 58% in acute; $P < .03$).

TABLE 2
Meniscus Tear Types in Children and Adolescents^a

Tear Type	Children	Adolescents	Total
Complex	31 (25)	60 (30)	91 (28)
Vertical	16 (13)	37 (19)	53 (16)
Discoid	32 (25)	14 (7)	46 (14)
Bucket-handle	13 (10)	32 (16)	45 (14)
Radial	9 (7)	22 (11)	31 (10)
Horizontal	13 (10)	13 (6)	26 (8)
Oblique	4 (3)	14 (7)	18 (5)
Fray	6 (5)	3 (2)	9 (3)
Root detachment	2 (2)	3 (2)	5 (2)
Total	126 (100)	198 (100)	324 (100)

^aValues are expressed as n (%).

There were 46 discoid tears, representing 14% of the cohort, and all of these involved the lateral meniscus. One of these patients also had a vertical tear to the medial meniscus. Children accounted for 70% of all discoid tears, and 41% required repair along the periphery after saucerization. Patients with discoid tears had a lower mean age (12.7 years) than those with nondiscoid tears (15.7 years) ($P < .0001$), with a lower mean BMI (22.1 vs 26.5 kg/m², respectively; $P < .0001$) and a female preponderance (56% vs 44%, respectively; $P < .23$).

The most frequent tear pattern was complex (28%), followed by vertical (16%), discoid (14%), bucket-handle (14%), radial (10%), horizontal (8%), oblique (5%), fray (3%), and root detachment (2%) (Table 2). Complex tears were associated with boys (32% vs 20% in girls; $P < .03$) and greater mean BMI (27.4 vs 25.1 kg/m² in those with noncomplex tears; $P < .002$), even when taking sex into account.

TABLE 3
Meniscus Repair Rates^a

Type ^b	Children			Adolescents			Total
	Not Repaired	Stable	Repaired (% of Tear Type)	Not Repaired	Stable	Repaired (% of Tear Type)	Repaired (% of Tear Type)
Complex	18	—	13 (42)	37	—	23 (38)	36 (40)
Vertical	1	4	11 (92)	6	6	25 (81)	36 (84)
Discoid	18	—	14 (44)	9	—	5 (36)	19 (41)
Bucket-handle	3	—	10 (77)	11	—	21 (66)	31 (69)
Radial	9	—	—	22	—	—	0 (0)
Horizontal	3	1	9 (75)	1	—	12 (92)	21 (84)
Oblique	4	—	—	14	—	—	0 (0)
Fray	6	—	—	3	—	—	0 (0)
Root detachment	—	—	2 (100)	—	—	3 (100)	5 (100)
Total	62	5	59 (49)	103	6	89 (46)	148 (47)

^aValues are expressed as n or n (%).

^bRepair percentages excluded stable tears.

The posterior horn was involved in 71% of the tears, the body in 50%, and the anterior horn in 23%. A ligamentous injury primarily involving the ACL was visualized arthroscopically in 45% of all patients, and of these, 54% had an injury to the lateral meniscus, 25% to the medial, and 21% to both. In comparison, in patients without a ligamentous injury, 77% had an injury to the lateral meniscus, 20% to the medial, and 3% to both. Surgical repair was performed in 47% of cases, partial meniscectomy was performed in 51%, and 4% were stable tears that the surgeon believed did not require intervention. All but 1 of the 11 stable tears were vertical. A majority of root detachment, vertical, bucket-handle, and horizontal tears were repairable, while a minority of complex tears were repaired. None of the radial, oblique, or fray tear patterns were repaired. Repair rates dropped from 56% in patients treated within 3 months to 42% in patients treated after 6 months ($P < .03$) (Table 3).

DISCUSSION

The purpose of this study was to describe meniscus tear patterns in the pediatric and adolescent populations. Previous studies in this population have shown that peripheral longitudinal and bucket-handle tears were most frequent, along with a predominance of medial meniscus tears.^{13,18,32} In contrast, our results suggest that meniscus tears more often affect the lateral meniscus than the medial and are also more likely to be complex in the age groups that we studied. Furthermore, complex tears were more likely to occur in boys and those with higher BMI.

As expected, discoid meniscus tears are predominantly seen in the lateral meniscus and primarily affect skeletally immature children. Adolescents were more likely to have concurrent ligamentous injuries, which might be explained in part by the increased participation in competitive sports of that age group or potential anatomic, biomechanical, and hormonal factors.^{9,10,25} There were no significant

differences in meniscus tear type, location, or zone between the 2 groups, and more importantly, the repair rate was similar in the 2 groups. Therefore, clinicians should expect to find more discoid meniscus tears in children and ligament injuries in adolescents but similar tear patterns and repair rates in both.

Breaking down the 2 age groups further, it appears that adolescent boys and those treated after 6 months from injury had lower rates of repair. Among children, boys were more likely to have complex meniscus tears, which inherently have lower repair rates. However, because children also present with more discoid and repairable tears, repair rates were not significantly lower in this group.

Lawrence et al²² recently reported that skeletally immature patients with ACL tears who underwent surgical reconstruction more than 12 weeks after injury had significantly more irreparable meniscus injuries. Similarly, our study showed a significant association between irreparable meniscus tears and longer time from injury to surgery. Patients treated within 3 months after injury had a 56% rate of repair compared with 42% in the group treated more than 6 months from injury. In adolescents, the repair rate dropped from 58% to 37%, indicating that an earlier surgical intervention may increase the likelihood of repair in younger patients, especially in adolescent boys.

In the adult population, meniscus tears are associated with acute ACL injuries, but to varying degrees. Studies have shown that meniscus tears may occur in 33% to 65% of patients with acute ACL injuries.^{8,14,27,34} There is also little agreement on the frequency of tears to the lateral versus medial meniscus, ranging from 56% in the medial^{7,14} to 65% in the lateral.²⁶ In acute ACL tears, lateral meniscus tears occur about 56% of the time.⁴ Our study instead focused on all patients who were found to have meniscus tears, with the data showing that over 42% of all patients with meniscus tears also had a ligament injury. Most of the patients with a ligament injury were adolescents, and the lateral meniscus was more frequently

involved, although this number was decreased in the group without a ligament injury.

There were a few limitations to this study. The intra-operative assessment of tear types, as well as the determination of ability to repair the tear, was subject to examination by the operating surgeon. Patient BMI was based on height and weight on the date of surgery rather than the date of injury. Injury history, including the mechanism of injury and time to surgery, for each patient was based on estimates provided by the patients and their families, as recorded at the initial visit. However, most of these limitations are basic flaws to a retrospective study design, and only a prospective study could have potentially generated more accurate and complete information.

As acute knee injuries become more frequent with increased participation in recreational and competitive youth sports, the ability to repair such injuries becomes even more important for long-term joint health. This study has provided meniscus tear data on a large sample size that we believe reflects current knee injury trends in youth sports. Meniscus tears in adolescent and pediatric patients are more complex, preferentially affect the lateral meniscus, and are often less repairable than previously reported in the literature. Factors associated with greater tear complexity include male sex and obesity. Skeletally mature adolescents are more likely to present with concomitant ligament tears, while skeletally immature children more often present with a discoid meniscus tear, but both groups are affected by the same meniscus tear patterns. The ability to repair meniscus tears was significantly lower in patients treated after 6 months from injury, especially in male adolescents. The data suggest that earlier surgical interventions in pediatric and adolescent patients may result in greater repair rates of meniscus tears.

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