207 Meniscal Injuries and Discoid Lateral Meniscus in Adolescent Athletes

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Abstract

This chapter provides an overview of the anatomy and development of the meniscus and addresses the epidemiology, etiology, clinical presentation, diagnostic imaging modalities, and treatment for meniscal tears and discoid lateral menisci. Arthroscopic meniscal salvage is emphasized when surgically addressing meniscal tears and discoid menisci in children and adolescents due to the poor outcomes following total meniscectomy and the increased vascularity of the developing meniscus lending to an enhanced healing capacity.

Introduction

Meniscal formation occurs by 8 weeks of embryological development, and by the 14th intrauterine week, the normal anatomic appearance is evident. Contrary to early belief, the normal meniscus does not arise from a discoid precursor. Blood supply arises peripherally from a perimeniscal capillary plexus in the synovium. At birth, the meniscus is completely vascular. During postnatal development, the blood supply recedes, and by 9 months of age, the central third of the meniscus is avascular. At age 10, the meniscus assumes the vascular pattern of an adult, where only the peripheral 10–30 % of the medial and 10–25 % of the lateral meniscus, the red-red zone, receive direct vascular nourishment. Synovial diffusion delivers nutrition to the central two-thirds, the red-white and white-white zones, of the meniscus. Theoretically, the greater blood supply of the developing meniscus provides increased reparative potential compared to the diminished vasculature of the adult meniscus.

The medial meniscus is C shaped and firmly attached to the tibia via coronary ligaments and to the joint capsule at the midbody via the deep medial collateral ligament. During knee flexion, as the femoral condyle rolls backward, the medial meniscus translates 2.5 mm posteriorly. The lateral meniscus is more circular and covers a larger portion of the tibial plateau than the medial meniscus. Loose peripheral attachments to the joint capsule with no attachments at the popliteal hiatus result in increased mobility of the lateral meniscus, allowing 9–11 mm of translation with knee flexion. Accessory meniscofemoral ligaments (ligaments of Humphrey and Wrisberg) are also frequently present arising from the posterior horn of the lateral meniscus. Both menisci are joined anteriorly by the anterior transverse intermeniscal ligament. Functions of the menisci are load transmission and shock absorption, joint congruity and stability, joint lubrication, joint nutrition, and proprioception.

Histologically, the meniscus consists predominantly of type 1 collagen along with other collagen types, water, proteoglycans, glycoproteins, and elastin. The circumferential oriented collagen fibers, parallel to the long axis of the meniscus, dissipate hoop stresses. Mechanical failure of an abnormal collagen fiber network in the midsubstance of a discoid meniscus may contribute to the pathogenesis of horizontal cleavage tears.

Meniscal Tears

Epidemiology

An increase in athletic participation and a heightened suspicion by physicians are believed to have contributed to the recent increase in the incidence of meniscal injuries in children and adolescents. Isolated, nondiscoid meniscal tears are uncommon in patients under 18 years of age, but increasing patient age and athletic demands result in a higher occurrence of meniscal injury. A high association between meniscal and concomitant ACL (anterior cruciate ligament) tears also exists. In a series of 124 skeletally immature patients with a mean age of 14 undergoing arthroscopic ACL reconstruction, 69.3 % had a meniscal tear (Samora et al. 2011). In the acute setting of an ACL reconstruction (within 3 months from injury), the lateral meniscus appears more likely to be injured although often in a repairable configuration (Samora et al. 2011). In contrast, delaying surgical treatment of ACL tears leads to a significant increase in irreparable medial meniscal tears (Lawrence et al. 2011).

Clinical Presentation

A history of trauma is extremely common in nondiscoid meniscal injuries in children and adolescents. About 80–90 % of these occur during sporting activities. A twisting injury to the involved knee is typical, particularly in sports requiring high-energy changes in direction, such as football, basketball, tennis, and soccer. Pain is the primary complaint, and other commonly associated symptoms are swelling, snapping, instability, and catching or locking.

On physical examination, joint line tenderness and effusion are common findings. Joint line tenderness is particularly sensitive for a meniscal tear, whereas an effusion is a strong indicator of intra-articular injury. Reproducible pain along the joint line during provocative knee flexion to 30–40° with rotational stress (modified McMurray test) may indicate meniscal pathology. Completing a proper exam can at times be challenging in children, especially due to apprehension or lack of cooperation, resulting in diminished diagnostic accuracy (Kocher et al. 2001). When performed by an examiner with significant pediatric sports medicine experience, physical examination can more reliably diagnose medial meniscal tears (62.1 % sensitivity, 80.7 % specificity) and lateral meniscal tears (50.0 % sensitivity, 89.2 % specificity) (Kocher et al. 2001).

Fig. 1 Sagittal view of MRI T1 image reveals a grade 3 tear (*arrow*) of the posterior horn of the medial meniscus

Imaging

Routine anteroposterior, lateral, tunnel, and sunrise radiographs of the knee should be obtained in suspected cases of meniscal tears in children and adolescents to rule out other intra-articular pathologies. Anteromedial or anterolateral joint line pain produced by a meniscal tear can be mimicked by osteochondritis dissecans (OCD), patellofemoral instability, and osteochondral fractures. A tunnel view is particularly important for detecting OCD, since most lesions are located toward the posterior aspect of the femoral condyle.

Magnetic resonance imaging (MRI) still remains a valuable adjunct in the diagnosis of intra-articular knee disorders in pediatric patients. However, the sensitivity and specificity of MRI in diagnosing meniscal tears in young children (less than 12 years of age) is lower than in adolescents and adults (Kocher et al. 2001). The increased vascularity of the child meniscus produces intrameniscal signal enhancement, which mimics a meniscal tear. A series of 108 asymptomatic pediatric knees identified 66 % with intrameniscal high signal intensity (Takeda et al. 1998). Grade 1 and grade 2 signal changes, reflecting uniformly low signal intensities or signal changes that do not contact the articular surface, respectively, are normal in pediatric patients. Only grade 3 signal changes, where the intrameniscal signal intensity extends to the articular surface or a morphologic abnormality of the meniscus is present, are considered tears (Fig. 1). One study determined the sensitivity and specificity of MRI diagnosing medial meniscal tears to be 79 % and 92 %, respectively (Kocher et al. 2001). The corresponding sensitivity and specificity for lateral meniscal tears were 66 % and 83 %, respectively (Kocher et al. 2001). Another study has reported similar numbers for the preoperative MRI diagnosis of meniscal tears (sensitivity 59 %, specificity 91 %) (Samora et al. 2011). Newer and more powerful 3-tesla MRI scans with shorter acquisition times and potentially diminished need for patient sedation have comparable accuracy in diagnosing meniscal pathology and other intra-articular knee pathologies in children and adolescents (Schub et al. 2012). In general, however, MRI should be used judiciously, not as a routine screening test, and diagnosis of meniscal tears before knee arthroscopy in pediatric patients must be interpreted with caution (Kocher et al. 2001; Bouju et al. 2011; Samora et al. 2011; Hagino et al. 2013). Interpretation of MRI by the orthopedic surgeon, who has the ability to correlate the advanced imaging results with clinical findings, improves presurgical diagnostic accuracy (Luhmann et al. 2005).

Treatment

The increased healing potential of pediatric nondiscoid meniscal tears compared to adult meniscal tears prompts a greater tendency toward surgical repair. The poor outcomes of total and subtotal meniscectomy in children and adolescents (Manzione et al. 1983; Wroble et al. 1992) paired with the lack of long-term results of partial meniscectomy have also encouraged meniscal salvage when possible. Additionally, contact stresses following a partial and total meniscectomy can increase up to 65 % and 235 %, respectively, whereas meniscal repair can restore normal stress loads (Baratz et al. 1986). Meniscal tears most amenable to repair are longitudinal and vertical in morphology and within the red-red or red-white vascular zones. Even tears extending into the white-white zone, such as horizontal

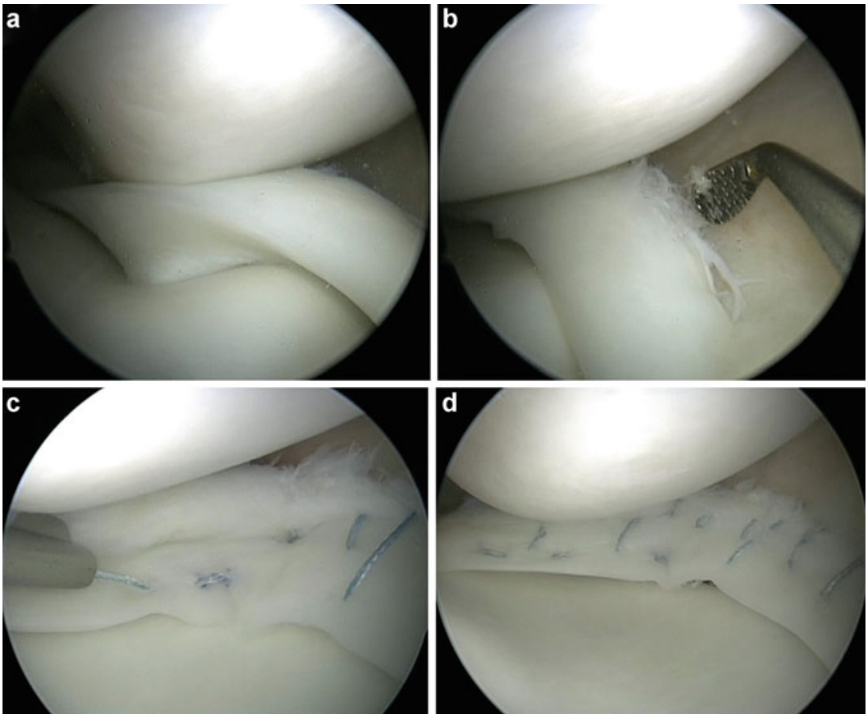

Fig. 2 Repair of a bucket-handle tear of the medial meniscus in a 12-year-old female athlete. (**a**) Arthroscopic image shows the displaced bucket-handle tear. (**b**) Initially, abrasion of the perimeniscal synovium is conducted. (**c**) After appropriate reduction of the meniscus, an inside-out repair with zone-specific cannulas is performed to place horizontal, vertical, and oblique sutures in mattress fashion. (**d**) Final appearance of the meniscus after the repair is demonstrated

cleavage tears, may be partially debrided back to the red-white zone and the remaining tear or cleavage component repaired. Nonoperative management of stable vertical longitudinal tears, especially in the peripheral vascular zone of the meniscus, can result in healing (Weiss et al. 1989). A 4–6-week period of immobilization is warranted in these cases and can be discontinued as long as the patient remains asymptomatic.

The majority of meniscal tears in children and adolescents are large and require surgical intervention. Arthroscopic-assisted management is standard with meniscal repair or partial meniscectomy using inside-out, outside-in, or all-inside techniques. Inside-out techniques are useful for tears of the medial or lateral anterior horn, midbody, and posterior horn. The technique accommodates various meniscal tear patterns and allows for anatomic reduction of the tear while providing a strong and customized construct regardless of the size of the knee or meniscus involved. Double-armed absorbable or nonabsorbable repair sutures with zone-specific cannulas allow precise direction of flexible suture needles to avoid intra-articular neurovascular structures. Outside-in suture techniques are often helpful for isolated anterior horn tears or the most anterior portion of bucket-handle configurations. Newer-generation all-inside suture devices have facilitated meniscal repair in adults and are more commonly being selectively employed in children and adolescents. Considerable concern still exists over employing adult-sized implants in the pediatric knee given the proximity and potential risk of injury to neurovascular structures. All-inside repair techniques may be used for isolated, vertical, and peripheral posterior horn tears. More commonly, they are used in a hybrid manner with the inside-out technique for repair of larger tears with displacement, specifically bucket-handle tears (Fig. 2). Important adjuncts to any repair technique to maximize meniscal healing are preparation of the repair site using abrasion or trephination, anatomic reduction of the meniscal tear, adequate strength and durability of repair devices, and protected postoperative knee mobilization.

Postoperative Care

Postoperative rehabilitation regimes are highly variable and most commonly are associated with an ACL reconstruction. For isolated meniscal repairs, weight-bearing and knee range of motion are typically restricted for the initial 4–6 weeks postoperatively to decrease compressive and shear forces that may disrupt the meniscal repair. Progressive mobilization, range of motion, strengthening, and sport-specific rehabilitation follow. Return to sports is generally allowed at 4–6 months postoperatively if the patient has full range of motion, adequate strength, no symptoms, and no pain on provocative maneuvers. Meniscal repair with concomitant ACL reconstruction usually permits a return to sports at 6–9 months postoperatively.

Clinical Outcomes

Few studies have specifically examined the long-term effects of meniscal preservation through repair in young, athletic patients. Although the data are encouraging, it remains unknown whether meniscal repair over partial meniscectomy results in lower rates of osteoarthritis in the future in this patient population. In the first report on meniscal repair specific to athletic adolescents, 29 posterior horn meniscal repairs were performed in 26 patients (Mintzer et al. 1998). No meniscal symptoms were present at an average 5-year follow-up in any of the patients, and all but two returned to their previous level of sports activity. Krych et al. identified a clinical success rate for isolated arthroscopic repair of 80 % for simple tears, 68 % for displaced bucket-handle tears, and 13 % for complex tears (Krych et al. 2008). Risk factors for failure included complex tears and meniscal tears located more than 3 mm away from the meniscosynovial junction. Meniscal repair performed with concomitant ACL reconstruction, however, improved successful outcomes to 57 % (Krych et al. 2008, 2010). In another series, 71 meniscal repairs of single or complex tears extending into the central avascular zone in 58 patients under 20 years of age were performed (Noyes and Barber-Westin 2002). At a mean follow-up of 51 months, 53 of 71 repairs (75 %) were asymptomatic. Particularly in young athletes where removal of complex tears would result in major loss of meniscal function and risk for future joint arthrosis, obtaining a stable repair of complex tears extending into the avascular region is possible (Noyes and Barber-Westin 2002). Additionally, an 87 % success rate of repair with concomitant ACL reconstruction was reported (39 of 45 patients) (Noyes and Barber-Westin 2002). Superior outcomes of meniscal repair in children and adolescents with simultaneous ACL reconstruction after an average follow-up period of 2.3 years have also been documented elsewhere (Kraus et al. 2012). Factors that correlate with enhanced healing of meniscal repairs include younger patient age, peripheral tears (within 3 mm of meniscosynovial junction), repairs of the lateral meniscus, concomitant ACL reconstruction, time from injury to surgery of less than 8 weeks, and tear length of less than 2.5 cm.

Discoid Lateral Meniscus

Epidemiology

First described in 1889, the discoid lateral meniscus is the most common abnormal meniscal variant in children, classically associated with the "snapping knee syndrome." However, due to a high number of asymptomatic cases, its true prevalence is unclear. In the United States, discoid lateral menisci are thought to occur in 3–5 % of the population, while a higher prevalence has been noted in Asian countries (Jordan 1996). Up to 25 % of cases may be bilateral, although the rate may be even higher in symptomatic patients (Patel et al. 2012). Discoid variants almost exclusively affect the lateral meniscus; however, medial discoid menisci have also been reported (Jordan 1996).

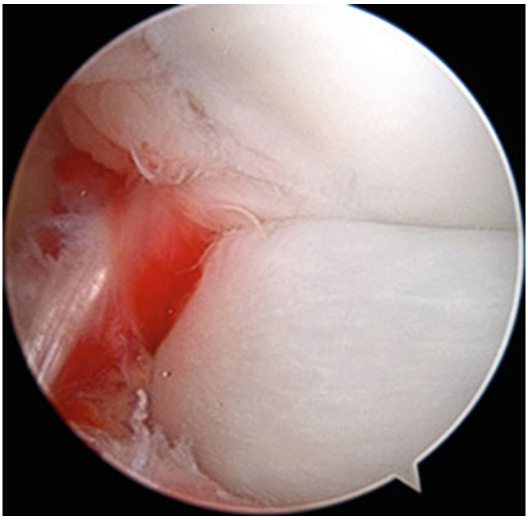

Fig. 3 Arthroscopic view reveals a complete discoid lateral meniscus in a 6-year-old child

Etiology

Initially, the discoid meniscus was thought to result from a failure of an embryonic sequence of degeneration at the center of the meniscus. Subsequent embryologic studies, however, demonstrated that the normal meniscus is not formed from a discoid precursor (Kaplan 1957). The abnormal shape of a discoid meniscus represents a congenital anomaly or malformation. An accompanying propensity for tearing may be due to an irregular collagen fiber network and increased abnormal intra-articular shearing forces (Papadopoulos et al. 2009). Familial inheritance may also play a role in the development of discoid menisci, as several reports on familial transmission and occurrence among monozygotic twins exist (Jordan 1996).

Classification

The discoid lateral meniscus represents a spectrum of morphological and stable variants. The Watanabe classification system, the most widely used, describes three types of discoid menisci based on the arthroscopic shape and the presence or absence of normal posterior capsular attachments (Watanabe et al. 1969). Type I, or complete, is the most common variant, characterized by a thickened lateral meniscus with complete coverage of the tibial surface (Fig. 3). Meniscus tissue is always between the joint surfaces. Type II, or incomplete, is of variable size and covers a lower percentage of the tibial surface compared to the complete type. Although they can become stretched or torn over time, both the complete and the incomplete types are thought to develop with normal peripheral attachments. Type III, or the Wrisberg ligament type, is the least common and describes a lateral meniscus with no peripheral attachments posteriorly. Instead it is stabilized posteriorly by a prominent posterior meniscofemoral ligament of Wrisberg that secures the posterior horn of the lateral meniscus to the lateral surface of the medial femoral condyle.

Other, more recent, classification systems have been proposed based on criteria in addition to meniscal morphology, including peripheral rim stability, the presence of associated tear, and the presence of clinical symptoms (Jordan 1996; Klingele et al. 2004). These classification systems provide a more complete description of the lateral meniscal types and aim to direct treatment strategy. They emphasize the practical considerations that symptomatic menisci should be treated similarly, regardless of meniscal morphology and the presence or absence of posterior capsular attachments.

Clinical Presentation

The clinical presentation of discoid lateral meniscus is highly variable. The complete and incomplete types may be asymptomatic, especially if they have stable peripheral attachments, and found incidentally during MRI or arthroscopy. A symptomatic discoid lateral meniscus in early childhood is usually due to an associated meniscal tear or absent peripheral attachments. An unstable discoid meniscus may cause a “snapping knee,” where anterior extrusion of meniscal tissue during flexion produces a pop and reduction with extension generates a loud click or clunk. These patients may present as early as 2 years of age but more commonly present after about 6 years of age. Most children with stable discoid lateral menisci present when symptoms of a meniscal

Fig. 4 Coronal view of MRI T2 image demonstrates a discoid lateral meniscus with high intrameniscal signal (*arrow*) indicative of intrasubstance delamination and mucoid degeneration

tear develop, often during their teenage years. As these patients gain weight with their adolescent growth spurt, they place increasing static and dynamic loads on the meniscal tissue, often with high-level sports. Degeneration in the central portion of the discoid lateral meniscus with direct weight-bearing (Fig. 4) makes the meniscus highly susceptible to injury and tears, producing lateral pain and swelling in the knee. Often, the snapping knee syndrome is not appreciated in these patients. Thus, younger children usually present with no history of trauma or acute inciting event but with a complaint of popping or snapping in the knee and possible swelling. Older children and adolescents often can recall an inciting event and may also report mechanical symptoms but more often note the lateral joint line pain and swelling.

On physical examination, a mild effusion and tenderness over the lateral joint line may be noted. An audible pop and protuberance at the anterolateral joint line may be appreciated with full knee flexion. Subsequent extension of the knee will cause the meniscus to snap back into the joint and for the protuberance at the lateral joint line to disappear. Other findings include a mechanical block to motion, quadriceps atrophy, ambulation with a flexed stance, and a positive McMurray test. Pediatric sports medicine specialists were reported to have diagnosed discoid lateral meniscus on physical examination with a sensitivity of 88.9 % and a specificity of 98.0 % (Kocher et al. 2001).

Imaging

Radiographs may help the diagnosis but are often normal in patients with discoid lateral meniscus. Standard anteroposterior, lateral, tunnel, and skyline views are typically obtained. Radiographs of the knee may show widening of the lateral joint space, calcification of the lateral meniscus, squaring of the lateral femoral condyle, cupping of the lateral tibial plateau, a hypoplastic lateral intercondylar spine, and elevation of the fibular head. However, since radiographic findings are uncommon and nonspecific, evaluation with MRI remains the modality of choice for the diagnosis of discoid lateral meniscus and associated meniscal pathology.

On MRI, criterion suggestive of a discoid lateral meniscus is continuity between the anterior and posterior horns on three or more successive sagittal 5-mm-thick slices (Silverman et al. 1989; Fig. 5). While many orthopedic surgeons find MRI of discoid menisci to correlate well with arthroscopic findings, the sensitivity of MRI diagnosis has been reported to be as low as 38.9 % (Kocher et al. 2001). Complete discoid menisci are more easily detected than incomplete types on MRI, and the Wrisberg ligament types can be particularly difficult to identify. Additionally, although the presence or absence of associated meniscal tears may be successfully determined, the ability for MRI to elucidate the tear type is questionable (Yilgor et al. 2013). In any case where clinical suspicion is high despite negative findings on imaging, a diagnostic arthroscopy may be warranted.

Treatment

Asymptomatic or incidentally found discoid lateral menisci without evidence of a tear or meniscal instability are treated nonoperatively with

Fig. 5 Sagittal view of MRI T2 image shows a discoid lateral meniscus with an associated tear in the posterior horn (*arrow*)

observation (Dickhaut and DeLee 1982). Counseling is provided regarding the increased incidence of meniscal tears in this patient population. Some patients and families may choose to subsequently select sports that avoid collisions and high impact although major activity restriction is not mandated from a medical standpoint. Patient education on recognizing early symptoms should be provided. If knee pain or mechanical symptoms limit activity or a meniscal tear develops, consideration for surgical intervention is recommended. Early operative treatment in the symptomatic patient may potentially prevent subsequent development of irreparable meniscal tears, osteochondral lesions, and focal traumatic arthritis.

For a stable, symptomatic discoid lateral meniscus, arthroscopic management consisting of saucerization, or partial meniscectomy, is the current treatment of choice. Total meniscectomy in children and adolescents is generally not advisable due to poor long-term outcomes, characterized by early radiographic signs of degenerative joint disease, knee pain, instability, and osteochondritis dissecans (Washington et al. 1995; Raber et al. 1998). The long-term prognosis after arthroscopic meniscectomy for discoid lateral meniscus may be related to the volume of meniscus removed, with patients undergoing partial meniscectomy showing improved outcomes after 5 years of follow-up (Kim et al. 2007). Nevertheless, total meniscectomy may still be necessary in certain situation, such as complete dislocation of the entire meniscus with poor remaining tissue quality and complex irreparable meniscal tears (Davidson et al. 2003).

The goal of saucerization is to reshape the discoid lateral meniscus into a stable and functional anatomically normal-appearing meniscus (Fig. 6). In order to accomplish this, an intact peripheral rim of 8–10 mm of meniscal tissue is left after debridement. Saucerization can be difficult to perform because of limited maneuverability and diminished visualization caused by the thickened discoid meniscus and small knee size of the pediatric patient. A mid-patellar portal, in addition to standard anteromedial and anterolateral portals, can facilitate discoid meniscal assessment and repair as well as eliminate crowding and collision of instruments during surgery. The majority of the associated tears of discoid lateral menisci are horizontal cleavage tears. Such tears may be reduced by resection or repaired, especially if the tear extends to the peripheral vascular zone. Following saucerization, a thorough assessment of the peripheral rim of the meniscus is necessary to assess for meniscal stability. Peripheral rim instability occurs in 28.1 % of discoid lateral menisci, more commonly at the anterior third (47.2 %) (Fig. 7) than the middle (11.1 %) or posterior third (38.9 %) attachment sites (Klingele et al. 2004). If present, peripheral stabilization is achieved by meniscal repair to the capsule with suturing by either inside-out or outside-in techniques. Postoperative protocols vary by institution and surgeon, but typically protected motion and weight-bearing are followed by progressive mobilization and rehabilitation.

Clinical Outcomes

The short-term results of partial meniscectomy, repair, and recontouring of symptomatic discoid lateral menisci in children and adolescents are promising. In one retrospective series, 30 knees in 27 consecutive children and adolescents

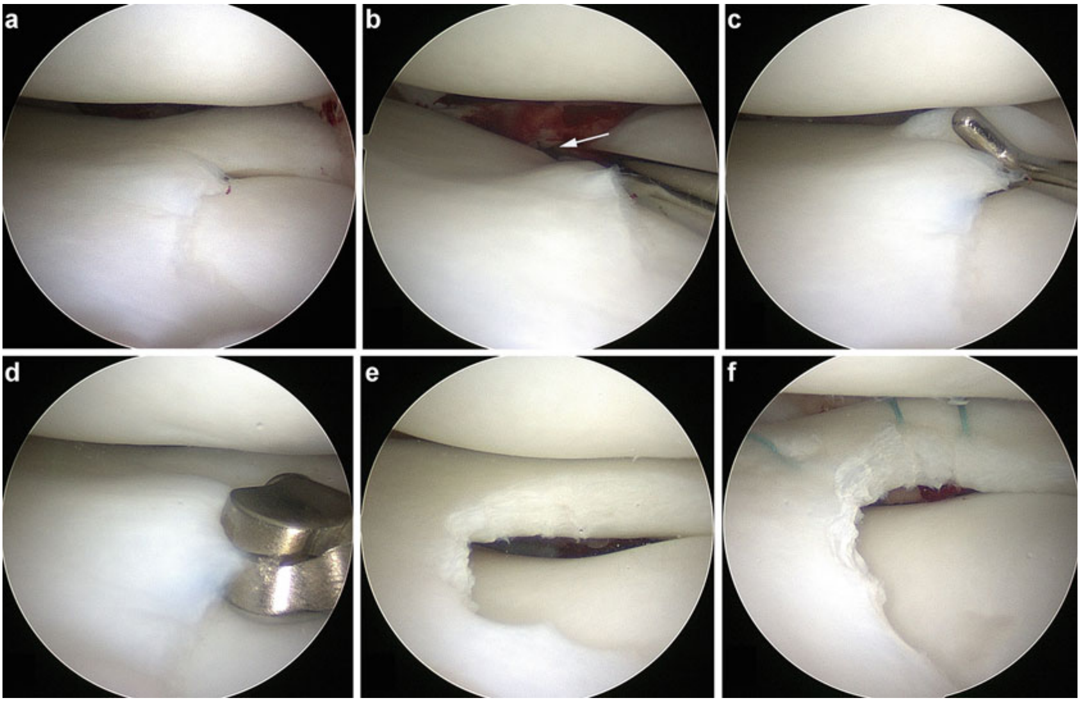

Fig. 6 Saucerization and repair of an unstable, symptomatic discoid lateral meniscus in a 13-year-old boy. (**a**) Arthroscopic image shows the incomplete discoid lateral meniscus. (**b**) Probing reveals a posterior horn peripheral rim tear (*arrow*) and (**c**) a complex radial tear in the meniscal midsubstance. (**d**) Saucerization is performed with a 90° meniscal biter through the central portion of the meniscus. (**e**) Final appearance of the meniscus after saucerization and (**f**) repair of peripheral instability is shown

Fig. 7 Sagittal view of MRI T2 image illustrates a discoid lateral meniscus with anterior detachment (*arrow*)

(mean age, 10.1 years) underwent arthroscopic saucerization and repair of meniscal instability, if present (Good et al. 2007). Of 21 patients (23 knees) with a minimum of 1-year follow-up (mean, 37.4 months), all patients demonstrated full knee flexion beyond 135°. Residual knee pain was reported by three patients, and intermittent mechanical symptoms were found in 4. In another series of 28 knees in 23 children (mean age, 9.0 years), arthroscopic partial meniscectomy in conjunction with peripheral tear repair was performed (Ahn et al. 2008). All patients returned to their previous life activities with little or no limitation, and no reoperation was required after a mean follow-up period of 50.9 months. Ogut et al. reported on 11 knees (mean patient age, 11.5 years) treated with arthroscopic partial meniscectomies (Ogut et al. 2003). At the end of a mean 4.5-year follow-up, nine knees were asymptomatic with full range of motion, and two had occasional pain. No radiographic degenerative changes were evident in any of the knees. Long-term studies are still needed, however, to determine whether meniscal preservation techniques for discoid lateral meniscus in pediatric patients will not just improve patient function and address comfort but also prevent the development of osteoarthritis.

Summary

Meniscal injuries are being seen with increasing frequency in children and adolescents. Often a result of a traumatic event during a sporting activity, meniscal tears in skeletally immature patients may have better reparative potential than tears in adults due to the increased vascularity of the developing meniscus. Attempts at meniscal repair in children and adolescents are emphasized, particularly of peripheral meniscal tears. The discoid lateral meniscus represents a spectrum of anatomical abnormalities with varying degrees of stability that may be asymptomatic or associated with a “snapping knee” in children or a meniscal tear in adolescents. Currently, observation is recommended for asymptomatic discoid menisci. Partial meniscectomy and repair for symptomatic discoid lateral menisci have shown satisfactory short-term results, although long-term outcomes for children and adolescents are lacking. In conclusion, the key to successful treatment of young athletes is to follow universally recognized principles that apply to all patients and to adjust them accordingly for younger patients with inherent physiologic differences from their adult counterparts.

Cross-References

- ► Anterior Cruciate Ligament Injuries with Concomittant Meniscal Pathologies
- ► Arthroscopic Repair of the Meniscus Tears
- ► Asymptomatic Meniscal Tears
- ► Meniscectomy
- ► Meniscus Variations

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