Management of Pediatric Meniscal Root Tears

Lacey C. Magee, BA; Nishank N. Mehta, BA; Margaret L. Wright, MD; Tomasina M. Leska, BS; Theodore J. Ganley, MD

The Children's Hospital of Philadelphia, Philadelphia, PA

Abstract: Tears of the posterior roots of the medial and lateral meniscus are relatively uncommon injuries but can be seen concurrently with anterior crucial ligament (ACL) injuries in young athletes. Despite a wealth of research on the diagnostics and therapeutics of root tears in the adult population, pediatric root tears have been relatively understudied despite the increasing incidence of youth sports participation and thus increasing ACL injuries. With an understanding that repair of the meniscal root is paramount to positive outcomes in the adult population, it is therefore, crucial to understand the incidence, presentation, and treatment of this pathology in pediatric patients as well. Our aim is to review the available literature on pediatric meniscal root tears, as well as special considerations for anatomy and diagnosis of this injury in children and adolescents.

Key Concepts:

- A meniscal root tear is defined as a radial tear or avulsion injury of the bone or soft tissue within 1 centimeter of the meniscal root.
- Due to its reduced mobility and significant loading as a secondary stabilizer of anterior translation, the posterior root of the medial meniscus is more prone to lesions than the posterior lateral meniscus root.
- While increased age, female sex, increased body mass index (BMI), and decreased sports activity levels have been reported as risk factors for root tears in the adult population, a few studies have cited increased BMI and male sex as risk factors in the pediatric population.
- The finding of meniscal extrusion on MRI has been shown to be highly associated with the presence of a meniscal root tear.
- Anatomic repair of the meniscal root should be attempted whenever possible in order to prevent further meniscus and cartilage damage and allow return to usual activities.[1]

Introduction

Although meniscal tears are seen concomitantly with ACL injuries in approximately 40-50% of pediatric knee injuries,[2-5] tears of the meniscal root have historically been considered to be an uncommon subset of these injuries. Most frequently seen in the setting of ACL tear in patients in their late-thirties,[1,6] root tears result in a loss of functional load distribution that can expose the articular cartilage to abnormal forces comparable to those following total meniscectomy.[7] The incidence of meniscal tears in pediatric patients has been rising in recent years as the nation sees increasing participation in athletics,[8] and a recent study cited an incidence of 18.5% in their cohort of pediatric meniscal injuries.[2] Multiple studies have shown that root injuries can be associated with knee instability and increased contact pressure in the compartment.[2,8,9] Although increasing information is

Table 1. Meniscal Root Tear Incidence in the Pediatric Population

Authors	Year	N	Age Group	Method	Prevalence
Wilson[2]	2018	314	10.5-19.6 years	Arthroscopy with meniscal pathology	18.5%
Shieh[12]	2013	293	<18	Arthroscopy with meniscal pathology	2%

becoming available about meniscal root tears in the adult population, few studies have considered characteristics of the root tear specific to the pediatric and adolescent populations. The aim of this review is to condense the available information about pediatric root tears to consider differences in anatomy, work-up, and treatment, and to discuss areas that require special attention in the pediatric (under age 18), and in particular adolescent (ages 12-18) age group.

Definition

The medial and lateral menisci are anchored to the tibia anteriorly and posteriorly at the meniscal root.[3] This strong attachment is crucial for load distribution but can lead to increased risk of tear in this region.[3] When the soft tissue or bone sustains an avulsion injury or radial tear within one centimeter of the meniscal root, it is defined as a root tear.[1] Tears of the root can lead to meniscus extrusion, and the resultant increase in tibiofemoral contact pressure can lead to progressive degenerative osteoarthritis.[10]

Anatomy

The meniscus becomes a clearly defined structure by the 8th week of fetal development.[11] The meniscus is completely vascularized at birth, but by about 9 months of age, the central third of the meniscus becomes avascular. At about age 10, only 10-30% of the peripheral meniscus will have a blood supply.[11] Therefore, while studies have shown that younger menisci heal better after repair than those in adults,[12] it is evident that there is not much variation between the menisci of the adolescent (12-18 years old) and the young adult (18-25 years old). The medial posterior root attaches to the slope of the intercondylar fossa anteromedial to the posterior cruciate ligament. This root attachment provides stability against external rotation and is the least mobile of the meniscal roots.[19] Because of its reduced mobility and significant loads, the posterior root of the medial meniscus is more prone to lesions than the posterior lateral root.[13,14] The posterior root of the lateral meniscus lends stability to the ACL, attaching posterior to the ACL but anterior to the PCL, at the lateral tibial eminence.[19] The exact insertion of the posterior root attachment varies with the presence of the meniscofemoral ligament.[11] The anterior roots of the medial and lateral menisci insert along the anterior tibial slope and lateral eminence, respectively.

Epidemiology and Risk Factors

The rate of meniscus tears has been cited to be between 33-65% in adult patients with acute ACL injuries.[8,15,16] In the pediatric age group, Wilson and colleagues found that posterior lateral meniscal root injuries were five times more common than posterior medial meniscal root injuries, with 18.5% of all adolescent meniscal injuries affecting the posterior root.[2] In their cohort, 75.2% of patients with a root tear had a coexisting ACL injury.[2] This was much higher than the previously reported incidence of meniscal root injuries of 2% in another pediatric and adolescent patient cohort with surgically treated menisci[13] (Table 1).

Several risk factors for meniscal root tears in the adult population have been reported. Increased age, female sex, increased BMI, and decreased sports activity levels

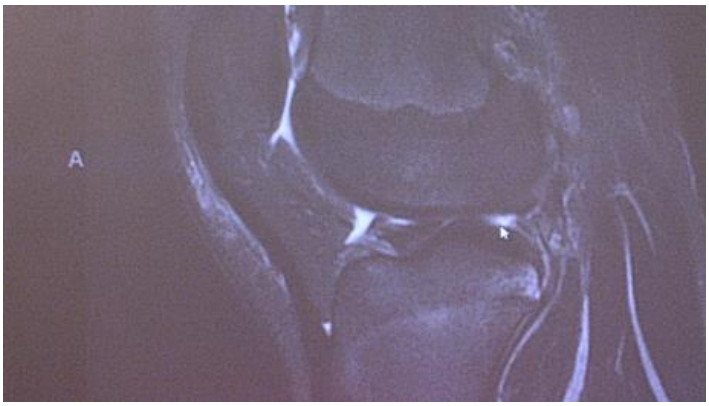

***Figure 1**. Sagittal MRI image from an 11-year-old female with a posterior lateral root tear*

have all been associated with a higher incidence of medial meniscal posterior root tears (MMPRT).[1,4] Increased incidence of MMPRT has also been described in parts of the world where kneeling and squatting are common daily activities.[5,13] Another study noted that contact sports and a medial meniscal tear were independent risk factors for lateral meniscal posterior root tear (LMPRT) in an ACL injured knee.[17] In pediatric patients, one study found that complex meniscal tears are more likely to occur in males and those with a higher BMI, though complete root detachments were not included in this group.[12] However, this study noted that the group of patients with a meniscal root tear and discoid meniscus was primarily male, whereas the group of patients with a meniscal root tear and a non-discoid meniscus was primarily female.[12] Additionally, taking into account contact sports as a risk factor, it is possible that adolescent male athletes suffer greater numbers of meniscal root tears associated with ACL tears, as previous studies have noted male athletes have higher rates of contact-related ACL tears.[18] Adolescents, in general, are more likely to have concurrent ligamentous injuries than younger children, likely due to greater sports involvement, and tears in younger children are more likely to be associated with discoid menisci and other congenital meniscal abnormalities.[11,12] Finally, there is a risk association between irreparable meniscus tears and time from injury to surgery in the adolescent population. Shieh et al. described their cohort of pediatric patients with meniscal tears with detachment of the root, stating that the majority of root detachment tears were repairable.[12] While all meniscal root tears should undergo an attempt at repair regardless of timing, this emphasizes the increased complexity of tear patterns and difficulty of repair as the time from injury increases.

History, Exam, and Workup

History

Diagnosis can be challenging due to the fact that root tears rarely present with the common signs and symptoms seen in tears of the meniscal body.[19] Some patients with tears of the posterior root may report a history of joint line pain on the affected side, but mechanical symptoms such as locking, catching, or "giving way" are less likely to be present.[19] Lee and coauthors noted that only 14.3% and 9.5% of their patients with posterior medial meniscal root tears complained of knee locking and giving way, respectively.[19,20] Meniscal root injury is not typically associated with an inciting traumatic event in adults, as their root tears are more commonly degenerative. In one study, 68.9% of adult patients with medial meniscal root tears recalled a minor traumatic event, such as squatting, whereas others could not recall any specific event leading up to their injury.[21] However, meniscal root injury in children is usually associated with a known injury; Wilson et al. noted that 41 of their 58 root tear patients sustained their injury during a noncontact sport, and 14 sustained an injury during a contact sport.[2]

Physical Exam

On physical examination, the most commonly encountered signs of root tear are posterior knee pain with flexion and joint line tenderness. In a study of pediatric meniscal injuries, Wilson noted that 55 of the 58 presented with joint line tenderness.[2] Lee et al. noted that 66.7% and 61.9% of their cohort of patients with MMPRT presented with pain in flexion and joint line

tenderness, respectively.[20] McMurray testing was positive in 57.1% of patients, and effusion was noted in only 14.3%.[20] Seil et al. described a novel varus stress test that could be used in the clinical diagnosis of a medial meniscal posterior root avulsion.[22] The test is performed with the patient fully relaxed and the knee in full extension. During varus stress testing, the anteromedial joint line was palpated, and meniscal extrusion could be produced. When the knee was brought back to normal position, the extrusion disappeared.[19,22] However, previous studies have shown that clinical exam as a sole modality of diagnosis of knee pathology is insufficient in children under 14 years old, and thus pediatric patients with a suspected injury of the meniscus should undergo imaging in addition to physical exam.[23]

Imaging

Standard anteroposterior, lateral, tunnel, and skyline radiographic views should be obtained in the setting of an acute injury. This series of radiographs can detect other possible pathologies, such as osteochondritis dissecans, osteochondral fractures, and physeal fractures.[24] MRI should be obtained when additional ligamentous and/or meniscal injury is suspected. The posterior medial meniscus root is best visualized in two consecutive coronal MRI images. It appears as a band of fibrous cartilage anchoring the posterior horn of the meniscus to the tibial plateau.[25] T2-weighted sequences are generally considered to be the best images for visualization of tears.[26] The sensitivity of MRI for MMPRT is as high as 93.3% when looking for radial tear, presence of a truncation sign, and ghost meniscus sign (Figure 1).[27] However, another study reported that 66% of LMPRTs were missed on initial MRI and emphasized that it is important to visualize the root during operative treatment of the knee for other associated pathology.[28] In one study evaluating 67 patients with arthroscopically confirmed posterior medial meniscal root tears, a root tear could be demonstrated on preoperative MRI in only 72.9% of the patients, while the rest demonstrated degeneration and/or fluid accumulation at the posterior horn without a visible meniscal tear.[24] Due to the small size of the root of the meniscus, it is sometimes challenging to identify on MRI. Therefore, the finding of meniscal extrusion has been shown to be highly associated with the presence of a tear.[29] Extrusion of the medial meniscus is defined as displacement of the meniscus from the tibial articular cartilage.[26,30] Wilson et al. noted meniscal extrusion evident in 8.9% of their pediatric cohort of meniscal injuries and reported its visibility in 66.7% of MMPRTs and 28.3% of LMPRTs, with an overall of 93% of MRI images showing meniscal extrusion associated with a true meniscal root tear or complex tear.

Fixation: Indications and Decision-Making

Indications

Because the meniscal root functions as the anchor for the entire meniscus, it provides a vital role for the stability and hoop stresses provided by the meniscus. Prior studies have shown that meniscal root tear leads to the loss of hoop stresses, meniscal extrusion, and the functional equivalent of a total meniscectomy.[12,31] Several studies looking at long-term follow-up of pediatric patients who underwent total meniscectomy showed lower subjective functional outcome scores, with 63% of patients rating their outcomes as 'unsatisfactory'.[32] Other studies have demonstrated the degenerative effects of total meniscectomy in young adults.[33,34] Therefore, the purpose of operative repair is to restore the meniscal and kinematics and delay the development of osteoarthritis and other long-term degenerative effects.[1,35-38]

Nonoperative Treatment

Nonoperative treatment is reserved primarily for patients who are not surgical candidates, either because of medical comorbidities or diffuse, high-grade osteoarthritis (OA), and is not the mainstay of practice for pediatric patients.[39-43] Treatment includes analgesics and activity modification, with an unloader brace if tolerated.[1,19]

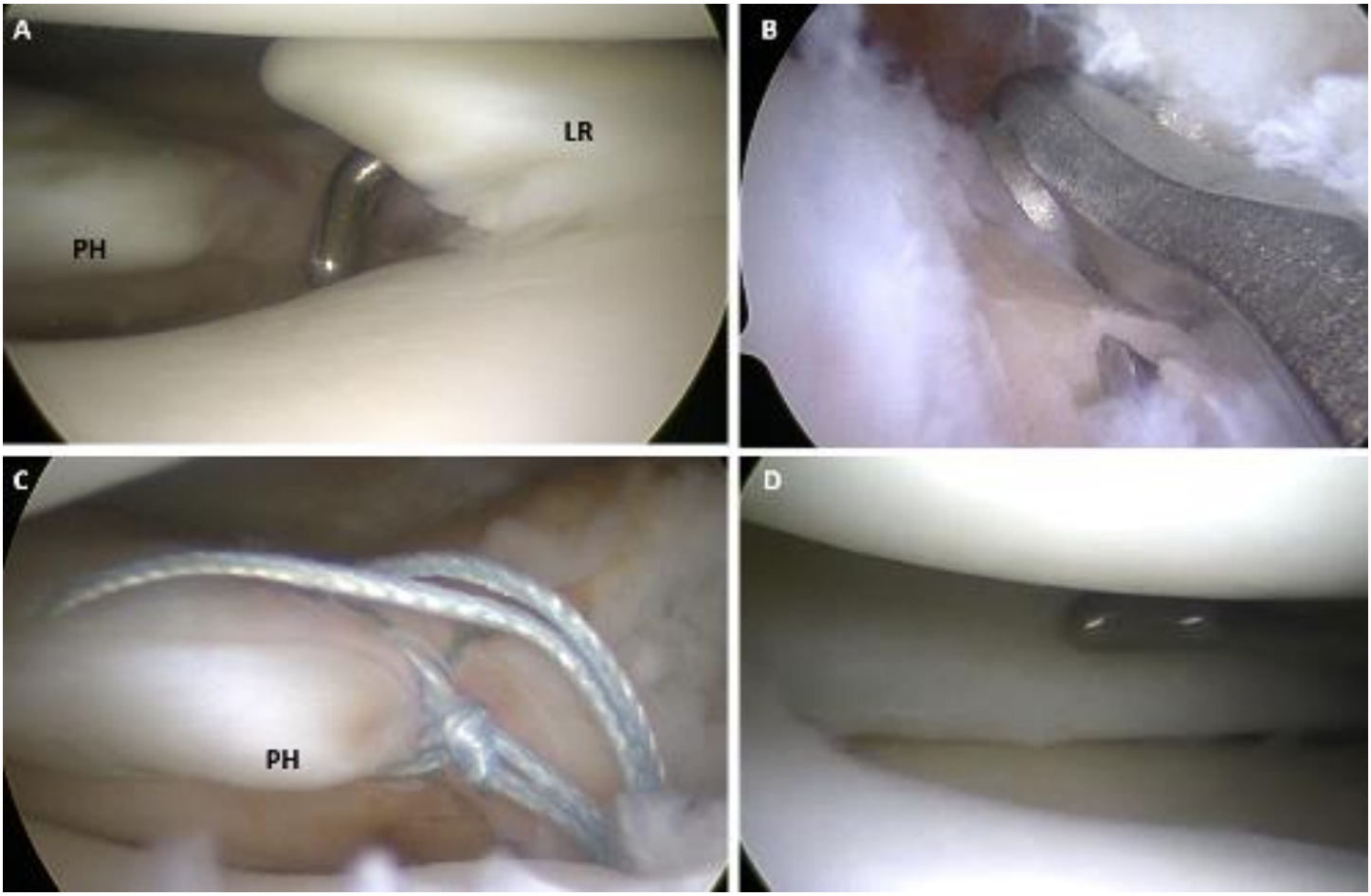

Figure 2*. Arthroscopic images from a patient with a right knee posterior lateral meniscal root tear.* ***2A.*** *A lateral meniscal tear within one centimeter of the root is demonstrated. Given the quality of the remaining root tissue, a transtibial repair technique was selected.* ***2B.*** *After the undersurface of the posterior horn was debrided to stimulate healing and sutures were placed in the meniscus, a drill guide was used to create a small tibial tunnel at the location of the lateral meniscal root. A curette was used to create a bony healing surface at this location.* ***2C.*** *A suture passer was used to shuttle the meniscal sutures out of the tibial tunnel, and these sutures were used to reduce the meniscal root.* ***2D.*** *The native anatomy and tension of the lateral meniscus is restored after reduction of the meniscal root.*

Meniscectomy

In the adult population, patients with persistent symptoms such as locking who have failed nonoperative treatment may benefit from a partial meniscectomy.[1] Despite the relatively rapid initial recovery after surgery, development of further OA almost always occurs, and symptom relief is short-lived when compared to surgical repair.[1]

The only scenario in which a meniscectomy may be used in the treatment of meniscal root tears at our institution is if the meniscus has become so degenerative or is of such poor quality that it cannot be surgically repaired. In this case, patients are then considered to be candidates for meniscal transplantation in order to restore a more normal meniscal anatomy and prevent rapid progression of arthritis.

Posterior Meniscal Root Repair

Anatomic repair of the meniscal root should be attempted whenever possible, particularly in young athletes and the pediatric population as a whole, in order

to prevent further meniscus and cartilage degeneration.[1] Chung and colleagues compared 20 partial meniscectomy patients to 37 root repair patients, and showed that the repair group had higher subjective knee rating and knee function scores, as well as less radiographic progression of arthritis.[44] Additionally, none of the repair patients required subsequent knee arthroplasty compared to 35% of the debridement group.[45]

Early surgical treatment of tears in pediatric patients may result in a higher chance of successful repair,[12] with healing rates ranging from 33-100%.[46] Suture anchor repair and transtibial meniscal root repair are the two most common meniscal repair techniques. Wilson et al. noted that all but one of their patients underwent root repair with a single trans-osseous stitch and reported favorable outcomes.[2]

Fixation Procedure

Transtibial Pull-Out Repair

There are several techniques describing trans-osseous suture fixation for medial and lateral posterior root tears,[1,15,43] and treatment can be variable depending on the pattern of the meniscal root tear.[1,43] Transtibial pull-out repair involves first passing sutures through the meniscal root and then drilling a tunnel in the proximal tibia in order to retrieve the sutures (Figure 2). A bony surface should be created for healing the meniscus to the proximal tibia, and this can be created with either a retrograde reaming device like the Flipcutter (Arthrex, Naples, FL) or with a curette in the area of the root insertion. The sutures can then be pulled down through the tunnel in order to tension the meniscal root down against bone, and they can be secured distally with a suture anchor or by tying them over an anterior bone bridge or a post. Even though the tunnel for this technique must be drilled across the proximal tibial physis, it is typically done with a small, non-threaded wire and therefore causes minimal physeal damage. This technique can be safely performed in children and adolescents, and no cases of growth disturbance as a result of meniscal root repair have been reported. Advantages of this technique include a biomechanically strong suture construct, no need for a posterior portal, and instrumentation designed specifically for the knee.[1,15,43] This technique is primarily indicated for tears with good quality remaining meniscal tissue and allows the hoop stresses of the native meniscus to be restored.[15] A reported downside of the pull-out suture method is that the length of the bone tunnel can subject the suture material to elongation or abrasions, and can be challenging in the setting of other ligamentous repair to ensure that the tunnels do not converge.[47] This technique is the primary method of repair at our institution.

All-Inside Repair

Some meniscal root tears are not avulsions of the root from bone but are a tear within one centimeter of the root. Depending on the pattern of tear, some of these tears may be amenable to all-inside repair, similar to other posterior horn tears, as children and adolescents have greater healing potential of meniscal tears compared to adults. If this technique is chosen, it is important to ensure that the meniscus is reduced to an anatomic position and that it is no longer extruded from the joint after repair. Another consideration if an all-inside technique is chosen is that the neurovascular bundle is in close proximity to the posterior horn and root of the lateral meniscus, and care should be taken with any all-inside device in this location.[48]

Suture Anchor Repair

Treatment of medial meniscal root tears has also been reported with suture anchor repair, where one suture anchor with two sutures is placed via an all-inside technique.[1] The knee is positioned in near-extension during the entirety of the procedure while valgus stress is applied.[47] The anchor is inserted at the anatomic footprint of the meniscal root through a high posteromedial portal.[1] Then, the two sutures are passed through the meniscus and tied in order to reattach the root. This technique has primarily been reported in

patients with grade 3 medial collateral ligament tears, as access to the posterior root with this method is very challenging.[1] Another downside is that the posterior portal presents an increased risk to neurovascular structures.[47] This technique is not part of the practice pattern at our institution.

Postoperative Management and Outcomes

At our institution, in the first-month post-surgery, range of motion (ROM) is permitted from 0-90 degrees in the brace, but weight-bearing is only permitted while in full extension in a brace. After a 4-week interval, the brace can be discontinued, and the patient may begin full weight-bearing and full knee ROM as tolerated. The authors recommend early mobilization and ROM exercises to prevent subsequent knee stiffness. Knee loading at flexion angles greater than 90 degrees is not recommended until 4 months after the procedure. The results of meniscus posterior root repair are good in pediatric patients.[49] While there is not vast anatomic variation between the pediatric and adult age groups, children have more cartilaginous joints than adults, as well as open physes, which has been associated with better outcomes in meniscal healing.[46] Vanderhave et al. reported a 100% healing rate post meniscal repair in patients with open physes, versus 80% in patients already deemed skeletally mature.[50]

Several authors have commented on outcomes in the general adult population. While Chung et al. reported that increased age was predictive of worse outcomes after medial root repair, other studies have reported no significant correlations between older patients and successful meniscal root repair.[41,42,51,52] Jiang et al. found that knee varus alignment of greater than 5 degrees was associated with lower scores in functional outcome instruments (including IKDC, Tegner, AKS, and Lysholm scores) after medial root repair.[36] In general, however, the pediatric population appears to experience improved clinical and functional outcomes with repaired meniscal root tears and repair should be attempted for all tears.[1]

Summary

As participation in youth athletics continue to rise, the incidence of knee pathology has also increased, particularly injuries of the ACL and concomitant tears of the menisci and meniscal roots. Little research has been done in the pediatric population regarding treatment techniques and outcomes. Surgeons should be aware of the implications of untreated root tear and the importance of anatomic repair. Further research may help to improve the identification of pediatric meniscal root tears, identify the best modalities of diagnosis and treatment, and understand the long-term outcomes of root repair in this population.

References

1. Pache S, Aman ZS, Kennedy M, et al. Meniscal Root Tears: Current Concepts Review. *Arch Bone Jt Surg.* 2018;6(4):250-259.

2. Wilson PL, Wyatt CW, Romero J, Sabatino MJ, Ellis HB. Incidence, Presentation, and Treatment of Pediatric and Adolescent Meniscal Root Injuries. *Orthop J Sports Med.* 2018;6(11):2325967118803888.

3. Choi CJ, Choi YJ, Lee JJ, Choi CH. Magnetic resonance imaging evidence of meniscal extrusion in medial meniscus posterior root tear. *Arthroscopy.* 2010;26(12):1602-1606.

4. LaPrade CM, Ellman MB, Rasmussen MT, et al. Anatomy of the anterior root attachments of the medial and lateral menisci: a quantitative analysis. *Am J Sports Med.* 2014;42(10):2386-2392.

5. Bin SI, Kim JM, Shin SJ. Radial tears of the posterior horn of the medial meniscus. *Arthroscopy.* 2004;20(4):373-378.

6. DeHaven KE. Diagnosis of acute knee injuries with hemarthrosis. *Am J Sports Med.* 1980;8(1):9-14.

7. Matheny LM, Ockuly AC, Steadman JR, LaPrade RF. Posterior meniscus root tears: associated pathologies to

assist as diagnostic tools. *Knee Surg Sports Traumatol Arthrosc.* 2015;23(10):3127-3131.

8. DeHaven KE, Lintner DM. Athletic injuries: comparison by age, sport, and gender. *Am J Sports Med.* 1986;14(3):218-224.

9. Forkel P, Herbort M, Sprenker F, Metzlaff S, Raschke M, Petersen W. The biomechanical effect of a lateral meniscus posterior root tear with and without damage to the meniscofemoral ligament: efficacy of different repair techniques. *Arthroscopy.* 2014;30(7):833-840.

10. Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: in situ pull-out repair restores derangement of joint mechanics. *Am J Sports Med.* 2014;42(3):699-707.

11. Andrish JT. Meniscal Injuries in Children and Adolescents: Diagnosis and Management. *J Am Acad Orthop Surg.* 1996;4(5):231-237.

12. Shieh A, Bastrom T, Roocroft J, Edmonds EW, Pennock AT. Meniscus tear patterns in relation to skeletal immaturity: children versus adolescents. *Am J Sports Med.* 2013;41(12):2779-2783.

13. Bonasia DE, Pellegrino P, D'Amelio A, Cottino U, Rossi R. Meniscal Root Tear Repair: Why, When and How? *Orthop Rev (Pavia).* 2015;7(2):5792.

14. Vedi V, Williams A, Tennant SJ, Spouse E, Hunt DM, Gedroyc WM. Meniscal movement. An in-vivo study using dynamic MRI. *J Bone Joint Surg Br.* 1999;81(1):37-41.

15. Feucht MJ, Izadpanah K, Lacheta L, Sudkamp NP, Imhoff AB, Forkel P. Arthroscopic transtibial pullout repair for posterior meniscus root tears. *Oper Orthop Traumatol.* 2019;31(3):248-260.

16. King D. The healing of semilunar cartilages. 1936. *Clin Orthop Relat Res.* 1990(252):4-7.

17. Praz C, Vieira TD, Saithna A, et al. Risk Factors for Lateral Meniscus Posterior Root Tears in the Anterior Cruciate Ligament-Injured Knee: An Epidemiological Analysis of 3956 Patients From the SANTI Study Group. *Am J Sports Med.* 2019;47(3):598-605.

18. Takahashi S, Nagano Y, Ito W, Kido Y, Okuwaki T. A retrospective study of mechanisms of anterior cruciate ligament injuries in high school basketball, handball, judo, soccer, and volleyball. *Medicine (Baltimore).* 2019;98(26):e16030.

19. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. *Am J Sports Med.* 2014;42(12):3016-3030.

20. Lee JH, Lim YJ, Kim KB, Kim KH, Song JH. Arthroscopic pullout suture repair of posterior root tear of the medial meniscus: radiographic and clinical results with a 2-year follow-up. *Arthroscopy.* 2009;25(9):951-958.

21. Kim SB, Ha JK, Lee SW, et al. Medial meniscus root tear refixation: comparison of clinical, radiologic, and arthroscopic findings with medial meniscectomy. *Arthroscopy.* 2011;27(3):346-354.

22. Seil R, Duck K, Pape D. A clinical sign to detect root avulsions of the posterior horn of the medial meniscus. *Knee Surg Sports Traumatol Arthrosc.* 2011;19(12):2072-2075.

23. Eiskjaer S, Larsen ST. Arthroscopy of the knee in children. *Acta Orthop Scand.* 1987;58(3):273-276.

24. Ozkoc G, Circi E, Gonc U, Irgit K, Pourbagher A, Tandogan RN. Radial tears in the root of the posterior horn of the medial meniscus. *Knee Surg Sports Traumatol Arthrosc.* 2008;16(9):849-854.

25. Koenig JH, Ranawat AS, Umans HR, Difelice GS. Meniscal root tears: diagnosis and treatment. *Arthroscopy.* 2009;25(9):1025-1032.

26. Lerer DB, Umans HR, Hu MX, Jones MH. The role of meniscal root pathology and radial meniscal tear in medial meniscal extrusion. *Skeletal Radiol.* 2004;33(10):569-574.

27. Choi SH, Bae S, Ji SK, Chang MJ. The MRI findings of meniscal root tear of the medial meniscus: emphasis on coronal, sagittal and axial images. *Knee Surg Sports Traumatol Arthrosc.* 2012;20(10):2098-2103.

28. Krych AJ, Wu IT, Desai VS, et al. High Rate of Missed Lateral Meniscus Posterior Root Tears on Preoperative Magnetic Resonance Imaging. *Orthop J Sports Med.* 2018;6(4):2325967118765722.

29. Magee T. MR findings of meniscal extrusion correlated with arthroscopy. *J Magn Reson Imaging.* 2008;28(2):466-470.

30. Costa CR, Morrison WB, Carrino JA. Medial meniscus extrusion on knee MRI: is extent associated with severity of degeneration or type of tear? *AJR Am J Roentgenol.* 2004;183(1):17-23.

31. Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus. Similar to total meniscectomy. *J Bone Joint Surg Am.* 2008;90(9):1922-1931.

32. Wroble RR, Henderson RC, Campion ER, el-Khoury GY, Albright JP. Meniscectomy in children and adolescents. A long-term follow-up study. *Clin Orthop Relat Res.* 1992(279):180-189.

33. D. MI, A. AA. The consequences of meniscectomy. *The Journal of Bone and Joint Surgery British volume.* 2006;88-B(12):1549-1556.

34. Beaufils P, Becker R, Kopf S, Matthieu O, Pujol N. The knee meniscus: management of traumatic tears and degenerative lesions. *EFORT Open Rev.* 2017;2(5):195-203.

35. LaPrade RF. Editorial Commentary: We Know We Need to Fix Knee Meniscal Radial Root Tears—But How Best to Perform the Repairs? *Arthroscopy.* 2018.

36. Jiang EX, Abouljoud MM, Everhart JS, et al. Clinical factors associated with successful meniscal root repairs: A systematic review. *Knee.* 2019;26(2):285-291.

37. Forkel P, von Deimling C, Lacheta L, et al. Repair of the lateral posterior meniscal root improves stability in an ACL-deficient knee. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(8):2302-2309.

38. Bernard CD, Kennedy NI, Tagliero AJ, et al. Medial Meniscus Posterior Root Tear Treatment: A Matched Cohort Comparison of Nonoperative Management, Partial Meniscectomy, and Repair. *Am J Sports Med.* 2020;48(1):128-132.

39. Kocher MS, Klingele K, Rassman SO. Meniscal disorders: normal, discoid, and cysts. *Orthop Clin North Am.* 2003;34(3):329-340.

40. Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med.* 1982;10(2):90-95.

41. Chung KS, Ha JK, Ra HJ, et al. Pullout fixation for medial meniscus posterior root tears: clinical results were not age-dependent, but osteoarthritis progressed. *Knee Surg Sports Traumatol Arthrosc.* 2019;27(1):189-196.

42. Moon HK, Koh YG, Kim YC, Park YS, Jo SB, Kwon SK. Prognostic factors of arthroscopic pull-out repair for a posterior root tear of the medial meniscus. *Am J Sports Med.* 2012;40(5):1138-1143.

43. Ahn JH, Lee YS, Chang JY, Chang MJ, Eun SS, Kim SM. Arthroscopic all inside repair of the lateral meniscus root tear. *Knee.* 2009;16(1):77-80.

44. Chung KS, Ha JK, Ra HJ, Kim JG. Prognostic Factors in the Midterm Results of Pullout Fixation for Posterior Root Tears of the Medial Meniscus. *Arthroscopy.* 2016;32(7):1319-1327.

45. Kim JH, Chung JH, Lee DH, Lee YS, Kim JR, Ryu KJ. Arthroscopic suture anchor repair versus pullout suture repair in posterior root tear of the medial meniscus: a prospective comparison study. *Arthroscopy.* 2011;27(12):1644-1653.

46. Yang BW, Liotta ES, Paschos N. Outcomes of Meniscus Repair in Children and Adolescents. *Curr Rev Musculoskelet Med.* 2019;12(2):233-238.

47. Balke M, Akoto R, Offerhaus C, Hoeher J. Suture Anchor Refixation of Meniscal Root Tears Without an Additional Portal. *Arthrosc Tech.* 2018;7(5):e511-e515.

48. Yen Y-M, Fabricant PD, Richmond CG, et al. Proximity of the neurovascular structures during all-inside lateral meniscal repair in children: a cadaveric study. *J Exp Orthop.* 2018;5(1):50-50.

49. Willimon SC, Christino M, Busch M, Perkins C. MENISCUS ROOT TEARS IN CHILDREN AND ADOLESCENTS. *Orthopaedic Journal of Sports Medicine.* 2019;7(3 Suppl):2325967119S2325900032.

50. Vanderhave KL, Moravek JE, Sekiya JK, Wojtys EM. Meniscus tears in the young athlete: results of arthroscopic repair. *J Pediatr Orthop.* 2011;31(5):496-500.

51. LaPrade RF, Matheny LM, Moulton SG, James EW, Dean CS. Posterior Meniscal Root Repairs: Outcomes of an Anatomic Transtibial Pull-Out Technique. *Am J Sports Med.* 2017;45(4):884-891.

52. Cho JH, Song JG. Second-look arthroscopic assessment and clinical results of modified pull-out suture for posterior root tear of the medial meniscus. *Knee Surg Relat Res.* 2014;26(2):106-113.