VILNIUS UNIVERSITY

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The Final Thesis

Comparison of MRI and Functional Outcomes after Meniscus Suture Surgery

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SUMMARY

The menisci of the knee execute many significant biomechanical functions that are related to their specific morphological, structural and compositional characteristics. These functions include shock absorption, stabilization, proprioception, nutrition and lubrication of the knee joint. Furthermore, the menisci have a big role in decreasing contact stresses, increasing the contact area and improving the knee joint congruency. Meniscal tears of the knee are common and meniscal surgeries are one of the most frequently performed orthopaedic procedures around the world. Many studies have shown that meniscal tears and loss of meniscal tissue can predispose to early onset of osteoarthritis, pain and disability. This highlights the importance of meniscal tissue preservation especially in pediatric population. Limited data have been published regarding the treatment strategies in pediatric group of patients. Although consensus may exist on the operative indications, variability of surgical techniques still persists.

The aim of this thesis is to evaluate and compare results of magnetic resonance imaging and functional outcome scores after meniscal repair surgery. Furthermore, an overview is provided of the meniscus anatomy, functions, trauma genesis, injury patterns, diagnostics and operative management of meniscal tears. Additionally, a clinical case regarding a meniscal tear is presented to give an insight to above mentioned topics.

Based on the studies reviewed in this thesis, it seems that postoperative magnetic resonance imaging results does not have a strong correlation with functional outcome scores. Moreover, the available data suggest that arthroscopic meniscal repair provides good clinical and functional results at the follow-up with relatively low failure rates and is suitable treatment option in both pediatric and adult population.

Keywords: Meniscus, menisci, meniscal tear, meniscal repair, anatomy, injury, treatment

1 INTRODUCTION

1.1 General Background

The menisci of the knee execute many significant biomechanical functions that are related to their specific morphological, structural and compositional characteristics. Meniscal tears are very common injuries and meniscal surgeries are one of the most commonly performed orthopaedic procedures around the world. The annual frequency of meniscal injuries has been reported to be 60-70 per 100,000 inhabitants. (1) (2)

Based on several studies, meniscal tears occur approximately four times more in males than in females. In males the peak incidence occurs between 21 and 30 years of age, while in females the incidence peak is between 11 and 20 years of age. (3)

Many studies have shown that meniscal tears and loss of meniscal tissue can predispose to early onset of osteoarthritis, pain and disability. This highlights the importance of meniscal tissue preservation. In the older population meniscal tears are most often related to a combination of both long-term degeneration and trauma. Meniscal injuries in adults are usually more complex as the meniscus undergoes degenerative changes as people gets older. In addition, meniscal injury rates increase with advancing age. (4) Although consensus may exist on the operative indications, variability of surgical techniques still persists.

The purpose of this thesis is to evaluate and compare results of magnetic resonance imaging and functional outcome scores after meniscal repair surgery. Moreover, meniscus anatomy, functions, trauma genesis, injury patterns, diagnostics and operative management of meniscal tears are reviewed. To make it more interesting, a clinical case regarding a meniscal tear is presented to give an insight to above mentioned topics.

1.2 Anatomy of The Knee Menisci

1.2.1 Gross Anatomy

The two knee menisci, lateral and medial, are structures composed of fibrocartilaginous material that are crescent in shape in axial view. In cross section they are wedge shaped, being thicker in the outer border and flattening centrally. They are located on the lateral and medial aspect of the knee joint, between the femoral and tibial articulation respectively. The superior surface of the menisci is concave, enabling good articulation with the convex femoral condyles. The inferior surface of the menisci, however, is slightly convex and accommodates the tibial plateaus. Thus, this is why the menisci have a major role in the knee joint congruency. (5)

The meniscus can be divided into different parts – the middle part that is also called the body, the anterior and posterior horns, which are the meniscal ends, and the meniscal roots, which attaches to the tibial surface. (6)

On the lateral side, the lateral meniscus has less ligamentous and capsular attachments making it more mobile and thus protecting it better from injuries. (7) As in medial meniscus, anterior and posterior horns of the lateral meniscus also attach to the intercondylar area of the tibia. Contrary to the medial meniscus, lateral meniscus doesn't have any connections to the lateral collateral ligament. (8)

Additionally, two accessory meniscofemoral ligaments that stabilizes the lateral menisci can be found in approximately 66% of the patients: ligament of Wrisberg and ligament of Humphrey. (7) These both ligaments arise from the posterior horn of the lateral meniscus and inserts to the lateral aspect of the medial femoral condyle. Difference between these two meniscofemoral ligaments is the course. Wrisberg ligament, which is the more common variant of these two, travels from the posterior horn of the lateral meniscus and runs upward and posteriorly to the posterior cruciate ligament (PCL) and then inserts to the medial femoral condyle, whereas ligament of Humphrey runs anteriorly to the PCL. (6) (Fig. 1)

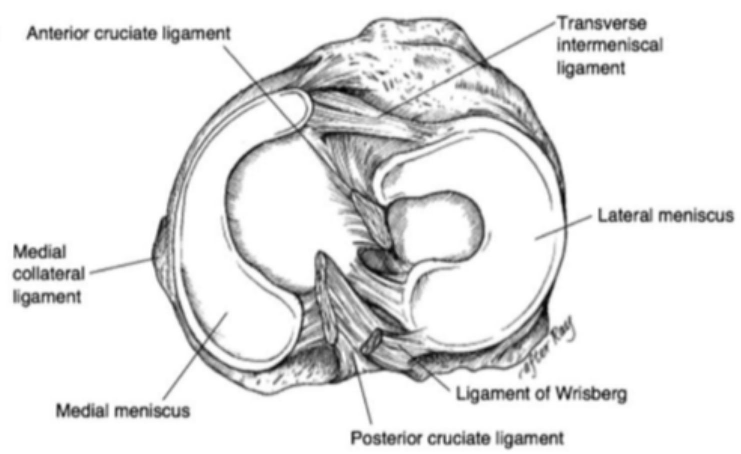

Figure 1. Meniscus anatomy viewed from above.
Fox AJ, Bedi A, Rodeo SA. *The basic science of human knee menisci: structure, composition, and function. Sports Health. 2012 Jul;4(4):340-51.*

1.2.2 Vascular- and Neuroanatomy

In adults the menisci are vascularized only partially by the perimeniscal capillary plexus. The main blood supply to this plexus originates from the lateral inferior genicular artery, medial inferior genicular artery and the middle genicular artery.

Based on the vascularization, the meniscus is classified into three vascular zones. (Fig. 2) The peripheral 1/3 is known as the “red-red zone”, this is the most vascularized zone and due to its high vascular concentration has the best healing potential. The middle 1/3 is called the “red-white zone”. This zone is partially vascularized and diffuse dependent from the “red-red zone”. The healing potential in this zone is less predictable. The inner 1/3 of the meniscus is termed the “white-white zone” and is avascular in adults. This zone is nourished by the passive diffusion from the synovial fluid. Thus, tear in this zone have a poor healing potential and the outcomes after repair attempts remains poor. (7)

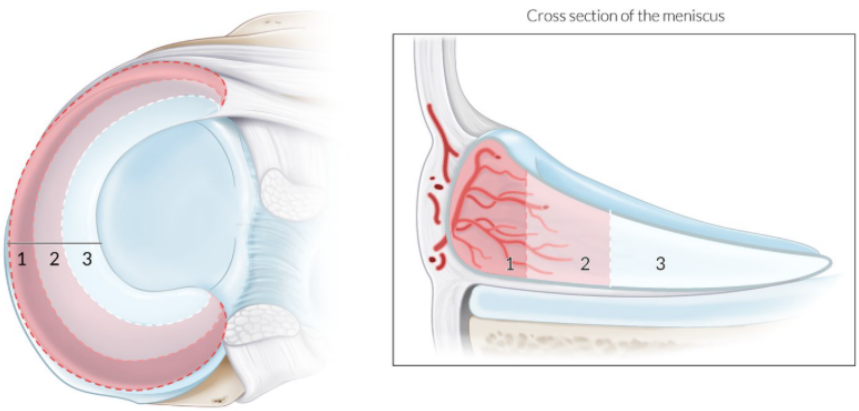

Figure 2. Vascular zones of the meniscus seen in superior view on the left and cross section on the right. Retrieved from Amboss.
https://next.amboss.com/us/article/oQ00Cf?q=meniscus+anatomy#Zca3c68d7291c39ae629d05695999a6df

The innervation of the menisci is through posterior articular branch of the posterior tibial nerve and the femoral and obturator nerve terminal branches. Some parts of the lateral capsule are also innervated by the common peroneal nerve branch, which is called recurrent peroneal nerve. (9)

Similarly to the vascular anatomy, neural components are distributed more on the peripheral outer third and anterior and posterior horns of the menisci rather than the central parts. In these regions both mechanical and sensory nerve fibers have been recognized. These neural components contribute both to pain signalling and proprioception of the knee and are important for maintaining tissue homeostasis in the knee. (7)

1.3 Biomechanics and Functions of the Knee Menisci

The importance of the menisci in everyday life is well documented. Like previously was briefly mentioned menisci execute many significant functions. In 1948, Fairbank published a study where he demonstrated degenerative changes in the knee joint after meniscectomy. In his study, Fairbank described that narrowing of the joint space, flattening of the femoral condyle and formation of the osteophytes where due to meniscal removal. (10) After this, several other studies have confirmed Fairbank's findings that the menisci have a protective and load-bearing role in the knee joint. (4)

Meniscal shock absorption functions are related to their viscoelastic properties. Vibrations during walking are absorbed partially by the menisci. In 1983 Voloshin and Wosk demonstrated that in meniscectomized knees shock absorption capacity decreases approximately 20% compared to healthy knees. This again increases the risk of degenerative osteoarthritis later in life. To minimize the risk for developing degenerative changes in the knee joint, meniscal tissue should be preserved whenever it is possible. (11) (9)

Between the convex femoral condyles and flat tibial plateau menisci serve as a stabilising structure that decreases the mismatch between these bony structures, thus making the knee joint more congruent. (4) The lateral meniscus has fewer peripheral attachments compared to medial meniscus. This makes the lateral meniscus more mobile and also less prone to injuries. The medial meniscus on the other hand is more firmly attached to the medial tibial plateau and plays a major role as a secondary stabilizer. (9) Levy et al. demonstrated this by showing that in anterior cruciate ligament (ACL) deficient knees where medial meniscectomy was performed, anterior tibial translation increased almost double in Lachman and Pivot shift tests when compared to ACL deficient knees with intact medial meniscus. (12) Similar to medial meniscus, lateral meniscus serve also as a stabilizer. This was more lately demonstrated by Musahl et al. by showing that rotation and translation in pivot shift test was much greater in those knees where lateral meniscus had been removed compared to intact lateral meniscus. (13) These study results indeed confirm the important role that the menisci serve in knee joint stabilization.

Proprioception is mediated by mechanoreceptors that are located in the anterior and posterior horns and peripheral outer third of the menisci. It is believed that sensation of joint motion is mediated through quick-adapting mechanoreceptors that are called Pacinian corpuscles. The sensation of joint position instead is thought to be mediated through slow-adapting mechanoreceptors called Ruffini endings and Golgi tendon organs. (14) These mechanoreceptor findings confirms that menisci are able to detect proprioception in the knee joint and therefore play a role in the knees sensory feedback mechanism. (15) (16)

Furthermore, both medial and lateral meniscus may have a role in lubrication and nutrition of the knee joint. The mechanisms of this remains still unknown but it is believed that during menisci compression, synovial fluid and specialized proteoglycan called Lubricin is pumped out and transported through specialized microcanals to other parts of the knee joint which then reduces the friction and lubricates the knee joint. (17) (18) These meniscal microcanals are located close to the meniscal blood vessels and communicate with the synovial cavity. It is believed that this connection may provide fluid transport for lubrication and nutrition in the knee joint. (19)

1.4 Classification of Meniscal Tears

Currently no universal meniscal tear classification system has been accepted by the orthopaedic community. Typically, when tears are observed they are categorized according to their morphology and tear pattern. The most common tear types include longitudinal, horizontal, radial, complex and bucket-handle tears. (Fig. 3)

Tears can be further classified also according to the vertical depth of the tear: full-thickness or partial thickness. Different tear types require different treatment modalities which is why it is particularly important to identify and describe the tears accurately. (4) (20)

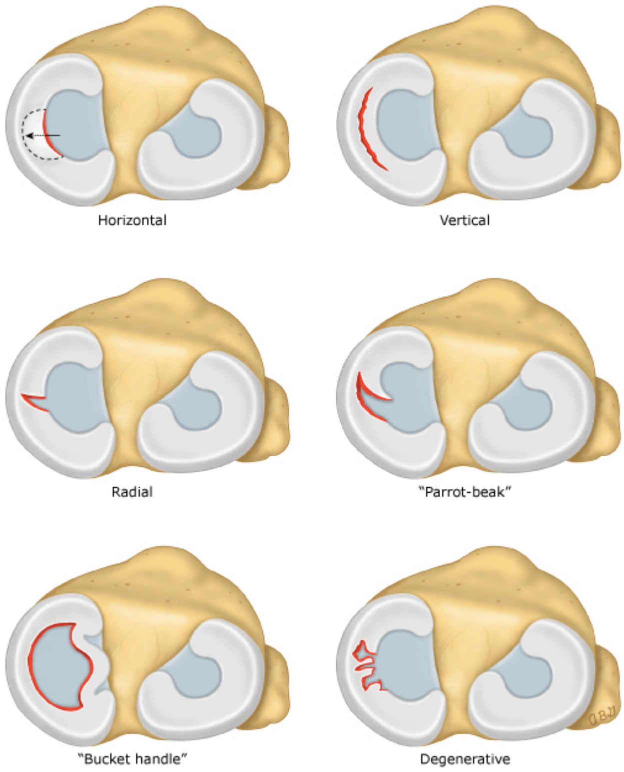

Figure 3. The most common types of meniscal tears.
By Dennis A. Cardone, Bret C. Jacobs, Meniscal Injury of The Knee, UpToDate, 2021

1.5 Operative Management and Surgical Repair Techniques

Limited data have been published regarding the treatment strategies in pediatric group of patients. Although consensus may exist on the operative indications, variability of surgical techniques still persists. As the incidents of reported knee injuries in pediatric and adolescent population is increasing it is particularly important to understand the best available treatment options for these kinds of injuries. (21)

During the last decades the treatment philosophy has changed from tissue removal to tissue preservation, meniscus repair has become the treatment of choice in many cases. Meniscal repair has evolved from open repair to more sophisticated arthroscopic repair. Open repair technique is now rarely used because it has a higher neurovascular injury risk compared to arthroscopic techniques. The main arthroscopic repair techniques include outside-in, inside-out and all-inside techniques.

In both outside-in and inside-out techniques a suture is passed via arthroscopy from either the outside or the inside of the knee and then tied on the join capsule through a small incision. These techniques are suitable especially in meniscal tears located in anterior and middle thirds of the meniscus. Disadvantages in these two techniques compared to all-inside technique are accessory incisions that are needed and the higher risk for neurovascular damage. (22)

In all-inside technique the meniscus tear can be repaired completely intra-articularly and no accessory incisions are needed. Early all-inside techniques were technically challenging and in many cases this technique was more demanding compared to above-mentioned options. Thanks to technologic advances and improved implants, complication incidents have reduced. With the help of new implants, the healing rates have improved, and all-inside technique has become more popular treatment choice. Additional advantage compared to other techniques include also shorter operative time. (23)

However, according to several studies that have tried to establish the optimum repair technique, no statistical difference in the failure rates has been found between the different repair techniques. (22)

1.6 Functional Outcome Measures for Meniscal Tears

Different kinds of patient-reported questionnaires have been developed and used to interpret outcomes after meniscus surgery. These questionnaires help to evaluate symptoms and functional limitations caused by knee injury.

Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) Subjective Knee Form, Lysholm Knee Scale (LKS) and Tegner Activity Scale (TAS) are specific questionnaires commonly used when evaluating meniscus injury patients. In these questionnaires, patients answer questions regarding pain, function, sport activity, quality of life and a total score is calculated. Pre-operative and post-operative scores can be then compared. Higher scores indicate less knee related problems and better outcomes. (24)

2 CLINICAL CASE

A 17-year-old boy came to emergency department after jumping from high. During the clinical evaluation the range of motion was evaluated, a decreased extension of the knee was present. Knee stability was tested with Lachman and pivot-shift tests and no instability was found.

Small effusion was present and joint line tenderness was documented on the medial side. Mcmurray test was positive for the medial meniscus.

Knee MRI was indicated, and it showed a bucket-handle tear in medial meniscus in the left knee. Tear was located in the "red-white zone" of the meniscus and no other injuries were found. An elective arthroscopic repair was scheduled, and patient was operated 1 month after the trauma. Hybrid suturing technique was successfully performed using all-inside and inside-out suturing techniques. In total 5 sutures were used in the operation, 3-all-inside and 2 inside-out sutures.

Surgery was performed under the general anasthesia and standard anteromedial and anterolateral portals were used. Preoperatively a single dose of prophylactic Cefuroxime 1.5 g was given intravenously. (Fig. 4)

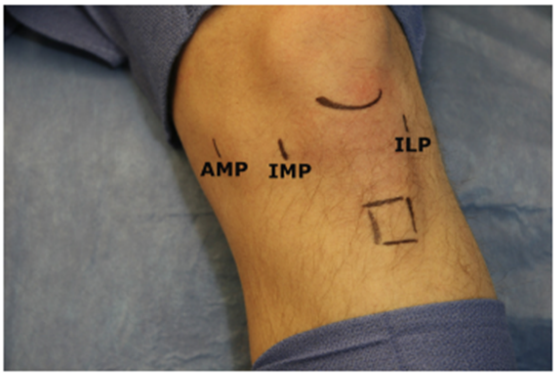

Figure 4. Demonstrative picture of a left knee showing standard portal locations. (AMP, accessory medial portal; ILP, inferolateral portal; IMP, inferomedial portal.)
Hendrix ST, Kwapisz A, Wyland DJ. *All-inside Arthroscopic Meniscal Repair Technique Using a Midbody Accessory Portal. Arthrosc Tech. 2017 Oct 16;6(5): e1885-e1890.*

An examination probe was used to assess the localization, stability and repairability of the meniscal tear. A displaced bucket-handle tear was found, and it was reduced with the probe. Before the repair an arthroscopic shaver was used to prepare the tear edges and a rasp was used to generate capillary bleeding.

All-inside sutures were performed arthroscopically using the Fast-fix device by Smith & Nephew, following the manufacturer's technical guidelines. (Fig. 5)

For inside-out sutures, cannulated guides were used to pass suture needles through both ends of the meniscal tear. For protection of saphenous nerve and peroneal nerve branches, no additional incisions were made. Stab incisions were used instead to tie the knots on the joint capsule. At the end of the surgery, incisions were closed with absorbable nylon sutures.

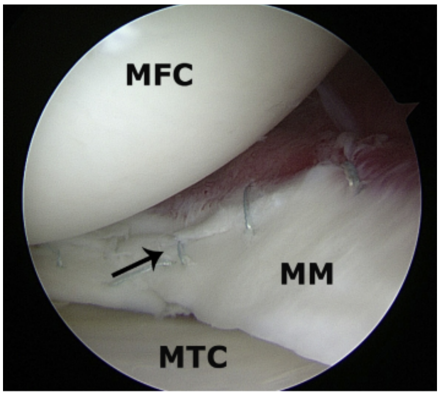

Figure 5. Demonstrative picture of a left knee viewed from the inferolateral viewing portal after a medial meniscal repair using all-inside technique. (MFC, medial femoral condyle; MM, medial meniscus; MTC, medial tibial condyle.)
Hendrix ST, Kwapisz A, Wyland DJ. *All-inside Arthroscopic Meniscal Repair Technique Using a Midbody Accessory Portal. Arthrosc Tech. 2017 Oct 16;6(5): e1885-e1890.*

Postoperative management plan was as follows; during the first six weeks after the surgery patient wear a knee orthosis, first four weeks with 0/60 degree of motion and the last two weeks with 0/90 degrees. Additionally, partial weight bearing was instructed for the first four weeks and after that total weight bearing was allowed. Return to sports was recommended six months after the surgery. Ibuprofen 600 mg 1x1-3 and Paracetamol 1000 mg 1x1-3 per day was prescribed for the pain and for stomach protection Pantoprazole 40 mg 1x1 per day was prescribed. No thromboprophylaxis was needed in this case.

During preoperative visit patient was interviewed and his symptoms and knee functioning was evaluated using the Lysholm knee score and Pedi-IKDC score. Preoperatively Lysholm score was 42 and Pedi-IKDC was 28.73.

Post-operative period was without complications and recovery process went smoothly. The last follow-up visit was 15 months after the operation. Patient did not have any complains and he was able to live his usual active life. During the last follow-up visit Lysholm and Pedi-IKDC scores were again evaluated. Both scores were significantly improved; Lysholm score was 100 whereas Pedi-IKDC was 98.90. (Fig. 6)

Patient's quality of life was also assessed during the last follow-up using the PedsQL questionnaire and the score at the follow-up was 96.73/100, indicating a very good quality of life. Additionally, an MRI of the left knee was taken during the last follow-up and it showed a fully healed medial meniscus. In this particular clinical case, both functional outcomes and MRI showed significant improvement after the arthroscopic suture surgery using hybrid suturing techniques.

orthotoolkit

Lysholm Knee Scoring Scale

Patient Name: ______________________

Date: ______________________

Affected Knee: (R) L (Circle One)

Limp

☑ I have no limp when I walk	+5
☐ I have a slight or periodical limp when I walk	+3
☐ I have a severe and constant limp when I walk	+0

Support

☑ I do not use a cane or crutches	+5
☐ I use a cane or crutches with some weight-bearing	+2
☐ Putting weight on my hurt leg is impossible	+0

Locking

☑ I have no locking and no catching sensation in my knee	+15
☐ I have catching sensation but no locking sensation in my knee	+10
☐ My knee locks occasionally	+6
☐ My knee locks frequently	+2
☐ My knee feels locked at this moment	+0

Instability

☑ My knee never gives way	+25
☐ My knee rarely gives way, only during athletics or other vigorous activities	+20
☐ My knee frequently gives way during athletics or other vigorous activities; in turn I am unable to participate in these activities	+15
☐ My knee occasionally gives way in daily activities	+10
☐ My knee often gives way in daily activities	+5
☐ My knee gives way every step I take	+0

Pain

☑ I have no pain in my knee	+25
☐ I have intermittent or slight pain in my knee during vigorous activities	+20
☐ I have marked pain in my knee during vigorous activities	+15
☐ I have marked pain in my knee during or after walking more than 1 mile	+10
☐ I have marked pain in my knee during or after walking less than 1 mile	+5
☐ I have constant pain in my knee	+0

Swelling

☑ I have no swelling in my knee	+10
☐ I have swelling in my knee only after vigorous activities	+6
☐ I have swelling in my knee after ordinary activities	+2
☐ I have swelling constantly in my knee	+0

Stair-climbing

☑ I have no problems climbing stairs	+10
☐ I have slight problems climbing stairs	+6
☐ I can climb stairs only one at a time	+2
☐ Climbing stairs is impossible for me	+0

Squatting

☑ I have no problems squatting	+5
☐ I have slight problems squatting	+4
☐ I cannot squat beyond a 90° bend in my knee	+2
☐ Squatting is impossible because of my knee	+0

Scoring Guide:

Lysholm Knee Score: Summation of points

Lysholm Knee Score: 100 Points

Figure 6. Lysholm Knee Scoring Scale representing thesis case. Retrieved from Orthotoolkit.

3 DISCUSSION

Meniscal tears in young patients are usually related to sport injuries, such as football, soccer, basketball and skiing and accounting approximately one third of the meniscal injuries in this particular population. (3) The injury mechanism commonly involves cutting and pivoting movements in knee flexion or hyperextension and actions dealing with great force leading to shear load on the meniscus. (25)

Common symptoms related to meniscal tears include physical impairment, pain, swelling and less often, depending on the tear type and severity, mechanical symptoms such as locking, grinding, catching, knee instability and decreased range of motion.

Accurate diagnosis of meniscal tears can be done through detailed history and physical examination alone in many cases. Nevertheless, radiographic studies using X-Ray and MRI is crucial to confirm the clinical suspicions and to localize and classify meniscal tears more precisely. X-Ray is usually taken first to rule out possible concomitant fractures but it is not useful detecting soft tissue injuries such as meniscal tears. MRI is the imaging modality of choice, with sensitivity as high as 93% and specificity 88% for medial meniscal tear and for lateral tear 79% and 95% respectively. (7) (23)

Despite high diagnostic accuracy of MRI some problems can exist. Multiple previous studies have shown high percentage of asymptomatic patients with meniscal tear findings in MRI. This can lead to overtreatment of patients and therefore it is important not only to look for MRI findings when making treatment decisions but to correlate these findings with physical examination results and symptoms of the patients. (7) Diagnostic arthroscopy is also an accurate screening tool, but MRI is the preferred choice in many cases because surgical risks can be avoided with MRI. (23)

To assess the successfulness of meniscal repairs, different kinds of PROMS are used in studies to evaluate patient's functional outcomes. Furthermore, MRI can be used to evaluate the healing process of the menisci after the repair.

The Knee Injury and Osteoarthritis Outcome Score (KOOS) include questions from 5 subscales: pain, other symptoms, physical functioning during daily living, sports activity and quality of life. Scores are calculated for each subscale separately since it is recommended to analyse the five domains individually, score of 100 indicates no symptoms whereas score of 0 indicates extreme symptoms. KOOS-child is a modified version of the questionnaire used to evaluate children aged 7-16 years. (24)

IKDC Subjective Knee Form has been used to evaluate a variety of knee disorders such as ligamentous and meniscal injuries as well as osteoarthritis and patellofemoral pain syndrome.

Questionnaire include questions from symptoms (7 items), functioning (2 items) and sports activity (2 items). Maximum score is 100 points, and 0 points is the lowest. Pedi-IKDC is a modified version of IKDC and is used with children and adolescents aged 9- to 18-years-old.

Lysholm knee scoring scale was originally designed to evaluate patients who underwent a knee ligament surgery, but it's proven to be valid and reliable tool to assess other knee related problems as well. Lysholm score consists of 8 questions that evaluate limping, need for support, locking, instability, pain, swelling, climbing stairs and squatting. Total score ranges from 100 to 0. Higher scores indicate lesser symptoms and higher level of functioning. (24) (26)

Tegner activity scale (TAS) is often used together with Lysholm knee score and it was originally created to complement it. Tegner scale is a one item score that is used to determine patient's activity level in work and sports activities before and after the injury. The scores range from 0 to 10. A score between 8-10 represents the ability to play competitive sports in high levels whereas a score of 0 indicates a sick-leave or disability because of the knee problem. (27)

As already mentioned, during recent decades meniscal tear treatment has shifted from tissue removal to tissue preservation and nowadays it's recommended to save meniscus tissue as much as possible. Data shows that loss of meniscal tissue increase the risk for early degenerative changes and may lead to lower quality of life. This is particularly important in pediatric population. Thanks to technologic advances, meniscus tear techniques have evolved, and meniscus repair has become a popular treatment option. Due to its increased popularity also, many studies have been published regarding the long-term outcomes after meniscal repair.

The main finding in above mentioned clinical case was that both functional outcome scores and MRI showed significant improvement after meniscal repair. Functional outcomes were evaluated in this particular case using Lysholm knee score (LKS) and Pedi-IKDC. Preoperative LKS increased from 42 to 100 in the last follow up. Also, Pedi-IKDC increased from 28.73 to 98.9. Additionally, a postoperative MRI was taken, and it showed a fully healed meniscus. Unfortunately, due to Covid-19 and patient data security reasons only one patient case with limited patient information could be used in this thesis.

Many other studies have also reported similar functional outcome scores following meniscal repair. Liechti et al. (28) published a systematic review regarding the outcomes in pediatric population after meniscal repair in 2019. A total of 1003 studies were retrieved by authors but only eight studies fulfilled the inclusion criteria. The review included 287 patients with mean age of 15.1 years and a total of 301 meniscal tears were included. The average follow-up time in the selected studies were 51.6 months. Different tear patterns and locations were reported with the predominance of complex and bucket-handle tears. In the selected studies the most common repair techniques included inside-out and all-inside techniques. (Table 1.)

Outcomes were evaluated using Lysholm knee score (LKS), Tegner activity score (TAS), International knee documentation committee (IKDC) score, 36-Item Short Form Health Survey and need for reoperation. Postoperative LKS was measured in five studies and the average score ranged from 85.4 to 96.3. In two studies, both pre- and postoperative LKS were reported and in both of these studies, scores were improved after meniscal repair. Five out of eight studies that were included in the systematic review included pre- and postoperative TAS. The average postoperative TAS ranged from 6.2 to 8 but only two studies reported improvement in TAS. IKDC was measured both pre- and postoperatively in two studies. Post-operative IKDC ranged from 89.4 to 90.3 and both of these studies showed improvement. Surgical failure was documented in 52 out of the total 301 meniscal repairs, giving a failure rate of 17.3%. Failure was defined by the need for reoperation. Because of different outcome measures were used in the systematic review, objective conclusions cannot be made. Nevertheless, the data collected in the review showed improvement in functional outcome scores following meniscal repair suggesting that meniscal repair in pediatric population is an effective treatment option that has a relatively low failure rate.

Study Design, Patient Demographics, and Outcomes of the Included Pediatric Meniscal Repair Studies[a]

Lead Author	Study Design	Technique	No. of Patients (Menisci)	Sex	Mean Age, y (range)	Mean Follow-up (range)	Time From Injury to Surgery	Outcome Measures
Lucas[15]	Case series	1 outside-in 17 all-inside 1 abrasion	17 (19)	9 M 8 F	14 (9-18)	22.3 mo (3.5-46 mo)	5.3 mo	Lysholm, Tegner, MRI
Mintzer[17]	Case series	25 inside-out 4 all-inside	26 (29)	12 M 14 F	15.3 (11-17)	5.0 y (2-13.5 y)	6.7 mo	IKDC, Lysholm, SF-36
Kraus[11]	Case series	25 all-inside 4 outside-in	25 (29)	13 M 12 F	15 (4-17)	2.3 y (1.2-5.1 y)	Not reported	Lysholm, Tegner
Vanderhave[24]	Case series	Inside-out for all	45 (49)	31 M 14 F	13.2 (9-17)	27 mo (17-52 mo)	88 d	IKDC, Tegner
Accadbled[1]	Case series	4 all-inside 4 outside-in 2 additional open arthrotomy 1 inside-out 1 abrasion	12 (12)	7 M 5 F	13 (8-16)	37 mo (24-58 mo)	7 mo	IKDC, Lysholm, Tegner, MRI, SF-36
Krych[12]	Case series	17 inside-out 13 hybrid 15 all-inside	44 (45)	38 M 6 F	15.8 (9.9-18.7)	5.8 y (2.5 mo to 13.8 y)	69 d for the successfully repaired menisci 77 d for failed initial repair	IKDC, Tegner
Schmitt[22]	Retrospective study	19 all-inside meniscal	19 (19)	12 M 7 F	14.8 (9.1-16.3)	6.1 y (3-9 y)	Not reported	IKDC, Lysholm, Tegner, KOOS
Krych[13]	Case series	29 inside-out 64 all-inside 6 hybrid	99 (99)	43 M 56 F	16 (13-18)	8 y (2-19 y)	107 d	Tegner, IKDC

[a]All studies were level 4 evidence. F, female; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; M, male; MRI, magnetic resonance imaging; SF-36, 36-Item Short Form Health Survey.

Table 1. Liechti DJ, Constantinescu DS, Ridley TJ, Chahla J, Mitchell JJ, Vap AR. *Meniscal Repair in Pediatric Populations: A Systematic Review of Outcomes. Orthop J Sports Med. 2019 May 13;7(5):2325967119843355.*

Another study by Özcafer et al. (29) reported significant improvements in functional outcome scores at the final postoperative follow-up. In their study a total of 50 patients with mean age of 32.9 ±7.6 underwent an arthroscopic medial meniscal repair for either longitudinal or bucket-handle tears and were retrospectively assessed. Functional outcome scores were evaluated pre- and postoperatively using the LKS, IKDC, TAS and KOOS scores. The mean follow-up time ranged from 36 to 110 months. At the final postoperative follow-up LKS, IKDC, TAS and KOOS scores showed significant improvement compared to preoperative scores. (Table 2)

TABLE II Comparative results of pre- and postoperative outcome scores			
	Preoperative	Postoperative	
	Mean±SD	Mean±SD	*p*
LKS	24.1±19.5	85.0±12.2	0.001
TAS	2.9±1.4	4.9±1.9	0.012
IKDC	23.8±10.1	74.6±21.3	0.001
KOOS	37.6±14.8	79.9±14.6	0.001

SD: Standard deviation; LKS: Lysholm Knee Score; TAS: Tegner Activity Scale; IKDC: International Knee Documentation Committee; KOOS: Knee Injury and Osteoarthritis Outcome Score.

Table 2. Pre- and postoperative functional outcome scores.
Özcafer R, Dırvar F, Mısır A, Dinçel YM, Büyükkuşçu MÖ, Aykut ÜS. *Mid-term evaluation of clinical and functional outcomes after arthroscopic medial longitudinal and bucket-handle meniscus repair. Jt Dis Relat Surg. 2021;32(2):363-370.*

According to these studies, meniscal repair is an effective treatment option particularly in longitudinal and bucket-handle tears. The data showed improved clinical and functional outcomes and low failure rates in both pediatric and adult population suggesting that meniscal repair can be performed in older individuals as well.

Although MRI has a high accuracy for detecting meniscal tears and is almost always used before surgery, the usefulness of postoperative MRI to evaluate successfulness and healing status after meniscal repair is more debatable. Hoffelner et al. (30) published a study in 2010 where the purpose was to correlate clinical and radiological results using 3-T MRI to confirm meniscal healing after all-inside meniscal repair. A total of 27 patients with an average age of 31 ± 9 years was selected. Medial meniscus repairs were performed in 19 patients whereas lateral meniscus repairs were performed in 8 patients. A concomitant ACL reconstruction was performed in 17 patients. The mean follow-up period was 4.5 ± 1.7 years. LKS and TAS were used to evaluate functional outcomes. To evaluate meniscus healing using MRI, four grades were used: central globular (grade 1); linear horizontal or band-like (grade 2); intrameniscal alterations and linear signal alterations communicating with the articular surface (grade 3); and complex tears (grade 4).

At the follow-up, the average LKS was 76 ± 15 and TAS ranging from 2 to 6 with majority of the patients belonging to group 6. According to MRI findings, 3 patients did not show any signal alteration, 0 patients belonged to grade 1, 5 patients had grade 2, 13 patients had grade 3 and 6 patients had grade 4 signal alterations. Nineteen out of the total 27 patients included in the study had no complains at the follow-up.

In their study Hoffelner et al. found no significant correlation between the functional outcome scores and radiological grading, meaning that patients with good clinical outcomes could still show high radiological grades in MRI and vice versa. They also concluded that it is very difficult to distinguish between post repair scar tissue and a new tear because a scar in healed meniscus can mimic the signals that can be seen in meniscal tears.

Pujol et al. (31) reported similar results in their 10-year follow-up after arthroscopic meniscal repair. They concluded that MRI is not suitable for evaluating meniscal healing after meniscal repair. Furthermore, they reported that several vertical or horizontal hypersignals can be seen in MRI 10 years after the repair although patients are asymptomatic. (Table 3.)

Neither showed this study correlation between clinical outcomes and MRI signals in the repaired meniscus.

Summary of the MRI features of the meniscus ten years after repair

Meniscus	No hypersignal	Hypersignal			Bone marrow oedema	Extrusion
		Horizontal	Vertical	Complex		
Lateral meniscus, $n = 8$	3 (37.5 %)	4 (50 %)	1 (12.5 %)	0	0	0
Medial meniscus, $n = 15$	0	5 (33 %)	6 (40 %)	4 (27 %)	1 (femoral side)	2
Total, $N = 23$	3 (13 %)	9 (39 %)	7 (30 %)	4 (17.5 %)	1 (4.3 %)	2 (8.7 %)

Table 3. Pujol N, Tardy N, Boisrenoult P, Beaufils P. *Magnetic resonance imaging is not suitable for interpretation of meniscal status ten years after arthroscopic repair. Int Orthop. 2013 Dec;37(12):2371-6.*

In the light of the two above-mentioned studies, MRI is not very suitable postoperatively for assessing meniscal healing and therefore routine postoperative MRI should not be recommended.

From patient’s standpoint, postoperative clinical and functional outcome scores can often give more relevant information about the meniscus healing status and successfulness of the repair than MRI findings. However, MRI is a valuable diagnostic tool if symptoms reoccur or get worse after the operation.

4 CONCLUSIONS

In conclusion, the available data suggest that arthroscopic meniscal repair provides good clinical and functional results at the follow-up with relatively low failure rates and is suitable treatment option in both pediatric and adult population. Based on the studies reviewed, a postoperative MRI is not very suitable for assessing successfulness of the repair because it is difficult to distinguish between healed postoperative scars and recurrent tears. On the other hand, in the clinical case presented above, magnetic resonance imaging showed a healed meniscus 15 months after the operation during the last follow-up visit, this finding was controversial to above mentioned studies regarding the findings of postoperative MRI.

In the future, improved magnetic resonance imaging sequencing is needed to evaluate postoperative meniscal healing more precisely. Addition to this, more research regarding its usefulness during postoperative period is required.

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Figure 1. Meniscus anatomy viewed from above.
Fox AJ, Bedi A, Rodeo SA. *The basic science of human knee menisci: structure, composition, and function. Sports Health. 2012 Jul;4(4):340-51.*

Figure 2. Vascular zones of the meniscus seen in superior view on the left and cross section on the right.
https://next.amboss.com/us/article/oQ00Cf?q=meniscus+anatomy#Zca3c68d7291c39ae629d05695999a6df

Figure 3. The most common types of meniscal tears.
Dennis A Cardone, Bret C Jacobs. *Meniscal Injury of The Knee, UpToDate, 2021 https://www.uptodate.com/contents/meniscal-injury-of-the-knee?search=meniscus%20tear&source=search_result&selectedTitle=1~55&usage_type=default&display_rank=1*

Figure 4. Demonstrative picture of a left knee showing standard portal locations. (AMP, accessory medial portal; ILP, inferolateral portal; IMP, inferomedial portal.)
Hendrix ST, Kwapisz A, Wyland DJ. *All-inside Arthroscopic Meniscal Repair Technique Using a Midbody Accessory Portal. Arthrosc Tech. 2017 Oct 16;6(5): e1885-e1890.*

Figure 5. Demonstrative picture of a left knee viewed from the inferolateral viewing portal after a medial meniscal repair using all-inside technique. (MFC, medial femoral condyle; MM, medial meniscus; MTC, medial tibial condyle.)
Hendrix ST, Kwapisz A, Wyland DJ. *All-inside Arthroscopic Meniscal Repair Technique Using a Midbody Accessory Portal. Arthrosc Tech. 2017 Oct 16;6(5): e1885-e1890.*

Figure 6. Lysholm Knee Scoring Scale representing thesis case.
https://orthotoolkit.com/tegner-lysholm/static/media/Tegner-Lysholm-Knee-Score.e27a5c1f.pdf

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