Meniscal root tears

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Meniscal Root Tears

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ABBREVIATIONS:

- ECM: Extra Cellular Matrix
- MCL: Medial Collateral Ligament
- LCL: Lateral Collateral Ligament
- ACL: Anterior Cruciate Ligament
- PCL: Posterior Cruciate Ligament
- BMI: Body Mass Index
- MPRT: Medial Posterior Root Tear
- LPRT: Lateral Posterior Root Tear
- TKA: Total Knee Arthroplasty
- MRI: Magnetic Resonance Imaging

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1. ABSTRACT

Title: Meniscal Root Tears

Key words: meniscal roots, medial meniscus, lateral meniscus, meniscectomy, meniscal root repairs

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Meniscal root tears are defined as lesions at the insertions of the menisci. Since their first identification, they are now considered a major orthopaedic issue regarding the biomechanics of the knee joint. Menisci integrity is required for proper load transmission to the knee. These injuries cause changes in joint loading and weight load bearing due to failure of the meniscus to resist compression. It can result in joint overstress and degenerative changes in the knee.

The lesions can be divided in two main categories: acute injuries and chronic injuries. Acute lesions usually are traumatic in origin and involve mainly the lateral meniscus. Chronic lesions are degenerative and the medial meniscus is most likely to be affected. The goal of this review is to make a descriptive distinction between all the possible lesions of the roots of the menisci, to identify risk factors and how to make a diagnosis. All these steps are meant to evaluate all the possible treatments, conservative and surgical, in order to get the best positive clinical outcomes out of it.

1.1 SAZETAK

Naslov: Avulzijske Ozljede Korijena Meniska

Ključne riječi: korijena meniskusa, medijski meniskus, lateralni meniskus, meniscektomija, popravak korijena meniskusa

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Lezije korijena meniskusa definiraju se kao poderotine na umetcima meniskusa. Od njihove prve identifikacije smatraju se jednim od glavnih ortopedskih problema u biomehanici zgloba koljena. Integritet meniscusa je neophodan radi pravilnog prijenosa opterećenja na koljeno. Ove ozljede uzrokuju promjene u opterećenom zglobu i opterećenju teškog tereta uslijed nemogućnosti meniskusa da se odupre kompresiji. To može rezultirati preopterećenju zglobova i degenerativnih promjena u koljenu. Lezije se mogu podijeliti u dvije glavne kategorije: akutne ozljede i kronične ozljede. Akutne lezije su obično traumatskog porijekla i uglavnom uključuju lateralni meniskus. Kronične lezije su degenerativne, a obično je zahvaćen medijski meniskus. Cilj ovog preglednog rada je napraviti deskriptivnu razliku između svih mogućih lezija korijena meniskusa, identificirati čimbenike rizika i kako postaviti točnu dijagnozu. Svi ovi postupci namijenjeni su ocjenjivanju svih mogućih tretmana, konzervativnih i kirurških, kako bi se dobili najbolji pozitivni klinički ishodi.

2. INTRODUCTION

The knee joint has two menisci. Each meniscus is a crescent-shaped fibrocartilage which divide partly a joint cavity. They are crucial to the healthy knee. They are responsible for load transmission across the knee, increasing the conformity between the articular surfaces while reducing the joint contact pressure. They are shock absorbers and they are involved in stabilization, proprioception, lubrication and nutrition for the joint articular cartilages.

Each meniscus has two insertions, an origin and an attachment. These 4 strong ligaments in clinical practise are referred as roots and they link this moon shaped cartilages to the articular surface of the tibial bone, also called tibial plateau. (14) Meniscal roots are essential for maintaining the meniscal ability to convert axial loads into circumferential tension. Participation in sports and recreational activities are risk factors for knee injury. (13) Often unrecognised, when a root tears, the knee cartilages are exposed to increased stress. These are severe meniscal injuries that predispose the knee joint to degenerative changes and early osteoarthirtis. Moreover, injuries to the meniscal attachments can also lead to meniscal extrusion, decreased contact surface, and ultimately articular degeneration. (14)(15).

These root lesions can occur in two different settings: (i) acute and ii) chronic. Acute root tears usually take place in acute knee traumas; they can usually be seen as sport injuries. Chronic root tears instead are mainly seen in degenerative diseases where the knee is involved. (15)

Common clinical symptoms are knee pain, joint line tenderness and mechanical symptoms such as locking, giving away and catching. (16) Although, these symptoms can vary greatly among patients, ranging from undetectable to very severe.

Management is variable based upon many factors like the injury itself, its timing and the baseline conditions. It spans from a non-operative and conservative approach to complete surgical interventions if the former becomes refractory and fails. (15)

2.1. Knee Anatomy

The knee is the largest joint in the body and it is also one of the most complex. Due to its importance in weight-bearing and body movements, it is also one the most susceptible to injuries. (82) Four main structures are involved in the knee joint: bones, cartilage, ligaments, and tendons.(1)

The knee is a synovial joint, a membrane bag covered by hyaline cartilage. It means it contains a fluid-filled capsule. This viscous fluid filling the capsule, called synovial fluid, is secreted by the

so-called synovial cells located in the inner side of the covering membrane. It fulfils very important functions in lubricating and nourishing the joint. Not only, It also crucial in the mechanics of the knee: it increases the elasticity and viscosity of the articular cartilage while reducing friction between the articular surfaces of the bones.

Moreover, within the knee joint there is also another dozen of small fluid-filled sacs. These bursae reduce friction between all the tissues of the knee preventing inflammation and degeneration.(1)

Three bones meet to form the knee joint: femur, tibia and patella. This is where the condyles of the femur (medial and lateral) sits on the tibial plateau at the proximal end of the tibia. The knee joint in fact keeps these bones in place.

The patella, or kneecap, is a small, triangle shaped bone that sits at the front of the knee, and it lies within the quadriceps muscle. It endures a great deal of force and to bear this burden it is provided of a very thick layer of cartilage, the thickest of the body. The knee comprises 2 articulations—the patellofemoral and tibiofemoral articulation. (2)

The knee joint is made of two types of cartilages: the articular cartilages and the menisci.

The ends of the femur and tibia, and the back of the patella are covered with articular cartilage. This slippery tiny substance helps the knee bones to glide smoothly across each other in bending or straightening your leg. The menisci instead are two wedge-shaped pieces cartilage that act as "shock absorbers" between femur and tibia. Differently, the meniscus is tough and rubbery to help cushion (here it is the “shock-absorbing” capacity of the knee) and stabilize the joint. They prevent femur and tibia to directly rub against each other so to avoid damages. They are highly innervated in order to help improve balance and stability and ensure the correct weight distribution between the femur and tibia. According to their anatomical position inside the joint, there is a medial and a lateral meniscus. The articular surfaces of the bones are connected to each other by ligaments, very strong fibrous tissue bands . This four ligaments act to hold firmly the bones together and keep the knee stable. They are paired and distinguished by anatomical position. The collateral ligaments are on each side of the knee joint from where they get the name from: medial and lateral collateral ligament (MCL and LCL). They control the sideways motion of your knee and brace it against unusual movement, preventing side to side movement of the femur. Another pair of ligaments, the cruciate ligament, they are found inside the knee joint and they get they name from the characteristic X shape they form anatomically once they cross over each other. The anterior cruciate ligament (ACL) lies in front and the posterior cruciate ligament (PCL) lies in the back. The cruciate

ligaments control the back and forth motion of your knee. More specifically, ACL prevents the femur from sliding backward on the tibia, and the tibia from sliding forward on the femur; the PCL prevents the femur from sliding forward on the tibia, or the tibia from sliding backward on the femur. (2) (3)

Finally tendons also play an important role in the knee joint. They provide further stability to the knee. They are tough bands of soft tissue that link bone to muscle. The quadriceps tendon and the patellar tendon connects the muscles of the thigh and the leg to the knee joint. (1)(15)

2.2. Knee Movements

The knee is a hinge joint, also called ginglymus. Compared to a ball and socket joint, it is stronger but it shows less range of motion. (1) In this type of joint, the articular surfaces are structured in a particular manner as to permit motion in only one plane. It means they are uniaxial. It is though consider a less typical hinge-joint, as it allows a slight degree of rotation and a side-to-side movement in certain positions of the lower limb. (2)

Although they are not technically part of the knee joint, the muscles are what moves the knee joint. Flexion and extension are the two main movements possible. (1) (2)

The hamstrings and quadriceps are the muscles that strengthen the leg and help flex the knee and they essentially work together. The quadriceps muscles they all originate somewhere higher in the leg or in the hip bone and insert in the patella. The quadriceps straighten the knee, allowing extension of the knee while the hamstrings instead bend the knee, allowing flexion. The gluteal muscles, gluteus medius and minimus, take part in positioning the knee. Small range rotary movements are also possible. They are permitted by ligaments depending on whether they are relaxed or tense. Small lateral movements can also be done with the knee flexed at 90°. (1)(3)

2.3. Menisci anatomy

The knee joint comprises two semilunar-shaped fibrocartilages called menisci, differentiated anatomically based on their location inside the knee as medial and lateral meniscus. (3). Microscopically, their composition is basically the same. They have extensive collagen fibre material (70% is collagen type I) infiltrated with cartilage-like cells. Each meniscus appears to be a whitish-jelly cartilage with specialised extracellular matrix (ECM) molecules and a highly specific blood and nerve supply. They are localised at the meeting point between the femoral condyles and the proximal end of the tibia, also called tibial plateau. (3)

Differently from an articular disk, it only partially separates a joint cavity. (4) They are constituted by two types of fibres that run opposite to each other, longitudinal ones that follow the direction of the menisci and a transverse one. (4) According to Shrive et al, these fibers are oriented in a circumferential pattern. This way, any compressive forms to the knee is converted into tensile force and transmitted to the menisci. (1)(3)(78)

The word meniscus comes from the greek word “meniskos” that means “crescent moon".

They are fundamental structures in a healthy knee joint. (3) As they are required to promote stabilisation, support compressive forces and shock-absorbing properties to the knee, they need to be strenghtened and stabilised as well. These tasks are assured by a number of other smaller intracapsular ligaments. Each meniscus is anatomically formed by three parts: an anterior horn, a body and a posterior horn. They show meniscocapsular attachments and 4 meniscal roots that firmly attach the meniscus to the articular cartilages. (4)

The main stabilizing ligaments are the medial collateral ligament, the transverse ligament, the meniscofemoral ligaments, and attachments at the anterior and posterior horns. (7) On the external surface, they fuse with the synovial membrane of the capsule. The two menisci are connected to each other by the transverse ligament of the knee. (3)

2.4. Medial meniscus

The medial meniscus is semicircular, 40 to 45 mm long, and it covers majority of the space in the medial compartment. (8). The coronary ligaments link the medial meniscus to the tibia. Its anterior end is thin and pointed and it joins the tibia in front of the ACL at the anterior intercondyloid fossa. Its posterior end instead is attached peripherally to the joint capsule and joins the tibia at the posterior intercondyloid fossa close where the attachments of the lateral meniscus and the PCL are. Very characteristic is the fusion with the tibial collateral ligament: this makes the medial meniscus far less mobile than the lateral meniscus and more susceptible to injuries. (4) The medial meniscus does not have a direct muscular connection.

Anterior end: inserts along the anterior part of the medial intercondylar eminence, anterior to the apex.

Posterior end: inserts just antero-medial to the posterior cruciate ligament (PCL) on the posterior aspect of the medial tibial intercondylar eminence

2.5. Lateral meniscus

The lateral meniscus is almost circular in shape. It involves a large portion of articular space than the medial meniscus. Even though it is shorter than the medial meniscus, it can present differences in shape, size ad thickness. (9). Differently from the medial meniscus, it has the same width throughout its whole course and its attachments (or horns) are closer to each other. It can be happen to notice a fusion with the posterior aspect of the ACL. (10).

The lateral meniscus is more mobile than the medial meniscus with an anteroposterior range of motion: due to its groove for the popliteal tendon, there is no attachment with the fibular collateral ligament. This way, it is less stressed by movements. In fact while the medial meniscus may shift just a few millimeters, the lateral meniscus may move at least 1 cm.

(4) Contraction by the popliteus during knee flexion pulls the lateral meniscus posteriorly, avoiding entrapment within the joint space.

Anterior end:inserted in front of the intercoldylar eminence and fused deeply beneath the ACL

Posterior end: attached at the back of the intercondylar eminence.

2.6. Meniscal blood and nerve supply

The menisci are supplied mainly from the inferior and superior lateral and medial genicular arteries. All together these vessels anastomose and form the perimeniscal marginal arterial arcades, a plexus supplying also the synovial and capsular tissues. (4)

Blood supply to the menisci is a very remarkable issue, also in terms of treatment and regeneration. This is due to the peculiar growth process: during the first year of life the blood supply is consistent and widely distributed uniformly throughout the whole meniscal body. With the beginning of the physiological weight bearing, the circulatory network slowly constantly diminishes. Only 25-33% of area remain vascular. (11)(81)

In 1990, Renstrom and Johnson reported a 20% decrease in the vascular supply by age 40 years, which may be attributed to weight bearing over time. Around the 4th decade of life in fact the result is that only the periphery is vascular and the center of the menisci is completely avascular. The latter depends entirely upon the synovial fluid for nutrition.

This particular blood supply pattern gives rise to the distinction of three zones in the menisci:

zone 1 (peripheral and vascular), also called red zone, zone 2 (zone of transition) and zone 3 (completely avascular), also called white zone. The presence of a vascular supply to the menisci is

an essential component in the potential for repair. The blood supply must be able to support the inflammatory response normally seen in wound healing. This is the reason why injuries to the menisci show a particular limited regeneration power. They heal very slowly, if not not healing at all, predisposing the zone 1 at permanent post traumatic and degenerative lesions. According to this, roots receive abundant blood supply, thing not seen in the centre of the meniscus.(12)

Repair of lesions in the red zone has yielded good results, according to Stone. Reports describe techniques for manufacturing a vascular access channel from the peripheral vasculature to improve the chance that tissue in the central region will repair itself. (15)

The nerve supply follows the same pattern as the blood circulation: the peripheral areas are well innervated with nociceptors while the center is almost entirely insensitive. (13)(15)

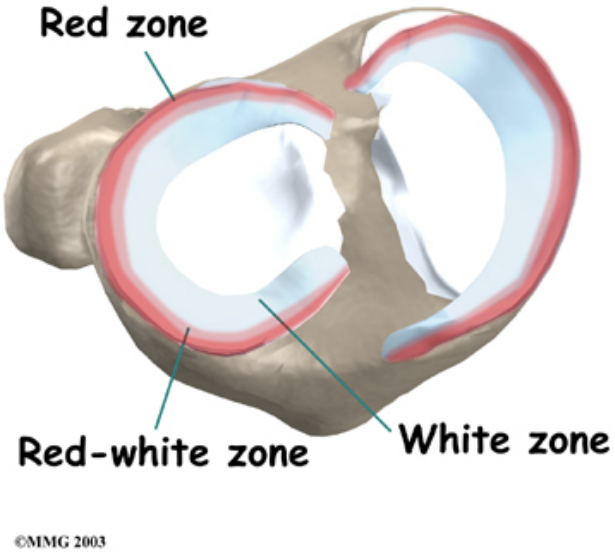

Figure 1. Meniscal blood supply. Red zone (zone 1) is at the periphery and it is the most supplied area. Between the innermost layer (white zone) and the red zone, there is the red-white zone (zone 2), an area of transition. Adapted with permission from eOrthopod, MMG 2003.

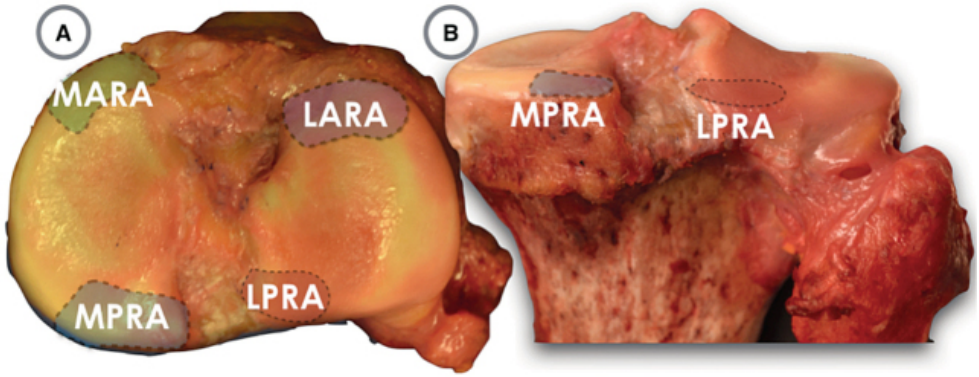

Figure 2. Picture A: Cadaveric image (superior view) demonstrating the anatomical landmarks to identify meniscus posterior root attachment in a right knee. MTE: medial tibial eminence; MARA: medial meniscus anterior root attachment; LARA: lateral meniscus anterior root attachment; MPRA: medial meniscus posterior root attachment; LPRA: lateral meniscus posterior root attachment. Picture B: right knee image demonstrating the close relationship between the posterior root attachment and the PCL. Adapted from Gilbert Moatshe et al, 27 June 2016 Acta Orthopedica 87(5): 452-458.

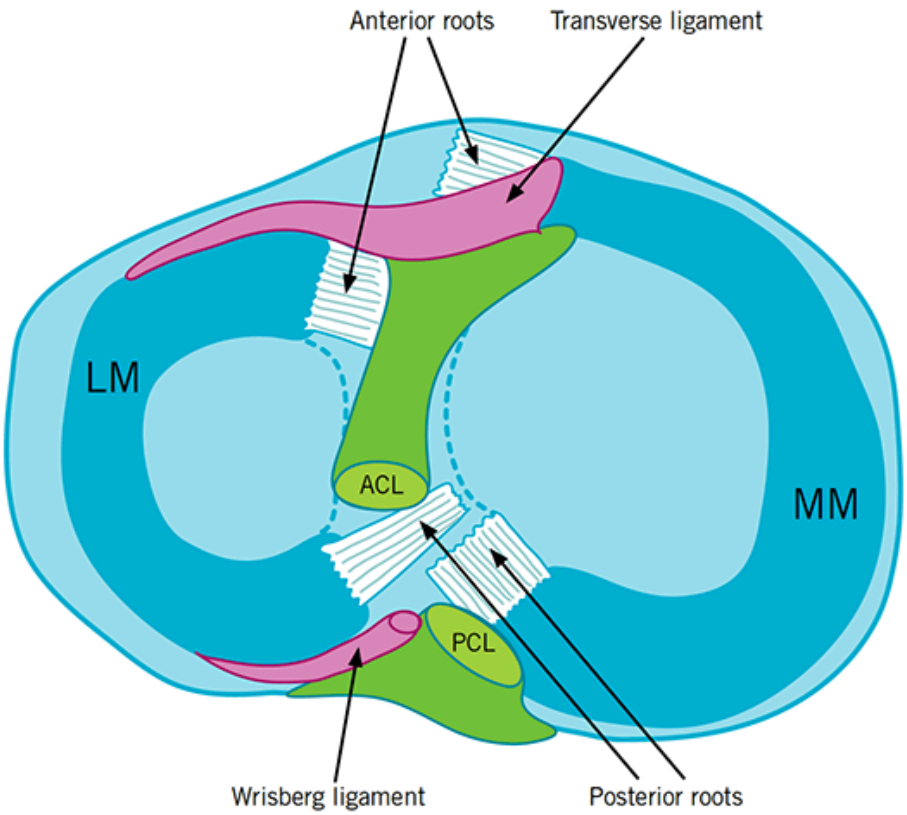

Figure 3. Anatomical configuration of the menisci, meniscal roots and ligaments in the right knee. LM=lateral meniscus; MM=medial meniscus, ACL=anterior cruciate ligament , PCL=posterior cruciate ligament. Adapted with permission from Edoardo Bonasia et all. Orthop Rev (Pavia). (14)

3. AETIOLOGY AND RISK FACTORS

Allaire et al. probably have provided the best definition of meniscal root tears. They are defined as radial tears within 1 cm of the meniscus insertion or avulsions right at the insertion of the meniscus. (79) Described for the first time in a 20-years old football athlete by Pagnani et al. (80), injuries to the meniscal attachments can lead to meniscal extrusion, decreased contact surface, increased cartilage stress, and ultimately articular degeneration.

Meniscal root lesions can be the result of either an acute traumatic event, usually involving mainly the lateral meniscus, and an acute blowout hit to the knee but also the consequence and the result of a chronic and degenerative condition. In these cases, the medial meniscus is almost always affected. In fact, in majority of cases, it occurs in degenerative knees without a specific injury event or after a minor traumatic movement. This is also seen in the clinical figure of spontaneous osteonecrosis of the knee, where the medial femoral condyle is particularly affected. (18)(20).

As a direct consequence of its particular anatomy, the medial meniscus shows the highest tendency to rupture. More in specific, its posterior root attachment is the most delicate due to its almost total immobility. (19). Because of its high tendency to rupture without any warning sign, history of trauma nor clinical history, in the presence of risk factors, the posterior root of the medial meniscus is usually investigated and examined. These chronic, degenerative root tears mainly affect the posteromedial root. (20)

The most common risk factors for degenerative meniscal root ruptures are genetic predisposition, female sex (middle aged women), high body mass index (BMI), increased age, low activity level, smoking status and varus alignment. (21) As reported by Lerer et al,

injury to the medial meniscal root precedes arthritis in around 20% of the patients. Meniscal root lesions are in fact a predisposing factor for degenerative and arthritic changes. (43)

Acute traumas can occur in any common daily activities or in any sport, mainly after the effect of rotational forces on the knee. A common mechanism of injury is either a varus or values force directed to a flexed knee, a twisting motion on the partially flexed, weight-bearing knee (3). Usually root lesions due to acute trauma are associated with rupture of one of the cruciate ligaments as well, mainly the ACL. They are not always immediately visible with radioimaginig and a careful physical examination with palpation of the knee joint as a whole should be done. (23)

While chronic lesions are mainly a middle aged woman issue, acute traumatic injuries are most commonly seen in young male adults. Even in these settings, the most common injured root is the

posterior root of the medial meniscus, basically always present especially in association with multiple knee ligament injuries. Instead, meniscal root lesions are rare injuries in the children population with morphologically normal menisci (22). Regarding the lateral meniscus, root lesions are mainly traumatic associated with knee sprains and other contact injuries. Differently from the lesions of the medial meniscus, in here the root tears are not predisposing to meniscal extrusion due to the presence of an intact meniscofemoral ligament (23).

4. CLASSIFICATION

The lesions of the roots of the meniscus are many and diverse. According to their morphology they can be classified and grouped in different classes. First of all, it is important to get a detailed clinical history, clinical imaging and arthroscopic examination to make a proper diagnosis in order to differentiate which kind of meniscus is involved and which one of its roots is injured, torn or broken. As previously said, the cause of injury is the main determinant: acute trauma involves mainly the lateral meniscus while a chronic degenerative process involves principally the medial meniscus. Another differentiation must be done between anterior and posterior roots of each meniscus. The posterior roots are more likely to be damaged because of their anatomical position.

The medial and lateral posterior root tears can be classified based on their morphology. This type of classification was made by LaPrade et al. (2015). This classification results very important in determining clinical approach and outcome. Following an arthroscopic assessment, according to LaPrade et al. there are 5 different types of posterior root lesions, with increasing damage (24). The most common tear found is the type 2.

Type 1: partial and stable root tears (7%)

Type 2: the most common type. A complete radial tear within the root attachment (68%). They are strongly associated with obesity and older age.

Type 3: a “bucket-handle” tear with complete detachment (6%)

Type 4: complex tear with complete root detachment (10%)

Type 5: a root bony avulsion

Clinicians can also rely on another classification. This system is based on the lateral posterior horns injuries in relation to the compromise of the meniscofemoral ligament. (25) According to Forkel and Petersen (2012), these lesions can be divided in the following subcategories:

Type 1: avulsion of the root with an intact meniscofemoral ligament.

Type 2: radial tear with intact meniscofemoral ligament.

Type 3: complete injury of the torn with rupture of the meniscofemoral ligament. (25)

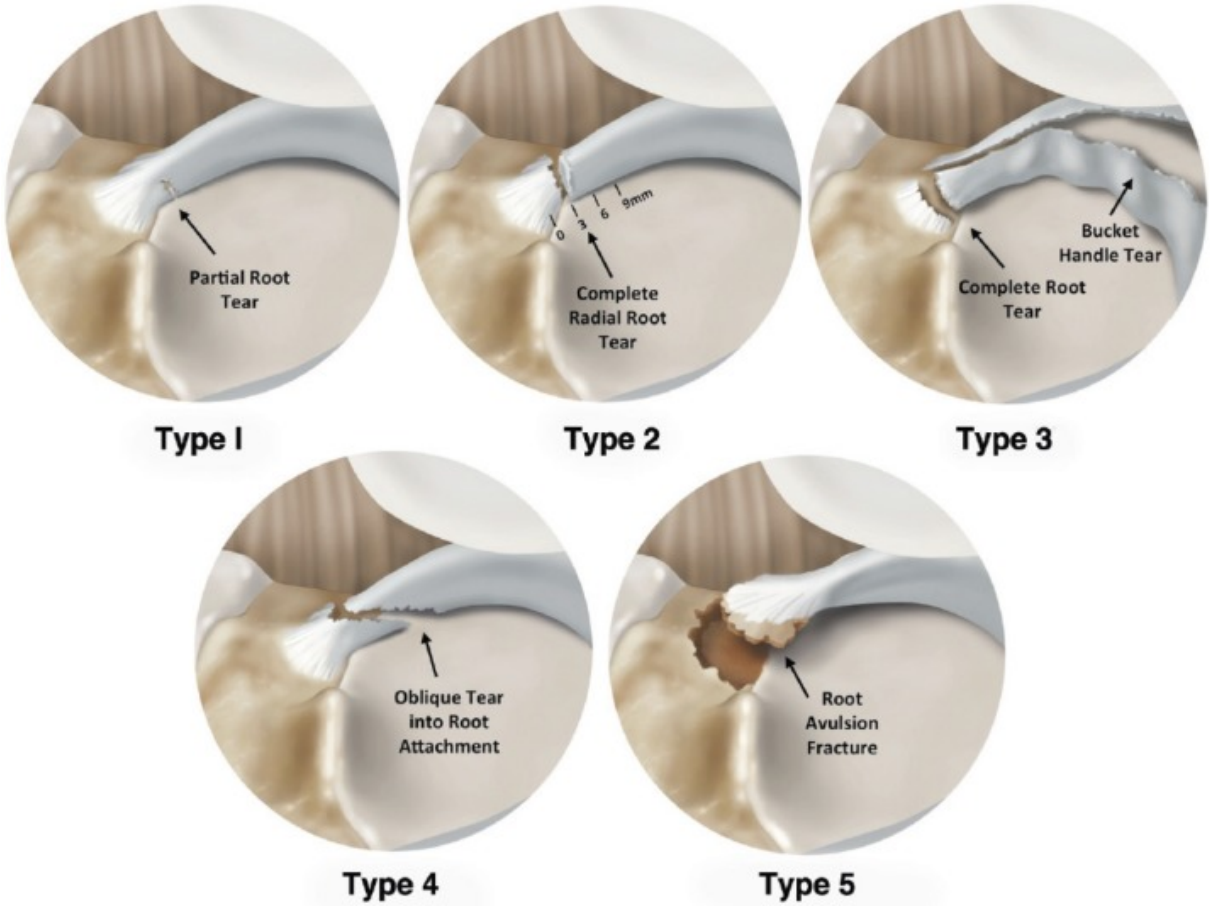

Figure 4. Meniscal root tear classification system illustrated in posterior medial meniscal root. Type 1: partial stable tear. Type 2: Complete radial tear within 9 mm from attachment. Type 3: Bucket-handle tear with complete root detachment. Type 4: Complex oblique or longitudinal tear with complete root detachment. Type 5: Bony avulsion fracture of the root attachment. (Adapted with permission from: LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal Root Tears. Am J Sports Med. 2015;43(2):363-9

5. PATHOPHYSIOLOGY

The menisci follow the motion of the femoral condyle during knee flexion and extension.

The lesions of the roots are an important subcategory of the meniscal injuries.

It is important to notice that both lesions of the meniscus itself and of the root can happen simultaneously but they can also be not associated to each other.

Physiologycally, the meniscus roots provide attachment and anchoring at the meniscus keeping it in place in the knee joint. Doing so, the meniscus can work properly allowing shock-absorbing functions, load transmission and preserving joint integrity and knee stability. The meniscus directly influence the transmission of forces, distribution of load, amount of contact force, and pressure distribution patterns. The ability to absorb mechanical load is doing converting axial load into circumferential *hoop stress*. (26) The integrity of the meniscal root insertions is fundamental to preserve correct knee kinematics and avoid degenerative changes of the joint. (27) Moreover, the damage of these roots is not limited to themselves, but it shows a wider clinical picture. Lesions of the roots lead to an alteration in the biomechanics of the knee. In fact, it can lead to a dramatically reduced normal meniscal function, due to meniscal extrusion, because the meniscus is no longer kept in place. The effect of a posterior root lesion is at the levels seen in a knee after total meniscectomy. This greatly accelerate the arthritic process.(28)

Posterior horns of the medial meniscus in general bear a significantly greater mechanical load than the anterior ones. This situation is even clearer and visible when the knee is under flexion. They are crucial as they can disrupt the essential abilities of the entire meniscus, lose its stabilising effect and render the knee joint unable to deal with the weight compression. (29)

6. CLINICAL PICTURE

Meniscal root lesions represent a challenging medical issue. Although they are less common than others meniscal tears and consequently often unrecognised (they usually stay clinically silent), they are a complicated cause of knee dysfunction and future osteoarthritic disease. These lesions in fact tend to present symptoms just later in life when the damage is already advanced and sometimes irreversible. Most root tears in fact have no history of inciting trauma. While in the presence of risk

factors or acute trauma symptoms, a good clinical approach and a high degree of suspicion are required. In an acute trauma setting the main complaint is joint pain that can be acute and of short duration. Usually even in a degenerative status picture, joint pain is the chief complaint. In fact, pain can be sudden and severe even with a minor or no evident trauma. Mechanical meniscal symptoms are not always present, like locking, catching and giving away. That's an important aspect because it makes a distinction with other meniscal lesions. Sometimes a popping sound can be present while certain movements, like flexing the knee, are performed. (30)

A palpable extruded mass is characteristic for the lesion of the posterior root of the medial meniscus. When an external force is applied laterally or medially to the knee during full extension, this mass becomes evident. It will disappear if removed. (31).

Patients usually complains about posteromedial pain related to the affected knee without other symptoms. Clinical examinations usually reveals joint line tenderness and discomfort in the area linked to the disease, joint effusion and reduced range of motion. Swelling of the affected knee is another common complaint. Pain and swelling can be worsened by specific movements, squatting in particular. Usually ligamentous exams are normal and they are not affected by the meniscal root lesion. (30)(31).

7. DIAGNOSIS

Diagnosis of a meniscal root tear requires a careful examination. In order to succeed in this difficult task, a careful medical history, physical examination of both knees and appropriate diagnostic tests are required. One of the few common signs that almost every patient present is joint line tenderness, over the affected areas (mainly posteromedial or posterolateral), Besides this, all other signs and symptoms are very unspecific and unique patient to patient. Locking, among the others mechanical symptoms, is the most common: it may not be recognised unless it is compared to the opposite normal knee. Another important part of an appropriate clinical examination is manipulative manuevrs in order to reproduce pain.

There are two examination tests usually routinely done in order to make a diagnosis out of it: Mccurray test and Thessaly test. Both of them are used to determine the presence of a meniscal tear. (32) These are important tests used to decide if to proceed further with diagnostic tests (MRI) and diagnostic arthroscopy, the gold standard procedure for knee. Both these tests are particular

important as first-line examinations. They act as a filter in order for the clinician to decide who will need and require further diagnostics (MRI). (34)

7.1 McMurray test

This is the most common knee examination to check for the presence of meniscal root tears, published in the British Journal of Surgery in 1942. (33)

With the patient supine and the knee flexed, extend the knee with either an internal or external rotation of the tibia and values or varus stressed. More specifically; internal rotation plus a varus stress tests for lateral meniscus while an external rotation plus a vagus stress is useful for medial meniscus.(34)

Pain and audible mechanical symptoms like locking and clicking, can indicate a damaged meniscus. (35)

7.2 Thessaly test

This is another screening method for the lesions of the menisci.

It is a dynamic reproduction of joint loading in the knee. (36) This test will be positive if the patient experiences medial or lateral joint line discomfort. Mechanical symptoms are also seen. In fact, it is thought that patients with meniscal tears will have for sure the same symptoms when the knee hint is subjected to loading conditions. The test is always done on both knees and especially important is that the first knee examined is the normal one. It is done at both 5° and 20° of flexion. (37)

7.3 Additional workup

Appley ’s test is another important diagnostic test. It is named after a British orthopaedic surgeon Alan Graham Appley. The patient is required to be in a prone position with the knee flexed at 90°. The examiner rotates the tibia laterally and medially, first with distraction and then while compressing. Any restriction, discomfort, locking or excessive movement are noticed. If rotation plus compression is more painful and more limited in motion, then the lesion is most likely to be meniscal in origin, if opposite (rotation plus distraction is more painful or with increased range of motion) it is ligamentous. (38, 39)

8. IMAGING

Imaging is crucial in orthopaedics, especially in knee pathology. It is very important in confirming lesions when physical examination and clinical history have identified a most likely lesion. It is the last step before therapy and its used is critical in order to determine which type of approach will be used, a conservative or a surgical one. The imaging modality of choice for meniscal root tears is the the MRI. It has the highest sensitivity for MPRT. True avulsions are not always visible and they should be explored for by hook palpation (41)

It is important though to mention that in the setting of a painful knee in middle-aged and in elderly subjects, MRI is usually not consider as first line imaging modality. It is replaced by weight-bearing semi-flexed knee (Rosenberg view) and skyline patella view radiographs; this because the risk of advanced osteoarthritis is high and radiographs show better arthritic changes than MRI. (40). Other radiographic views usually done as routine include the anterioposterior view (AP) and the lateral view (LAT). In the presence of mechanical axis problems sometimes the long leg alignment view is also required to check for malalignment. (42)

If radiographs shows any type of problem, nonoperative treatment should be initiated. In cases of individuals with persistent symptoms and local severe alarm signs to be examined, MRI can be requested (40), in order to confirm a diagnosis. A root tear can be a challenging diagnosis and, for example, a medial meniscal arthritis seen with x-rays, has to be confirmed with MRI. If even MRI fails in identifying and revealing any pathological sign, diagnostic arthroscopy can be considered. Meniscal root pathology may range from intrasubstance mucoid degeneration with or without superficial fraying and attenuation to partial-thickness or full-thickness tear. (41).

MRI is the gold standard diagnostic method for any knee joint pathology. It is a non invasive examination and it consists of obtain an exquisite image using a magnetic field in where electrons of the atoms are disturbed by an external radio frequency energy. Two different sequences can be used, T1-weight and T2-weight scans. According to De Smet and Mukherjee 2008, MRI has a 100% detection rate for meniscal root lesions, showing a 93% sensitive, 100% specific and with a predictive value of 100%. (44). They claimed that a posterior root lesion should be looked at 3 specific location in the knee joint: between the intercondylar tubercles, at the level of the lateral tubercle and on the lateral side of the tibial eminence. (44)

To assess a meniscal root lesion, the most common used sequences are T2-weighted sequences with axial, sagittal and coronal images. (45)

Evident signs of posterior root tears are the following: 1) a vertical linear defect on the root associated with meniscal extrusion (more than 3 mm); 2) a linear high signal intensity perpendicular to the meniscus identifying a radial tear; 3) ghost sign, absence of normal meniscus in the sagittal plane. These three signs together have high sensitivity and specificity for a meniscal root tear. (46)

As stated by Costa et all, the first sign that correspond to a medial meniscal extrusion is highly linked to the presence of a root lesion. Anatomically speaking, it is a displacement of the meniscus from the tibial articular cartilage that can be either partial or total. Any displacement more than 3 mm is associated with severe knee joint disease and articular cartilage degeneration. Bone marrow edema and microfracture are associated as well with tears. Surprinsigly, when the tear occurs, the edema resolves. (46) Lesions of the femoral condyles are also present due to stress-related edema and subchondral collapse. Recently has been identified arthroscopy as the only effective method to confirm posterior meniscal root tears. (46)

MRI guided diagnostic tests are also important in order to distinguish the exact area affected in order to proceed with the right treatment option. For example, it s important to notice and differentiate a true root tear from a lesion closer to the centre of the meniscus because the blood supply to these two different areas is different and also the outcome will be then differently. (46)

Arthroscopy of the knee joint is an endoscopic examination that allows visualisation of the interior of the knee joint cavity with minimal disruption of tissue. Thought tiny incisions called portals, the surgeons can investigate root lesions in detailed. Arthroscopy is used as well as a treatment option. (47)

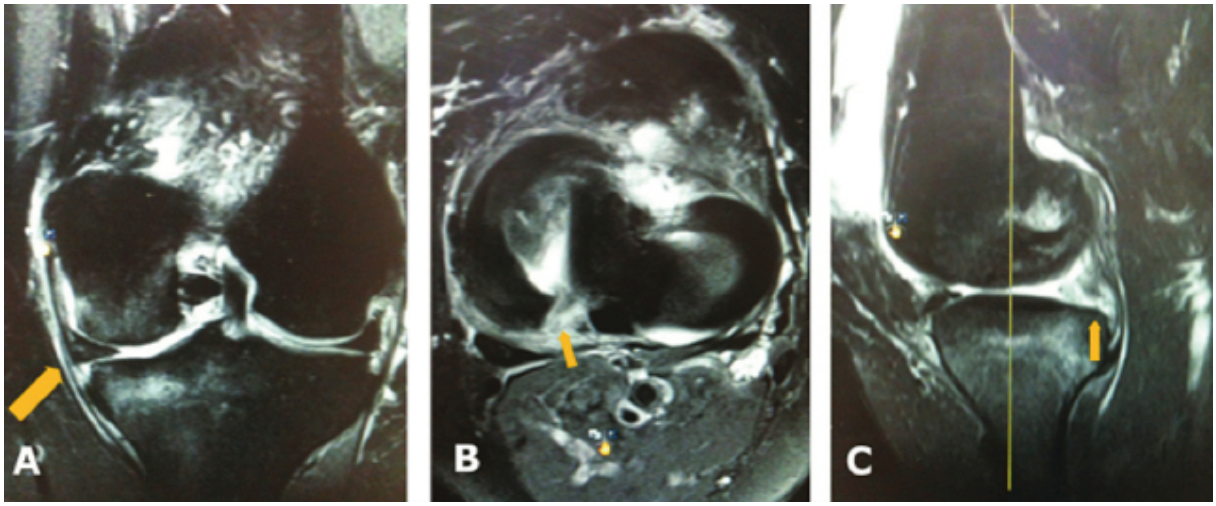

Figure 5. Visualization of meniscal root tears via magnetic resonance imaging. A. Coronal T2-weighted section demonstrating medial meniscal extrusion (arrow) (left knee). B. Axial image demonstrating high signal in region of meniscus root and posterior horn with a radial root tear (arrow) (right knee). C. Sagittal image demonstrating ghost sign (arrow) (right knee). Adapted with permission from Bhatia et al. (2014)

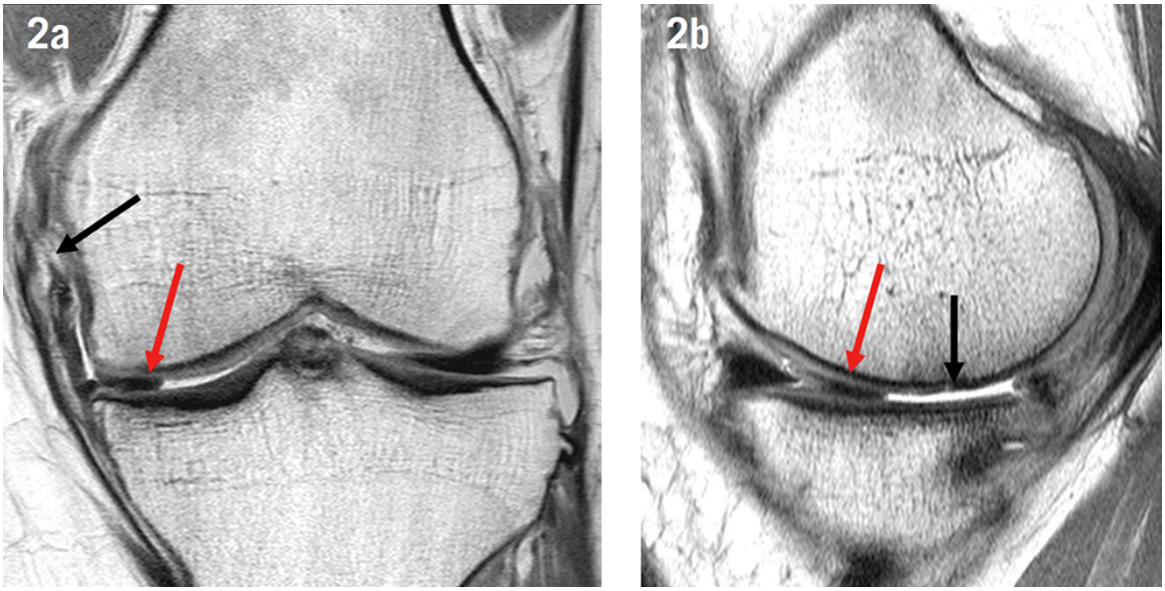

Figure 6. 20-year-old basketball player. a) Coronal intermediate-weighted MRI shows an amputated posterior horn of the medial meniscus (red arrow) and medial collateral ligament tear (black arrow). b) Sagittal intermediate-weighted MRI shows shattered posterior horn of the medial meniscus with a meniscal fragment anteriorly displaced (red arrow) just posterior to the anterior horn. There is also partial thickness loss of the weight-bearing central medial femoral condyle (black arrow). Adapted with permission from Nielsen et all. (81)

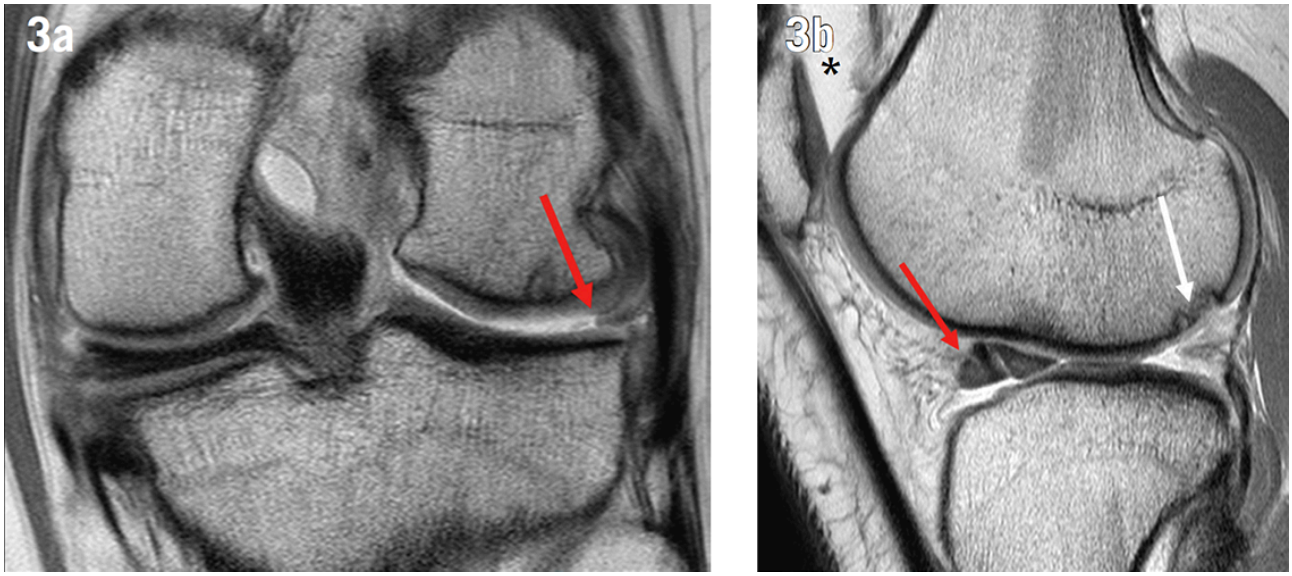

Figure 7. 28-year-old football player with injury 6 months earlier. a) Coronal intermediate-weighted MRI shows avulsion of the posterior root and posterior horn of the lateral meniscus (arrow). b) Sagittal intermediate-weighted MRI confirms the findings in a) and shows that the posterior horn is not lying in anteriorly to the anterior horn (red arrow). There is a large focal cartilage defect at the central weight bearing lateral femur with subchondral bone marrow cystic changes (white arrow). There is also a large joint effusion (star). Adapted with permission from Nielsen et all. (81)

9. MANAGEMENT REVIEW

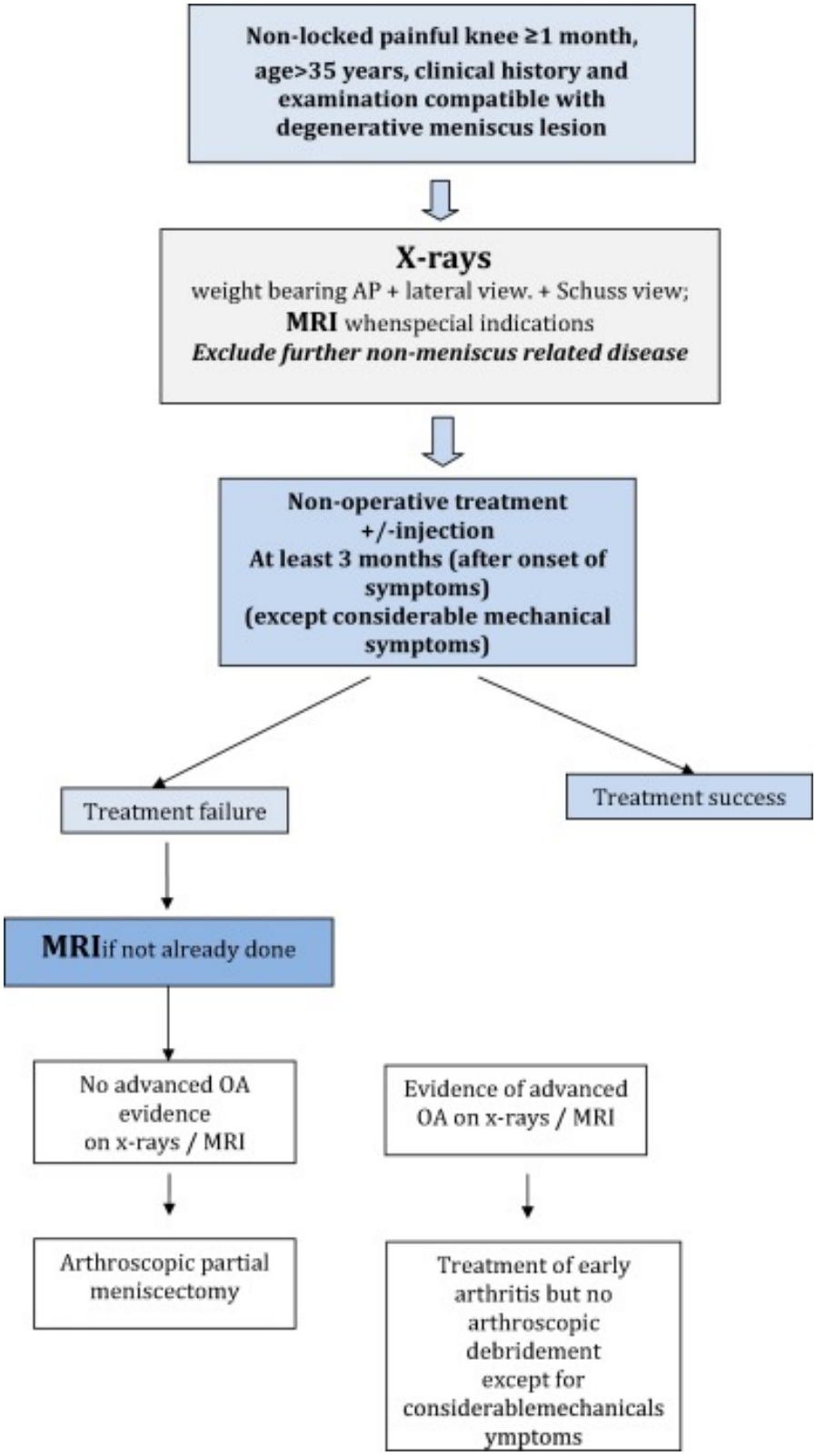

Figure 8. Adapted with permission from Edoardo Bonasia et all. (15)

10. TREATMENT

Meniscal root lesions represent a challenge even regarding their treatment. There are many options and the clinician should consider all of them before approaching to one of them. The choice depends on many factors: the etiology of the lesion, the type and chronicity of the lesion, the clinical history, the age and current health status of the patient, associated co-morbidities, all the possible outcomes and their consequences. Another important fact that has to be taken care of is the occupation of the patient: for example if the patient is a middle-age sedentary elderly person or a sportsman. Treatment of meniscal root tears is variable based upon the severity of the injury, timing of injury to surgical intervention and the condition of the articular cartilage. Treatment aims mainly at providing symptomatic relief and improve patient functioning. Before approaching any type of treatment is important to assess cartilage status and the risk of osteoarthritis of the knee joint. Ideally, in fact the treatment goal is the prevention of ostheoartritis and the progression of degenerative changes. (46)(47)

As we mentioned before, there are different treatment options. First of all, a distinction should be made if it will be a conservative management or a surgical approach. Besides the nonoperative treatment, common surgical options are: meniscectomy, that can be either partial and complete, and proper meniscal root repairs. A very common technique nowadays is arthroscopic repair. (47)

Approach is usually different according to the root lesion as well: while a medial lesion is most likely degenerative in origin and repair efficacy is controversy, lateral roots are mainly traumatic and associated with ACL rupture. This latter type of lesions are mainly resolved with surgery. Regarding MMRT instead, nonoperative management should be started in complicated cases, as in advanced arthritis and noncompliant patients. Authors reported nonoperative treatment in these complicated patients effective in controlling symptoms and improved conditions after 6 and 12 months. However, after this, clinical status declined again with evident signs at x-rays of arthritis at 35 month; nonoperative management of MMRT showed very high failure rates in the long run. (47-53)

10.1. Conservative management

Conservative management is always the first line of treatment. Many patients initially benefit from these non-operative procedures. (46) Then the matter is if to go on with it or to switch to a surgical approach. Non surgical management include administration of drugs, lifestyle modifications,

exercises, physical therapy and heat and cold therapy. Non-operative treatment is usually a common option for elderly patients, patients with significant co-morbidities, and those with advanced osteoarthritis (Outerbridge grade-3 or -4 and chondromalacia).(45) Effusion aspiration has been showing to have some benefits as well. All conservative methods aim at reducing and alleviating symptoms, improving pain and inflammation. Maintenance of ROM of the knee is very important and crucial in root pathologies.

Lifestyle modification

These are the so-called modifiable risk factors. The goal is to prevent or at least delay the onset of any type of meniscal root tear. The main approaches are the following: weight loss management, physical therapy, rest, cryotherapy, activity modification and medical unloader bracing. (48)

Weight loss is one of the main concern. It is crucial for successful management. Overweight and obesity increase the mechanical load on the knee joint and its menisci, so increasing the stress that they already bear and causing an increase burden for the already physiological stressed menisci. Goals should be aimed at weight loss and nonpharmacology treatment for this should be reached with the help of medical professionals.

The medical staff should promote rest and activity modification: reducing high stress activities and sports, while increasing awareness about physical therapy and a lifestyle for strengthening the knee joint. Physical therapy aims at strengthening the muscles of the leg and keep the knee in place. Rehabilitation is extremely important. Other nonpharmacologic modalities are cryotherapy and medical bracing. Cryotherapy is the usage of very cold to freezing temperatures as a medical treatment, usually applied over a single joint. As reported from Knight, 1995, by lowering the tissue temperature heat is withdrawn from the affected area. It has been resulted an effective method in achieving analgesia, reduce swelling and stop inflammation. It is also effective in relieving muscle spasms and to regain good muscle proprioception, facilitate and obtain effective recovery. (49)

Drugs

The goal is to reduce pain and inflammation, control them and alleviate and improve symptoms. Reduce morbidity and prevent complications. Drugs most commonly used are non-steroidal anti-inflammatory drugs (NSAIDs), oral or topical, and corticosteroid injections. These can be given orally or topical. An important route in this setting is the intra-articular injection. The most common prescribed painkillers are Acetanomiphen, Ibuprofen, Diclofenac, Naproxen and Celecoxib.

Corticosteroid and viscosupplementation injections are another class of drugs widely used. They provide short-term analgesia and relief and they result important in restoring a certain degree of physical ability, crucial for physical therapy. (50) Hyaluronic acid as well owns the same properties plus it shows some condroprotective effect. Even though, its benefit is still under investigation as Dragaoo et all, have shown in vitro some toxic effects on the fragile chondrocytes after meniscal repair. (51)

Medical unloading bracing

Unloading knee braces are personalised designed braces in order to provide stabilisation and strength to the knee joint, limiting its movement but protecting it from external forces and excessive mechanical loads while leg flexibility is still allowed. It promotes leg realignment as well. It decrease compressive forces transmitted to the knee and significantly improve quality of life delaying the need for surgery. (52)

10.2. Surgical management

Once the conservative treatment fails, a surgical approach is then considered. The goal of surgery is to restore original joint congruity and its ability to absorb compressive stress, eliminate joint space narrowing and prevent future or stop degenerative changes. The clinician has a pretty wide array of surgical techniques he can choose among. These choices are made according to the type of lesions, conditions of the affected knee and co-morbidities. Improved knee conditions after a surgical approach have been reported but it is still uncertained whether ostheoarthritic changes are effectively prevented. (54)

Nowadays the surgical options are meniscectomy, that can be either complete or partial, and meniscal repair, either a transeosseus or a suture anchor method. A relevant distinction between meniscectomy versus repair should be done regarding the status of the cartilage. If the cartilage is ruined and chondromalacia is present (Outerbridge grade II-III), then meniscectomy is preferred. Osteotomy is usually not a surgical approach for root lesions. (54)(15)

Depending on which meniscus is affected and which root, any lesion is a deal on its own. Meniscectomy is usually reserved for medial lesions: repair has been shown to have controversial effects due to their degenerative origins. Repair instead has more successful results with lateral lesions as they are traumatic in origin and often involving the ACL as well. Two techniques are

most commonly used. If the lesion is few millimetres from the root, repair is made with the edge-to-edge suture. The transtibial pullout suture is instead reserved for avulsion tears. (40)

10.2.1. Meniscectomy

Meniscectomy is one of the most frequent orthopaedic surgeries. It literally involved the removal of meniscal tissue from the knee joint with the help of an arthroscopic device. It is a minimally invasive procedure and it is usually done when a meniscal root tear is too complicated and large to be repaired. (15) Meniscectomy is usually indicated for symptoms refractory to conservative treatment and for any degenerative changes of the articular cartilage, synovial fluid changes and in particular for avascular zone tears. Moreover, it is usually suggested in patients experiencing mechanical symptoms affecting daily living activities, leg muscle atrophy and obesity. (62)

Recently, meniscal sparing as been supported. In fact, meniscectomy has been proposed as a factor towards future degenerative changes, above all in meniscal root lesions associated with ACL tear. Some studies show 100% link to osteoarthritis at 30 years time from the surgery. (55) Differently, in stable knees (not associated with ACL damage), 85% of patients are in relatively good conditions at 10 years time. (40)

Partial meniscectomy is less disruptive and it is usually the treatment of choice for meniscal root lesions. As little meniscus as possible is removed and the remanent is fixed and smoothen up. In fact, as stated by Shrive et al, the goal is to preserve as much as possible the peripheral rim of the menisci, in order not to disrupt the physiology of the menisci. In fact, it is essential to preserve it in order to avoid irreversible disruption of the hoop tension capability; if not, when a load is applied the meniscus will just spread. It can also be considered as an option for symptomatic relief when mild arthritis is present, followed by osteotomy. (56) Complications are the same present as the ones in other surgery: intraoperatively neural damage and anaesthesia complications, while postoperatively the most common are deep vein thrombosis, infection, synovitis, effusion, articular edema and stiffness. (64)

10.2.2. Repair

Repair (arthroplasty) is aimed at restoring the root attachment. Considering the biomechanics characteristics of meniscal roots and their rich blood supply, some authors started considering repair as a better option then meniscectomy. (63) There are three types of repair: edge-to-edge, transtibial pullout and suture anchors. Depending on the lesion and its pattern, one approach will be chosen.

All the techniques are done arthroscopically in order to avoid dissections of the knee and provide better outcome for the patient. Acute patients with traumatic root tears and a cartilage status Outerbridge 0–2 and chronic symptomatic root tears in young or middle-aged patients without significant pre-existing degenerative changes, are the most common indication for root repair. (57). An important contraindication for repair not yet mentioned is malalignment. A pretty high risk of meniscal repair failure has been reported. Meniscal repair is generally considered a low risk procedure and its complications are rare. Among these, the most common complications reported are injury to skin nerves, infections and knee stiffness. Usually, antibiotics and leg stocking are recommended to the patients after surgery. (15).

Transeossues pullout technique

The most common and surgical treatment of choice is the transtibial fixation of the torn root. It shows the best clinical outcome in terms of recovery and prevention of osteoarthritis. (58)

Indication for the transeossueus technique is avulsion tears. No ACL tear is involved, in fact a requirement to use this approach is an intact ACL. Small tunnels are drilled with an ACL guide in order to obtain an adequate visualisation of the knee joint. The meniscal root is armed with non absorbable sutures and then retrieved through the small drilled holes from the anteromedial tibia. Finally the sutures are tightened distally in fixation points. (60)

Side-to-side technique

This technique is usually chosen in posterior root lesions with radial shape close to the tibial insertion or in other complex shapes. The insertion is still intact. There are different procedures for positioning the stitches; all-inside, inside-outside and all-outside. The most common is an all-inside method, after entry portals are made either posteriorly or anteriorly. (15)

Suture anchors technique

Surgeons usually choose this technique in meniscal root lesions with associated ligamentous injuries (usually ACL) or in already operated knees. In fact, the transtibial fixation is contraindicated due to the risk of interferences with tunnels used for ligamentous reconstruction. Accessing the knee joint via posterior portals, suture anchors are placed onto the back of the tibia in order to achieve stable fixation. They are finally tightened through anterior portals. (15) (61)

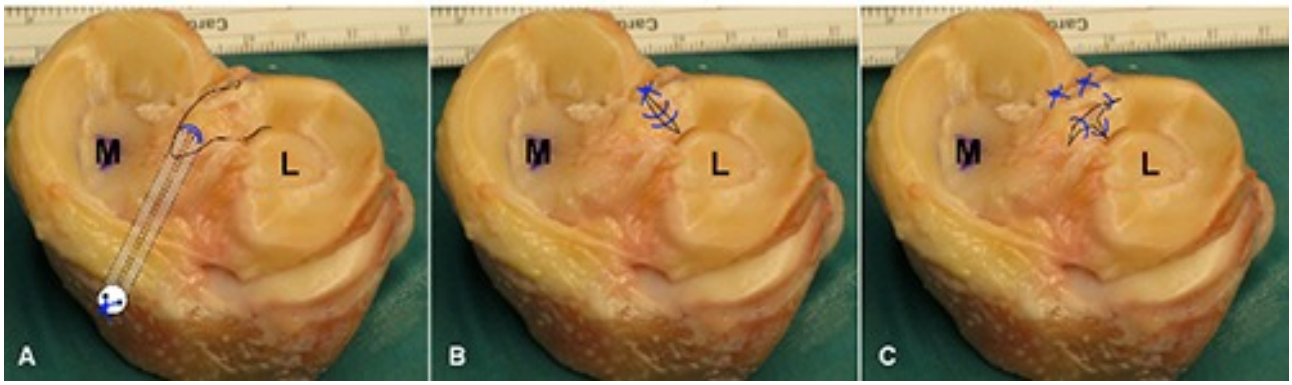

Figure 9. Specimens showing different repair techniques, according to different lesion patterns; A) Avulsion of the posterior root of the lateral meniscus. In this case a pull-out technique can be used. B) Lateral meniscus posterior root radial tear, with preserved tibial attachment. Am all-inside side to side suture is recommended. C) Complex T shaped tear of the posterior root of the lateral meniscus. In this cases multiple stitches are required according to the preferred meniscal suturing technique (all-inside, out-in, in-out). (15)

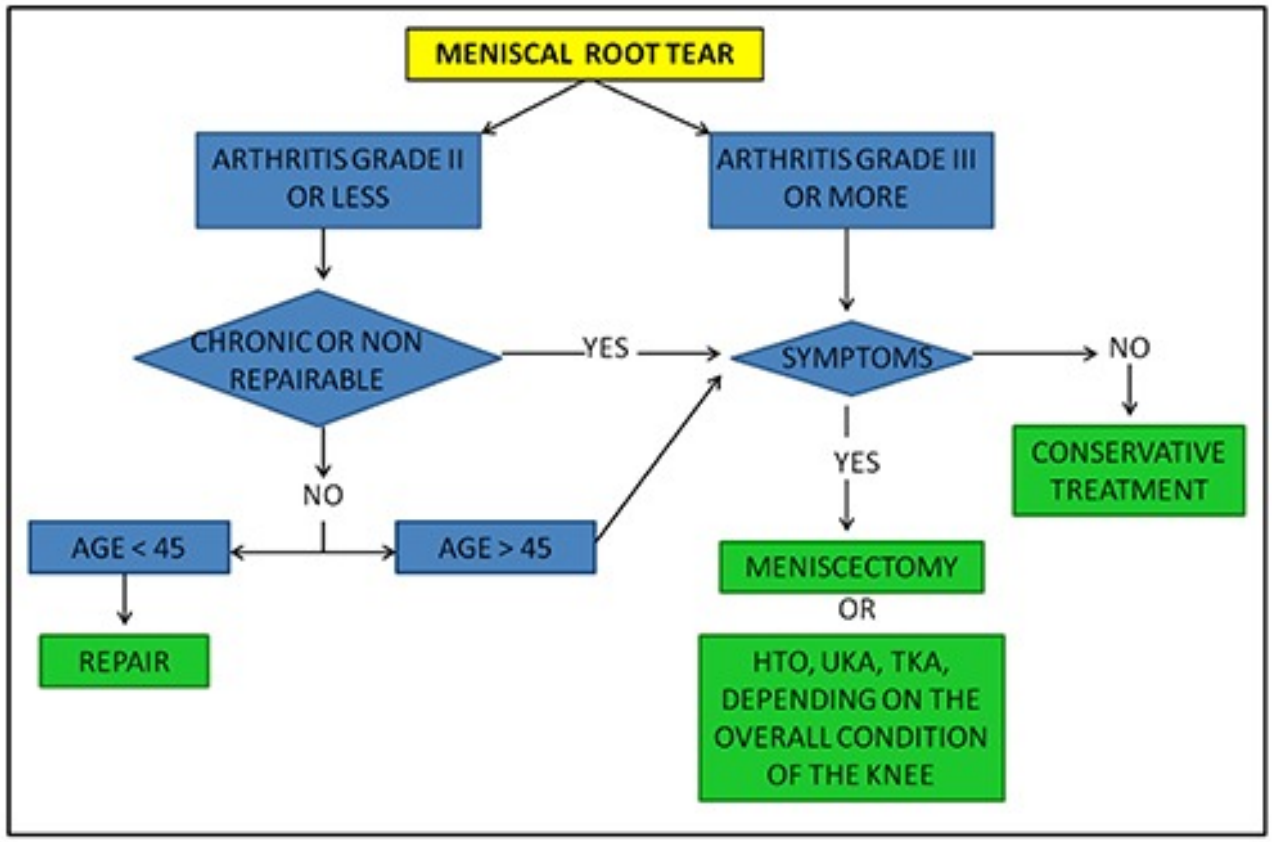

Figure 10. Adapted with permission from Edoardo Bonasia et all. (15)

11. OUTCOMES

Meniscal root tears treatment is a pretty recent surgical innovation. Because of this, clinical data regarding outcomes are limited. The main distinction in surgical approaches is between partial meniscectomy and repair. Partial meniscectomy can result in a significant posterior root tear improvement and thus improve the outcome score. However, there are degenerative changes that comes along with this surgical procedure. Imperatively, according to Kellgren-Lawrence scale, degenerative changes rose significantly at 5 years post-operatively(71)(72). Recently, Krych at al. compared the outcome between these two procedures. The group found no significant difference between partial medial meniscectomy and nonoperative treatment. They found that there were no changes in Tegner score or KL grading. However, approximately 54% of partial meniscectomy patients progressed to a total knee arthroplasty (TKA) in the following 5 years post-operatively (72). In recent meta-analysis, Chung et al. and Feutch et al. reported better outcomes in root repairs, specifically after arthroscopic trans tibial pullout technique. In fact, at a minimum of 5 years follow-up, there were much better clinical and radiological outcomes. No patients resulted in need of a TKA in the repair group compared to the 34% of patients who underwent partial meniscectomy. Meniscal repair can actually slow down the progression of arthrosis, at least in the short term. Degenerative changes were observed just in 10% in repaired lesions. (73) (74). This better clinical outcomes for repair surgery has been confirmed as well by LaPrade et al. in a retrospective study of 50 knees. After successful two-tunnel transtibial pull-out technique surgeries, patients satisfaction was high with significant improvements of initial symptoms like pain and faster recovery and return to activity level. The only issue with root repairs is the presence of meniscal extrusion after surgical interventation. Feutch et al. reported in fact a 56% rate of medical meniscus extrusion after repair. Therefore rehabilitation shows its important role in anatomical reduction and fixation of the meniscus after repair. (73)(74)(75)

Partial meniscectomy is not a harmless procedure. Recently, meniscectomy is being considered as an alternative when surgical repair is not possible. Yocum at al. observed in a study that only 54% of patients has achieved satisfactory results after 7 years post meniscectomy, with arthritic changes and limited ROM. Meniscectomy provides no benefit in stopping or preventing osteoarthritis and it shows poor clinical outcomes, above all in those cases correlated to risk factors like female gender, high BMI, high rate of cartilage loss and edema. (76) (77)

12. REHABILITATION

Post-operative management is crucial. It is based on two main concepts: self and guided. First of all it is individual directed: while still hospitalised and before their discharge, patients are taught how to cope with and manage their pain, swelling and the local symptoms. Rest, ice packs, heat and leg elevation are the most frequent instructions at first. Home exercises are usually suggested. Later on, patients follow a physical rehabilitation program, with exercise aiming at strengthening leg muscles, neuromuscular education and recover proper range of motion (ROM), muscular and proprioceptive functions. Sometimes clinician refers patients also to electric galvanic stimulation or transcutaneous electrical nerve stimulation. (66)

Goals of rehabilitation are improvements of symptoms, complete recovery of proper functional biomechanics and prevention of further damages. Rehabilitation is always a must in the settings of a repaired meniscal root lesions and after a meniscectomy. (65)

There are no standards protocols. (66). Even thought a standard protocol is not present, it is showed in biomechanical cadavers that early exercises and weight bearing are strongly beneficial in a repaired meniscal root tears. A rehabilitation protocol usually is made of several steps or phases distributed along a certain amount of time. It is based on clinical outcomes, patient conditions and clinical judgement. When not working on physiotherapy, patients should wear a brace in full extension for 6 weeks. (69)

A very good example to clarify a modern rehabilitation therapy is expressed in an article written by Hwa-Jae Jeong et al. During the first postoperative week, from the moment the patient is discharged, the aim is to control inflammation, reduce pain and maintenance of passive ROM of the knee. Suggested exercises are patellar mobilisation, active close chain exercises up to 90° flexion, straight leg raise and isometric quadriceps muscle contraction. This is called maximum protection phase. Not only are the passive movements stimulated, but also the active ones are restored, in order to avoid any scar tissue formation. In order to limit stress, weight bearing exercises are avoided since they are not allowed for at least the first six weeks. Once a full ROM is achieved, as well as a reduced joint effusion, the rehabilitation can progress to a moderate protection phase (phase 2). Here the aim is to restore pre-gait activities and obtain full flexion and extension of the knee. Balance, proprioception, stretching and weight bearing exercise are slowly introduced. (64)

According to Raphael Serra Cruz et al., in order to pass to the third postoperative phase, a patient must be able to feel comfortable to walk for at least 25 mins. Muscle strength and full normal gait

pattern are to be restored. During this phase, called minimum protection phase, continuation of exercises are responsible for a full complete return of daily activities and sport by the 5th or 6th month of rehabilitation, back at light running, jumping and endurance activities. (64)(68).

Rehabilitation therapies differ depending on which medical approach and which type of surgical interventions are chosen. Rehabilitation protocol following meniscal repair is slightly different from protocols following meniscectomy. The general principle is similar as it has been stated before; however, after repair, weight bearing exercises are reduced and limited due to the higher fragility of the newly repaired roots. Full-weight bearing is usually postponed until 2 months ca after surgery. Moreover, each phase of rehabilitation is longer, this way giving more time to the stressed new roots to recover and rest, and ROM exercises are done wit more caution. As the new meniscus has repaired weaker roots, it is crucial to assist their recovery and healing process carefully, in order to avoid any new damage, delay and problem. This might requires an increased amount of painkillers and anti-inflammatory drugs, as the pain during rehabilitation is usually more intense then after meniscectomy. Return to normal activities like running and jumping should we done slower than with meniscectomy protocol, in order to avoid tendinitis and further inflammation. Usually, this exercises are initiated when the quadriceps muscle of the affected leg has reached t lest 70% of the strength of the contralateral muscle. (70)(71)(72)

13. CONCLUSION

The lesions of the roots of the menisci are a challenging orthopaedic topic, in diagnosing them and for treatment as well. They are avulsion tears of the insertions of the menisci. These crescent-shaped cartilages are crucial for the correct physiology of the knee; they act as weight bearing structures and load distribution across the joint. Once one of them is either torn or damaged, this duty fails. The lesions can be traumatic and degenerative in origin. The posterior roots are usually the most affected, the medial meniscus with a degenerative etiology while the lateral meniscus is mainly involved in traumatic tears. Each of them has it s own risk factors that have to be in consideration once a medical approach is chosen. This lesions can be treated conservatively and surgically. Non operative treatment is usually the first line therapy when first symptoms appears. It involves physical training, treatment with anti-inflammatory and analgesic drugs, application of heat or cold, lifestyle modification and prevention of modifiable risk factors. When conservative treatment fails, either because of worsening conditions or patient misconductance, surgical options are considered. Meniscal root lesions can be treated by meniscectomy, either partial or total, and with many meniscal root repair techniques, the last ones with much better clinical outcomes.

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16. BIOGRAPHY

I was born on the 11th of March 1993 in Domodossola, a middle-size town situated in North Italy. After I had completed my primary and secondary education in my hometown, at “Liceo Giorgio Spezia” Institute, in September 2012/2013 I moved and enrolled at University of Pavia, a city close to Milano, where I started my Biological Sciences degree.

One year later, in 2013/2014, I got the chance to join the Medical Studies Program in English at the University of Zagreb. This choice and opportunity changed my life. During these six years, I deeply improved myself, both personally and academically and my experiences encountered in here had shaped myself in the person I am right now and that I will forever be.

Since childhood, medicine has always been a desire for me. Not only it is my passion, but also because I could define it as a family tradition. Both my parents are medical doctors and both my siblings are into pursing a medical career.

I am very interested in surgery and I have attended my clinical rotations in the departments of both Plastic Surgery and in the Trauma and Orthopaedics ward. During my studies, I have taken part in many meetings and congresses around Europe, as CIRSE and CIVR, in order to extend and to deepen my medical knowledge, sharing ideas with future colleagues from different parts of the world and improve my interpersonal relationships.

I have been involved in many student demonstrating roles during my six-year period contributing to strengthen my figure and character.

I supported my medical faculty in extra curricular activities as well. I took part in sport tournaments, charity jobs and meeting promotions.

On the 18th July 2019 I got my Medical Degree from the University of Zagreb, Medical Studies in English.