

Classification, Risk Factors, Diagnoses, and Examination for Six-Type Meniscus Tears

Maida Zhang *

College of Agriculture and Life Sciences, University of Arizona, Tucson, United State

* Corresponding Author Email: maidaz@email.arizona.edu

Abstract. The knee is the connection of the tibia and femur, which are two bones near to knees, and the menisci are in the knee joint shaped in two wedge pieces of fibrocartilage. Meniscus tears are considered the most common knee injuries and happen from acute trauma - like the fibrocartilage of meniscus tears, breaks, cracks, ruptures, or splits - or as the result of degenerative changes that happen over time. This study discussed the classification, risk factors, diagnoses, and examination for meniscus tears. The result shows that there are six common meniscus tears including bucket handle, flap, radial, degenerative, horizontal, and longitudinal meniscus tears. Risk factors of meniscus tears include age, gender, limb alignment, accidents, sports injuries, and osteoarthritis. Physical examinations and imaging examinations are commonly used techniques. Magnetic Resonance Imaging (MRI) is considered the most typical standard of testing meniscus tears. It can identify different types of meniscus tears and detect any associated damage to the ligaments, cartilage, and tendons.

Keywords: Classification, Risk Factors, Diagnoses, Examination, Meniscus Tears

1. Introduction

According to statistic in United State, more than 500,000 meniscus tears occurs each year with an incidence of 12% to 14% [1]. The meniscus was originally classified as a non-functional remnant of the leg muscles, but in recent decades, repeated scientific experiments have reclassified the meniscus as an important part of the knee joint with anatomy, physiology, biomechanical, and many important features [2]. The knee is composed of two menisci, one located on the inner side of each knee, which is considered as medial meniscus, and one located on the outer side of each knee, which is considered the lateral meniscus. Menisci are crescent-shaped thick bands of rubber cartilage and play an important role in absorbing shock between femurs and tibias, which help to distribute the weight from one bone to another and stabilize the knee.

Meniscal tears are noted for their appearance, size, severity, and shape because they can occur for a variety of reasons, such as growing age, improper sports, sudden force on knees, and so on. The incidence of meniscal injuries is increasing, due in part to increased participation in sports and the recent advances. As for diagnosis, ease of use of imaging techniques such as MRI so that more people can be tested. As for treatment, conservative treatments, including nonsteroidal anti-inflammatory drugs (NSAIDs) and steroid injection, and surgery, including partial meniscectomy and meniscus repair, are mainly utilized.

The current studies focus on treatment while there are some other weak aspects: (1) Incomplete diagnosis. Diagnosis should include the risk factors and the cause of the meniscus tear instead of just diagnosing how to repair the meniscus because this determines the follow-up treatment direction. (2) Non-uniform classification. Previous studies classify meniscus tear in many forms while there is no one uniform classification. According to different studies, this paper classifies and diagnoses the six most common tears including bucket handle, flap, radial, degenerative, horizontal, and longitudinal meniscus tears.

2. Classification of Meniscus Tear

2.1. Bucket Handle Meniscus Tear

A bucket handle meniscus tear accounted for 8.2% of all meniscal tear patterns and is considered to have a 19.2% chance of a barrel handle meniscus tear being a concomitant injury to an ACL injury [3]. A bucket handle meniscus tear occurs when the meniscus separates around and its medial part is displaced, which might slide into the joint (Figure 1). People who get bucket handle tear can still walk because it has a chance of flipping back into place and have no symptoms after it [4].

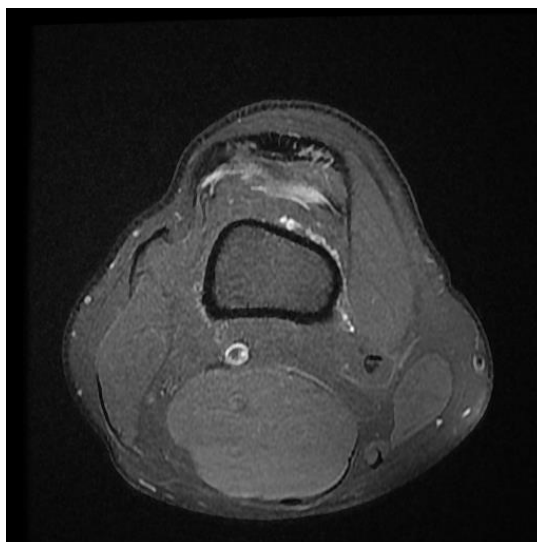


Figure 1. MRI Image of Bucket Handle Meniscus Tear

2.2. Flap Meniscus Tear

A flap tear (also called parrot beak lacerations) is an unusual pattern that usually occurs in the avascular portion of the meniscus. It can be removed without removing much tissue (Figure 2).

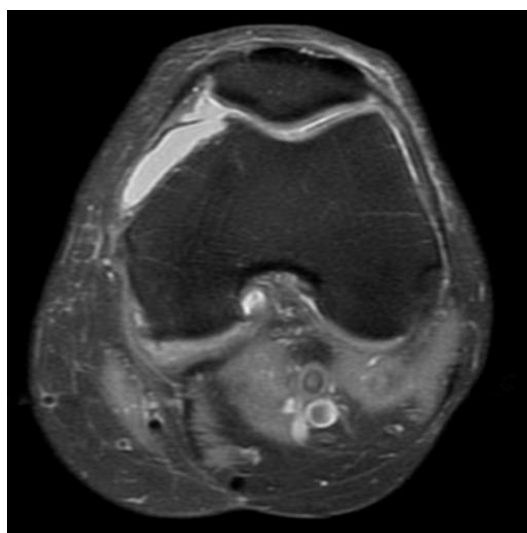


Figure 2. MRI Image of Flap Meniscus Tear

2.3. Radial Meniscus Tear

A radial tear is the most common type of meniscus tear in our daily life. It usually appears in the avascular part of the meniscus, which has no blood supply (Figure 3). Thus, a radial meniscus tear is hard to heal on its own. The radial meniscus tear is very serious. It can make the meniscus completely incapacitated and difficult to repair [5].

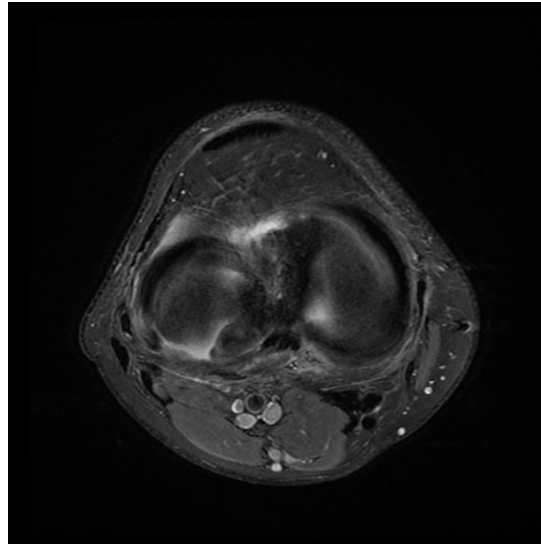


Figure 3. MRI Image of Radial Meniscus Tear

2.4. Degenerative Meniscus Tear

A degenerative meniscus tear forms gradually and suddenly appears because of wear and tear. It's considered a part of knee osteoarthritis, which is a degenerative process within the knee (Figure 4).

The blood supply to the meniscus decreases with age. Thus, degenerative meniscus tears, like radial meniscus tears, do not usually heal on their own.

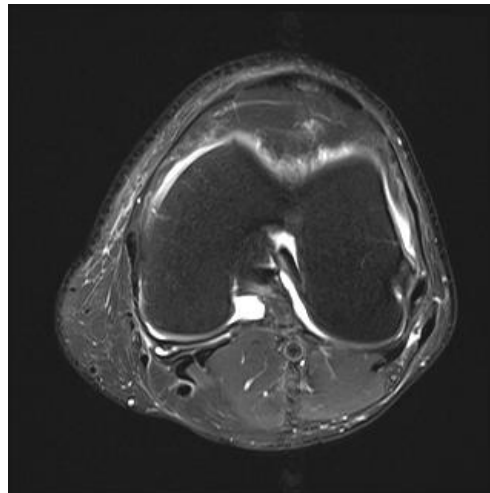


Figure 4. MRI Image of Degenerative Meniscus Tear

2.5. Horizontal Meniscus Tear

A horizontal tear most commonly responds well to surgical meniscus repair. A horizontal tear runs along the curved fibers of the meniscus. The vascular portion of the meniscus is the area of the cartilage with blood flow (Figure 5). Horizontal meniscus tears happen around the lateral part of the meniscus with the highest healing potential. Thus, repair may be a good option for horizontal tears in the vascular part. However, when the location is more medially, the tears cannot heal, even if repaired.

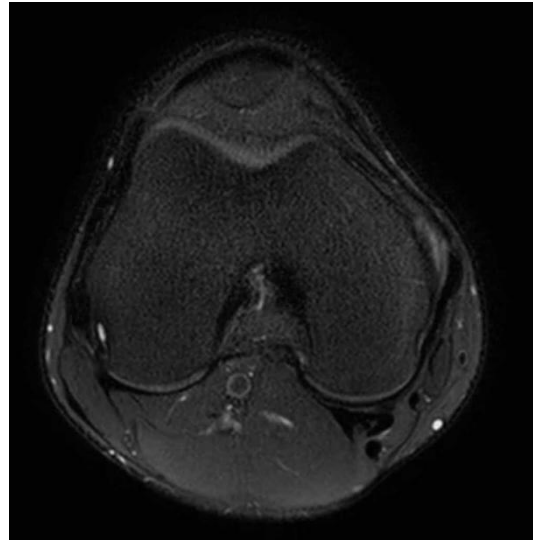


Figure 5. MRI Image of Horizontal Meniscus Tear

2.6. Longitudinal Meniscus Tear

Longitudinal tears in the medial meniscus posterior horn (MMPH) around the meniscus joint are frequently found in chronic ACL-deficient knees [6]. A longitudinal meniscus tear (also called a vertical meniscus tear) is a tear that develops along the circular curve of the meniscus tissue (Figure 6). When longitudinal meniscus tears become large enough, they can displace to the front of the knee, which is then called a barrel handle tear.

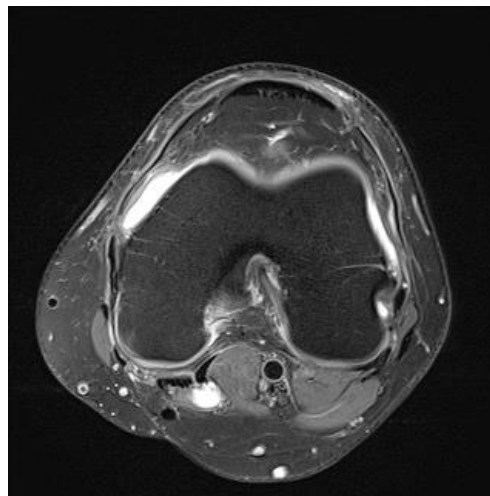


Figure 6. MRI Image of Longitudinal Meniscus Tear

3. Risk Factors

Meniscus tear is the result of age-related tissue degeneration, and some other risk factors also might cause it.

3.1. Age

Age elder than 30 is a risk factor for getting meniscus tears. In youth, menisci are strong cartilage that can withstand forces with ease. As age grows, cartilage begins to wear down and degrade. This means the meniscus is more prone to wear than before. Activities like kneeling and squatting can be done easily in youth could be hard to do in the elder life and people tend to get Degenerative meniscus tears with the growth as well. Based on 1485 patients with meniscal tears, Michael (2004) discussed

6 different types of meniscus tears. The results of data show that peripheral tears occurred in 37% of older people compared to 44% of younger people. The difference was significant ($P = 0.011$) [3].

There were also significant differences in the relative distribution of tear shape between older and younger patients. The result of statistics shows that the proportion of bucket handle tear of patients under 30 years old is 3.5% and that of patients over 30 years old is 21%; (Figure 7), degenerative (13% and 35%), flap (15% and 17%), horizontal (37% and 20%), longitudinal (7% and 17%), and radial tears (3.2% and 10%). Medial tears (78% and 62%) were significantly different from lateral tears (22% and 38%). The proportion of people over 30 years old with varus alignment (7.7%) was higher than those under 30 years old (1.1%); however, in the two age groups, their valgus alignment difference was not obvious (6.5% and 4.1%) [3].

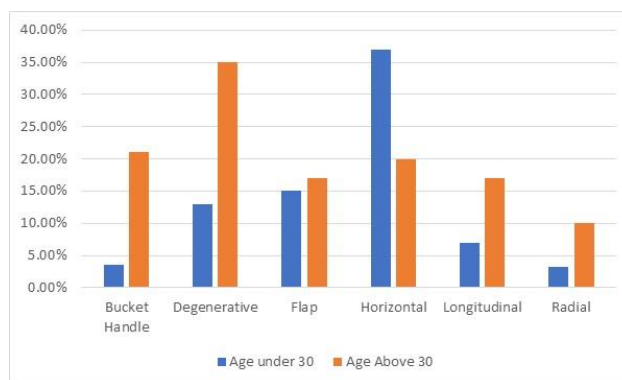


Figure 7. Relationship between Age and different types of Meniscus Tears

3.2. Gender

Compared with males, females have a higher chance of getting meniscus tears. 32% of women got peripheral tears while the percentage of men is 42%.

Different genders have different proportions of knee injury types, among which complex and horizontal are higher (Figure 8). Women and men differed in tear shape: bucket handle (3.8% and 11%), degenerative (31% and 27%), flap (13% and 16%), horizontal (37% and 30%), longitudinal (8.2% and 11%) and radial (6.9% and 4.7%) (Figure 8).

The probability of meniscal tears in different parts of the meniscus varies by gender, while the posterior part is the most fragile. The proportion of women with anterior tears (12%) is higher than men (5.1%), while the rates of women and men with posterior tears are 82% and 88%, (the following will briefly describe in 82% and 88%) and midbody tears rate (33% and 38%)

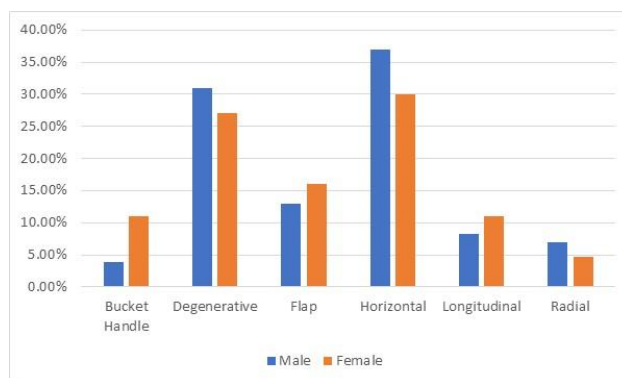


Figure 8. Relationship between Gender and different types of Meniscus Tears

3.3. Limb Alignment.

Compared with males, females have a lower probability of valgus alignment. Most of the patients had operated leg in the neutral position (88%), while 5.7% of patients were valgus aligned and 5.8%

were varus aligned. The valgus alignment rate of female patients is 12.6% and the varus alignment rate is 3.7%, while the rates of male patients are 2.9% and 7.0%

Compared with eversion alignment, patients with valgus alignment have a higher probability of getting meniscus tears. Among valgus alignment patients, 41% were medial tears, 47% were lateral tears, and 12% were both tears. Among varus alignment patients, 93% were medial tears, none were lateral tears, and 7% were both.

3.4. Accidents and Sports Injuries

Even though the meniscus is relatively strong, accidents can still cause tears. A person under the age of 30 with a torn meniscus may suffer from a hit to the joint, such as in football tackles, badminton's starts and pace, and many sports involving the knee. Excessive or substandard use of these maneuvers can also cause a meniscus tear. Repetitive sports like rope skipping and heavy barbells in the gym are at a greater risk of a meniscus tear. Even improper walking and running can damage your knees as well. For example, placing a foot on an uneven surface in the wrong way or overextending the knee can tear the meniscus.

3.5. Osteoarthritis

Degeneration of cartilage in the knee or osteoarthritis makes the cartilage thinner, less elastic, and unable to withstand normal forces. This condition increases the risk of getting all types of meniscus tears. Sometimes there is no specific accident or bad habit, but a meniscus tear might still occur. Unlike an acute meniscus tear, a pop and swelling within about 12 hours, people might feel weakness, pain, and mild swelling in the knee under this condition [7].

4. Diagnosis and Examination

More than 75% of osteoarthritis patients suffer from meniscus injuries, and meniscus and meniscal injuries are one of the most common sports-caused injuries in people's daily lives. In addition, different meniscus tears share some same symptoms and the common symptoms of meniscus tears [2]. Therefore, timely and correct diagnosis and proper administration become increasingly significant portions of orthopedic research. There are commonly two categories of examination: physical examination and imaging tests. A physical examination will use physical characteristics to test the condition of the meniscus. It mainly includes joint line tenderness, MacMurray tests, and Thessaly tests. Imaging tests will use technologies to represent knees in form of images to test the condition of the meniscus. It mainly includes X-ray and Magnetic Resonance Imaging (MRI) scans.

4.1. Physical Examination

Joint line tenderness tests pain on the inside or outside of the joint. This test is used for a physical examination to diagnose a meniscus tear. The patient lies supine on a table with the knee flexed to 90° and compressions are applied to the lateral and medial borders of the knee. Symptoms that may occur during the test include stiffness, swelling, redness, warmth, pain, and deformity [8].

McMurray tests for sensitivity, specificity, positive and negative predictive values, and accuracy of medial meniscal tears by testing for joint line tenderness at 90 degrees of knee flexion. The criteria for a positive test are pain, popping, clicking, or an association of one or more of these symptoms. McMurray and joint line tenderness are more often used for clinical history background [9].

Thessaly test is a dynamic clinical test. With the patient flat on the floor, the doctor holds the patient's outstretched hand to support the patient, then the patient stands on one leg to support the full weight of the side to be examined and has the non-test leg bend the knee and remove all weight-bearing surfaces. Next, the patient should place the test knee in a negative position between 5-20 degrees of flexion and rotate (or grind) the femur inside and outside the tibia 3 times. The test is positive if the patient reports recurrence of symptoms, joint tenderness, or adhesion/locking [10].

4.2. X-rays

X-rays are one common imagined test and can indirectly detect the meniscus tear. The first indirect way is detecting the density of bones' structures. Although an X-ray could not show a meniscus tear directly, it offers doctors help and can further check other causes of knee pain [11]. The second indirect way x-rays use to detect meniscus tear is the diagnosis of the bilateral discoid meniscus (DLM), which might cause a meniscus tear. Currently, there are no studies on whether contralateral meniscus condition and rupture are potential predictors in DLM patients, but the related contralateral meniscal rupture ranges from 4% to 33% in symptomatic DLM. X-rays can also be tested for DLM on a per-image basis: the high fibular head (shorter than 13 mm from the talar joint), the square lateral femoral condyle, outer tibial plateau cupping, enlarged space of tibiofemoral joint, and lateral intercondylar spine hypoplasia [12].

4.3. Magnetic Resonance Imaging

4.3.1. MRI examination system

Magnetic Resonance Imaging is considered the gold standard for testing meniscus tears. With an MRI scan, the tear can be seen as a white line directly through the dark body of the meniscus [13]. The main task of MRI examination is divided into three subtasks: (1) meniscus detection, testing the position of two corners; (2) meniscus classification, classifying whether there is a tear in the meniscus; (3) tear classification, testing the tear direction [12]. The detection of these three steps is all based on Fast Region CNN.

The second step of meniscus classification has four classes. Class 0 means normal meniscus. Changes in class I signals are spherical within the material and do not intersect the articular surfaces. The variation of the Class II signal is linear within the material and does not cross the articular surfaces. Change in class I and II shows in-material degeneracy in people over 30 years old or vascular in people under 30 years old. Changes in class III alternate the surfaces of superior and/or inferior articular and are diagnosed as a true tear. In addition, the sensitivity and specificity of MRI detection depend on the grade of the lesion. Class I lesions on MRI were not related to the arthroscopic meniscal injury. In 24% of Class II patients, arthroscopy revealed a true tear. The specificity and sensitivity of Class III lesions were 95% and 79%, accordingly, those of medial meniscus are 100% and 86%, accordingly, and those of lateral meniscus are 92% and 57% [14].

4.3.2. MRI diagnose on different types of meniscal tears

Although different types of meniscus tear tests are used for simple diagnosis, patients have to examine their meniscus by MRI for detailed information and see which type of meniscus tear they have. Based on the MRI technology characteristics, MRI can offer the most detailed image than other technologies. MRI of the knee can identify a meniscus tear and detect any associated damage to the ligaments, cartilage, and tendons. This means that doctors can diagnose different types of meniscal tears based on the different conditions of the knee (Table 1).

Bucket Handle tears can be represented as sensitive but not specific signs. The MRI of bucket handle meniscus tears most show in the sagittal plane, which is no bow tie sign, double PCL sign (inner meniscus stalk split), double ACL landmarks (lateral meniscus barrel hand layer), double anterior horn/inverted meniscus, double triangular positive and negative sagittal section and disproportionately small dorsal horn. It also has some signs in other places, including an intercondylar notch in coronal meniscus fragment and coronal image of meniscus body truncation, and small size in coronal view.

Flap meniscal tears have two types: horizontal tears and oblique tears. The horizontal type will be similar to horizontal meniscus tear but different in injury level. Oblique tears are also mechanically unstable and produce flaps associated with mechanical symptoms.

Radial meniscus tear is where a fluid fissure of the low-strength meniscus extends outward from the central free end, perpendicular to the articular surface. Signs of a marching cleft indicate radial fissures in the parrot's beak and signs of a ghost meniscus indicate complete radial fissures.

Degenerative meniscus tear represented in MRI is considered as a combination of radial, horizontal, and longitudinal components (any two or all three). Meniscus material often appears fragmented and tends to be spread over multiple planes.

A horizontal meniscus tear in MRI is an area of signal change that extends horizontally aside the meniscus, parallel to the tibial plateau. Some patients may have pararenal cysts.

A longitudinal meniscus tear is shown on MRI when an intrathecal vertical line of increased T2/PD signal intensity contacts the surface of the femur and/or tibia. A purely vertical cleft preserves the free end of the meniscus.

Table 1. Symptoms and Location of six meniscus tears

Type of meniscus tears	Symptoms	Location
Bucket Handle meniscus tear	Tends to slide into the joint and cause a locked knee joint that prevents the knees from flexing properly	Medial part of meniscus
Flap meniscus tear	Get stuck in the joint, causing it to "catch" or lock up	part of the cartilage is peeled back
Radial meniscus tear	No blood supply through the meniscus. A radial tear destroys the hoop strength of the meniscus, leading to loss of function and compression of the meniscus	Extends through the short axis of the meniscus perpendicular to the tibial plateau and will extend radially from the central intercondylar region
Degenerative meniscus tear	Pain, clicking, locking, and "giving" way	Direct on knee joint
Horizontal meniscus tear	Discoid meniscus	Extends horizontally aside to the meniscus parallel to the tibial plateau
Longitudinal meniscus tear	Subtypes like Wrisberg rip and ramp lesion	Always involves the rear corners, most commonly the outer third

5. Conclusion

Meniscus tear is a disease of the fibrocartilaginous meniscus of the knee joint, and there are generally six types. Bucket handle meniscus rupture, flap meniscus tear, radial meniscus tear, horizontal meniscus tear, and longitudinal meniscus tears are classified as acute situations resulting from a normal knee injury and meniscal stress. Degenerative meniscus tears are considered chronic and are caused by repeated normal forces acting on the worn meniscus. It indicates that growing ages would lead to meniscus tears. Furthermore, different gender causes different physical conditions of the meniscus. Limb alignment also causes compensatory responses, accident and sports injuries, and osteoarthritis.

There are two examination techniques: (1) physical examinations including joint line tenderness, MacMurray tests, and Thessaly tests, and (2) imaging examinations including X-ray and MRI scans. MRI is the most important examination technology. It classifies the meniscus tear in four levels from 0 to III and diagnoses different types of meniscus tears.

Reference

- [1] D.S. Logerstedt, L.Snyder-Mackler, R.C. Ritter, M.J. Axe, J. Godges, R.D. Altman, M. Briggs, C. Chu, A. Delitto, A. Ferland, H. Fearon. Knee pain and mobility impairments: meniscal and articular cartilage lesions: clinical practice guidelines linked to the international classification of functioning, disability, and

- health from the orthopaedic section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy*, 2010, vol. 40, pp.A1-A35. DOI: 10.2519/jospt.2010.0304
- [2] M. Englund, A. Guermazi, S.L. Lohmander. The role of the meniscus in knee osteoarthritis: a cause or consequence?. *Radiologic clinics of North America*, 2009, vol. 47, pp. 703-712. DOI: 10.1016/j.rcl.2009.03.003
- [3] M.H. Metcalf, G.R. Barrett. Prospective Evaluation of 1485 Meniscal Tear Patterns in Patients with Stable Knees. *The American Journal of Sports Medicine*. 2004, vol. 32, pp. 675-680. DOI: 10.1177/0095399703258743
- [4] Haiden Heath. What is a meniscus bucket handle tear? Rampfeshdson.com. 2021. Retrieved from <https://www.rampfeshudson.com/what-is-a-meniscus-bucket-handle-tear/>
- [5] P. Massey, K. McClary, D. Parker, R.S. Barton, G. Solitro. The rebar repair for radial meniscus tears: a biomechanical comparison of a reinforced suture repair versus parallel and cross-stitch techniques. *Journal of Experimental Orthopaedics*. 2019 , vol. 6, pp. 1-8. DOI: <https://doi.org/10.1186/s40634-019-0206-4>
- [6] J.H. Ahn, T.S. Bae, K.S. Kang, S.Y. Kang, S.H. Lee. Longitudinal Tear of the Medial Meniscus Posterior Horn in the Anterior Cruciate Ligament–Deficient Knee Significantly Influences Anterior Stability. *The American Journal of Sports Medicine*. 2011, vol. 39, pp. 2187-2193. DOI: 10.1177/0363546511416597
- [7] Maryland Orthopedic specialists. Who Is Most at Risk of Suffering a Meniscus Tear? The Centers for Advanced Orthopaedics. Retrieved from <https://www.mdorthospecialists.com/blog/who-is-most-at-risk-of-suffering-a-meniscus-tear>
- [8] O.T. Eren. The accuracy of joint line tenderness by physical examination in the diagnosis of meniscal tears. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2003, vol. 19, pp. 850-4. DOI: 10.1016/s0749-8063(03)00736-9
- [9] T. Skalina. Thessaly test. Reference article, Radiopaedia.org. 2022. <https://doi.org/10.53347/rID-68078>
- [10] Y. Gupta, D. Mahara, A. Lamichhane. McMurray’s test and joint line tenderness for medial meniscus tear: are they accurate?. *Ethiopian Journal of Health Sciences*. 2016, vol. 26, pp. 567-72. DOI: 10.4314/ejhs.v26i6.10
- [11] Michael J. Alaia, Rick Wilkerson. Meniscus Tears. *OrthoInfo*. March 2021. Retrieved from <https://orthoinfo.aaos.org/en/diseases--conditions/meniscus-tears/>
- [12] S.H. Kim, C.I. Bae, K.I. Kim, J.W. Lee, S.H. Lee. Factors associated with bilateral discoid lateral meniscus tear in patients with symptomatic discoid lateral meniscus tear using MRI and X-ray. *Orthopaedics & Traumatology: Surgery & Research*. 2019, vol. 105, pp. 1389-94. DOI: <https://doi.org/10.1016/j.otsr.2019.08.007>.
- [13] V. Roblot, Y. Giret, M. Bou Antoun, C. Morillot, X. Chassin, A. Cotten, J. Zerbib, L. Fournier. Artificial intelligence to diagnose meniscus tears on MRI. *Diagnostic and Interventional Imaging*. 2019, vol. 100, pp. 243-249. DOI: <https://doi.org/10.1016/j.diii.2019.02.007>.
- [14] R. Howell, N.S. Kumar, N. Patel, J. Tom. Degenerative meniscus: Pathogenesis, diagnosis, and treatment options. *World journal of orthopedics*. 2014, vol. 18, pp. 597. DOI:10.5312/wjo.v5.i5.597