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Meniscal allograft transplant in a 16-year-old male soccer player: A case report

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Meniscal allograft transplantation (MAT) is a relatively new procedure that has gained popularity in the last couple of decades as a possible alternative to a meniscectomy to provide significant pain relief, improve function, and prevent the early onset of degenerative joint disease (DJD). As of present, evidence is limited and conflicting on the success of such procedures. In this case, a 16-year old male athlete underwent numerous surgical procedures to correct a left anterior cruciate ligament (ACL) rupture with associated medial and lateral meniscal damage that occurred as a result of a non-contact mechanism of injury. Following multiple procedures, including repair of both menisci and follow-up partial meniscectomy of the lateral meniscus, the patient continued to experience symptoms on the left lateral knee, making him a candidate for MAT. This case is used to highlight what a MAT is, what makes someone a candidate for this type of procedure, the current evidence surrounding the success of this intervention, and some rehabilitation considerations following surgery. The role of chiropractors and primary

L'allogreffe méniscale (AM) est une procédure relativement nouvelle qui s'est répandue au cours des dernières décennies comme une solution de remplacement possible à une méniscectomie afin de soulager de façon significative la douleur, d'améliorer la fonction, et d'empêcher l'apparition précoce de l'arthrose. À l'heure actuelle, il y a peu de données probantes, qui sont d'ailleurs contradictoires, sur le succès de ces procédures. Dans ce cas, un athlète de 16 ans a subi de nombreuses interventions chirurgicales pour corriger la rupture d'un ligament croisé antérieur (LCA) gauche ainsi que les lésions associées au ménisque médial et latéral qui se sont produites à la suite d'un mécanisme de blessure sans contact. Après plusieurs procédures, y compris la réparation des deux ménisques suivie d'une méniscectomie partielle du ménisque latéral, le patient a continué à ressentir des douleurs latérales au genou gauche, ce qui a fait de lui un candidat pour l'AM. Ce cas est utilisé pour mettre en évidence ce qu'est un AM, ce qui rend quelqu'un un candidat idéal pour ce genre de procédure, les preuves actuelles relatives à la réussite de cette intervention, et certains enjeux liés à la réadaptation après la chirurgie. Le rôle des chiropraticiens et des médecins traitants est d'assurer que les jeunes athlètes subissent une

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clinicians is to ensure that young athletes undergo early intervention to offset any degenerative changes that would be associated with sustained meniscal lesions.

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intervention rapide pour compenser les changements dégénératifs qui seraient associés à des lésions méniscales soutenues.

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MOTS CLÉS : méniscal, allogreffe, greffe, chiropratique

Introduction

Increased athletic participation among youth and adolescents has been on the rise.[1] This has lead to an increase in sports related injuries. Trauma and sports related injuries are common and have been cited to account for upwards of 40% of all injuries experienced by youth.[2] The knee is one of the most commonly injured joints accounting for 15.2% of all injuries among high school athletes.[3] Trauma to the meniscus accounts for up to 23% of all reported knee injuries.[3] These numbers are highly dependent on age, as it has been demonstrated that the incidence of meniscal and intra-articular disorders increase with age, likely being related to morphological changes in tissue elasticity.[4] Meniscal injuries are common among athletes from amateurs to professionals, typically resulting from a non-contact mechanism of injury when sudden rotational forces coupled with acceleration and deceleration impinge meniscal fibers between the tibia and femur resulting in tearing.[5,6] However, due to the complexity of forces associated with meniscal tears, concomitant anterior cruciate ligament (ACL) rupture or damage is possible, dramatically changing the overall presentation and prognosis of the clinical case. Surgical studies have indicated that concomitant meniscal injuries occur in 69-78% of all ACL cases.[7,8]

Degenerative changes associated with meniscal pathology are well documented in the literature and are of particular concern for adolescents where developing early onset osteoarthritis (OA) can lead to premature joint replacement.[9] This apparent correlation has generated a significant amount of attention in the importance of meniscal preservation to prevent degeneration. Over the years, various techniques have been implemented to offset these degenerative changes associated with meniscal lesions and traditionally involve one of the three common interventions: (1) conservative management (leave-alone), (2) excision (partial or complete menisectomy), or (3) repair.[10] However, in the past decade with advancements in technology and surgical procedures meniscal allograft transplantation has become a viable alternative to prevent the long-term sequelae in lesions that are not amendable through repair or partial-excision and would traditionally result in complete-excision.[11]

This case report focuses on concomitant ACL and meniscal injuries in adolescents and highlights the importance of early recognition and intervention to prevent premature degenerative changes. This report also outlines that in the presence of unsuccessful primary management, meniscal allografts could provide significant pain relief and functional improvement.

Case

A 16-year-old male presented to a sports chiropractic clinic with severe left knee pain that occurred during warm-up before a soccer match. He reported that it occurred as he was running across the pitch and as he went to change directions (plant and pivot) his left foot was placed in a divot causing him to collapse. He described that following the incident swelling occurred immediately. During initial presentation he had difficulty localizing pain and bearing weight, as well as, significant global knee range of motion deficits. Orthopedic examination was unable to be completed due to rigidity and swelling. Follow-up MRI revealed a full thickness ACL rupture with associated medial and lateral complex bucket handle tears of the left menisci.

Upon diagnosis, the patient underwent ACL reconstruction (June 2003), where a procedure producing an autograft using the semitendinosus tendon was implemented. At the time of the surgery the patient was informed that the tears in the menisci were not addressed and would be corrected at a later date. Following surgical intervention, the patient was treated in accordance with ACL rehabilitation and a sports-specific return to play protocol. Successful intervention had the patient developing full ROM and good joint proprioception. However, in lieu of this progression the patient still experienced recurrent/persistent pain with a sensation of instability (i.e., "giving way"). Additionally, the patient continued to report left knee joint line tenderness (medial and lateral) and swelling, leading to the second surgical intervention to repair both menisci six months (December 2003) following the initial surgery. Again, rehabilitation was provided by a sports chiropractor to facilitate return to play, but was impeded by continued symptoms (i.e., joint line tenderness and swelling) of the lateral knee, resulting in a third surgical procedure to perform a partial lateral menisectomy four months later (April 2004). The patient was able to return to play by September, but despite a return to full strength, good agility, and adequate proprioception the patient complained that the knee never quite felt "right" and sought the opinion of a second orthopedic surgeon in hope of an improved outcome. As a result, the patient received a lateral meniscal allograft in January of 2005 and returned to competition in July.

As a result of the final procedure, upon return to competition the patient only required periodic treatment over the next three years. Following the final procedure there was a significant reduction in pain and feeling of instability, resulting in improved patient satisfaction. Currently, the patient is 26-years old and continues to have the ability to participate in all of the sports he desires, but has started to demonstrate clinical signs and symptoms of early degenerative joint disease (DJD). These symptoms include increased joint stiffness and audible crepitus, as well as, decreased flexibility at the knee.

Discussion

The menisci are a complex dynamic type-1 collagenous structure situated between the femoral condyles and the tibial plateau.[12] It has been well documented that the menisci serves to stabilize the tibiofemoral joint particularly in ACL deficient knees, dissipate loading, increase joint congruency all while aiding in the lubrication of the articular structure.[13-15]

The medial meniscus is significantly less mobile then the lateral meniscus as a result of it being firmly attached to the medial joint capsule through both the meniscotibial and coronary ligaments. This consequently limits posterior translation of the medial meniscus to about 2.5mm during knee flexion.[16-18] In comparison, the lateral meniscus covers approximately 70% of the lateral tibial plateau, where the anterior horn attaches anterior to intercondylar eminence of the tibia, just lateral and posterior to the ACL.[16-18] Attaching in the general proximity is the posterior horn, which in 84% of people will divide into either anterior or posterior meniscofemoral ligaments (Humphrey or Wrisburg). The lateral meniscus has no connection to the popliteal hiatus or the lateral collateral ligament, which explains the increased excursion (up to 11mm) with knee flexion.[16-18]

The menisci are mostly avascular, suggesting limited capability to undergo natural healing. The meniscus can be divided into three zones transitioning from an avascular region of the central meniscus to an area of increased vascularity on the periphery. The central portion is termed the white-white zone, indicating an area void of blood, relying on diffusion from synovial fluid to provide nourishment.[11] Progressing laterally a region known as the "red-white" zone, which can be viewed as an area of high variability in blood supply to the meniscus. By the age of ten the meniscus beings to take on the adult morphology, vascularity will begin to recede confining blood supply to the peripheral one-third or "red-red zone" of the meniscus (Figure 1).[19] Specifically, it has been observed that vascu-

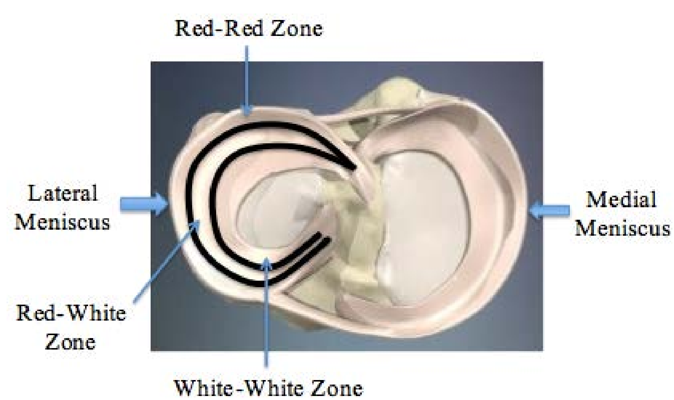

Figure 1
Superior tibial plateau with intact menisci demonstrating the 3 zones of vascularity (courtesy Primal Pictures Ltd. www.primalpictures.com)

larity in an adult meniscus can range from the peripheral 10-30% of the medial meniscus to 10-25% in the lateral meniscus.[19,20] Blood supply for the meniscus arises from a plexus of capillaries that comprise both superior and inferior branches of the lateral and medial genicular arteries.[19,20] The understanding of meniscal blood supply continues to be important, because an area high in vascularity has an increased potential to form a fibrovascular scar, crucial in the initiation of the reparative process. This has lead some to believe that younger individuals who sustain meniscal damage in the red zone have an increase propensity for healing.[19]

Surgical Management

Traditionally, surgical interventions of the meniscus involve excision of the damaged tissue (partial or complete meniscectomy) or attempted repair. The capacity of the meniscus to undergo healing is limited in the central portion (the red-white zone) and greatest in the menisco-synovial portion (red zone). It has been suggested that adolescents with tears confined to vascular zones (red/red and red/white) should undergo surgical repair to approximate damaged tissue and facilitate healing, through the formation of a fibrovascular scar.[17] However, in the circumstances that a tear is recognized in the avascular region (white/white zone), typically partial excision is recommended. It has now been recognized that such procedures can alter joint mechanics, increasing loading characteristics at the knee predisposing individuals to early DJD.[17] In a study by Baratz et al. it was described that following partial-menisectomies that the contact area would be reduced by 10% thus increasing point pressure by up to 65%, resulting in an increased rate of degenerative changes.[21] Full-menisectomies on the other hand would consequently reduce the contact surface by 75% increasing the associated joint contact pressure by 235%, resulting in the rapid onset of degeneration.[21] Due to this, full-menisectomies are now rarely performed and reserved for special circumstances, while not being recommended in youth.

In light of the negative side effects associated with menisectomies, attention has been directed at preserving functional meniscal tissue through repair to prevent continued catching, clicking, locking, instability ("giving way"), and to offset degenerative changes. Meniscal repair is the primary intervention prescribed in youth to facilitate healing and return to play in athletes, but may not be satisfactory in all circumstances.[22]

Current evidence suggests that early surgical management of meniscal tears is important in the long-term prognosis and the prevention of early onset OA in the knee.[22] Venkatachalem et al. demonstrated a 91% success rate with meniscal lesions repaired within three months of the initial injury, compared to only 58% in those after this period.[23] Additionally, other contributing factors to successful surgical repair include tear location, orientation, patient age, and concomitant ACL reconstruction.[22] Tear location speaks to vascular supply previously discussed with tears in the red zone likely to respond to surgical repair compared to those in the white zone.[22] Westin et al. performed a systematic review of the clinical healing rates of meniscus repairs in the red-white zone suggesting that repair is an acceptable intervention when appropriately indicated and should be considered before a meniscectomy is performed. It has also been suggested that future studies assessing healing rates in the red-white zone adequately report findings based on zone and type.[7] Additionally, it has been advised that authors separate findings from tears located in the red zone from the red-white zone because of the vastly different vascular characteristics of these areas.[7] Additionally, is has been suggested that tear orientation and type can affect healing following meniscal repairs. Vertical circumferential tears are likely to respond positively to surgical intervention, as these do not cause tearing of the circumferential collagen fibers, reducing the forces experienced by the lesion.[22] Comparatively, radial and complex multiplanar tears can cause significant disruption of collagenous fibers leading to a decreased propensity for tissue healing.[10]

In our case the MRI confirmed presentation of a full thickness ACL tear and associated medial and lateral complex bucket handle tears of the left menisci, which demonstrates the complexity of the lesion sustained by this athlete. Based on the available literature this could have warranted immediate surgical correction in hopes of protecting both the remaining meniscal tissue and the underlying articular structures.

When discussing meniscal injuries it is important to address associated ACL sequelae as concomitant injuries have been demonstrated to be associated with an increased risk of developing OA. In chronic ACL-deficient knees, increased instability leading to excess anterior translation and medial rotation of the tibia can predispose an individual to degenerative medial meniscal tears and early DJD.[24] Typically, it has been suggested that knee injuries resulting in concomitant ACL and meniscal lesions be repaired together producing significantly better outcomes.[22] It has been theorized that increased success is a result of increased intra-articular bleeding that supports fibrin clot formation and may provide the necessary vascular nutrition required to promote meniscal healing if repaired at the same time.[10]

When looking back at the case, it can be observed that these principals were not applied as ACL reconstruction was performed in isolation of meniscal repair. This is the result of determining during surgery that the meniscal lesions were in an area of high vascular supply and likely to respond to non-surgical repair. However, continued symptoms associated with both medial and lateral meniscal tears remained evident forcing multiple surgeries in attempt to repair and remove damaged tissue. This lead to many of the principals associated with successful meniscal repair not being addressed including: (1) not providing early surgical intervention on the meniscus to prevent degenerative changes (< 3-months), (2) progressive degeneration of the meniscus due to laxity associated with ACL reconstruction likely affected the type and location of the tear, resulting in a worse prognosis for this patient, leading to a drastic and relatively new procedure.

Meniscal Allograft Transplant (MAT)

After numerous failed surgical interventions the patient in this case report underwent a relatively new procedure involving a meniscal transplant from a cadaveric specimen (allograft). Meniscal transplants are highly involved surgical procedures requiring successful anchoring of meniscal tissue to the tibial plateau. Currently, there is a very limited number of orthopedic surgeons worldwide with a significant amount of experience in performing meniscal transplants. However, increased popularity as a result of a growing body of evidence demonstrating significant pain relief and functional outcomes has resulted in more procedures annually.[11]

In regards to meniscal allografts there are four primary procedures that are used including cryopreserved, fresh-frozen, fresh, and freeze-dried.[11,25] Each procedure comes with definitive pros and cons, which are unique to the histochemical and preservation method of the graft and is likely a concern for the operating surgeon.[11] Recently, most procedures are preformed using a fresh-frozen graft as they have become synonymous with elevated success rates, decreased risk of disease transmission, and maintenance of structural integrity preventing further degenerative changes to the knee.[26]

The indications for meniscal allograft transplantation (MAT) still remain vague and controversial, but recommendations have been established to suggest when this intervention is likely to have beneficial results.[11,26] First, it has been suggested that the ideal candidate is between the ages of 20-50 with a previous history of meniscectomy. Appropriate considerations should be taken to ensure skeletal maturity of the patient, as MAT procedures are not likely to be performed on subjects prior to closure of the epiphyseal plates.[11,26] Additionally, the patient should present with a stable knee joint, have minimal degenerative changes, no lower-limb radiographic misalignment, and no localized pain or swelling over the meniscus-deficient compartment.[11,26] Next, ACL-deficient patients who have previously had a medial meniscectomy are likely to yield positive results and improve joint stability if ACL reconstruction is performed in conjunction with MAT.[11,26] Finally, though not routinely performed, prophylactic MAT could be performed in young, athletic patients who have previously received a complete meniscectomy to prevent future DJD. This is not routinely performed because current evidence has not demonstrated significant evidence in the prevention of long-term joint arthrosis and is not void of surgical complications. However, some supporters have suggested that early intervention may significantly improve the surgical outcomes associated with MAT, likely making this conversation to be had between the patient and surgeon.[11,26] These recommendations have been suggested because like any invasive procedure there is associated risk beyond those commonly associated with surgeries and need to be actively discussed. Such surgical complications can include immunological concerns (i.e., host rejection), as the bone plug (an immunogenic substance) used to attach the meniscal graft has the potential to cause an immune reaction.[11] Further, concerns regarding disease transmission, primarily of Hepatitis C and HIV can occur even when appropriate sterilization procedures have been performed.[11] These risks are considered small but must be discussed with the patient prior to intervention.[11] Potential complications following MAT include detachment of the meniscus or bone plug, meniscal allograft failure, and arthrofibrosis.[11]

Conversely, contraindications include severe degenerative cartilaginous changes, resulting in ulceration and bone exposure. Radiographic evidence of advanced DJD (i.e., osteophyte formation, joint space narrowing, flattening of the femoral condyles) has been demonstrated to be associated with poor results during MAT. Additionally, it has been advised that patients over the age of 50 are not ideal candidates to receive MAT, while other negative prognostic factors include obesity (BMI>35), skeletal immaturity, and systemic diseases (e.g., synovial chondromatosis, inflammatory arthritis, and infection).[11,26-27]

Much of the initial evidence focusing on MAT, like many surgical procedures, has its roots in both cadaveric and animal studies providing limited translation into the active bipedal weight bearing human. However, recent studies have begun to look at the success of these procedures in humans, demonstrating various results both in the short-term and long-term. A study by Noyes and Barber-Westin revealed that 62 of 96 grafts (65%) were intact 2-years post surgical.[28] Similarly, Verdonk and colleagues demonstrated success rates to be 74.2% and 69.8% for medial and lateral MAT respectively, with a mean follow-up of 7.2 years.[29] However, a couple of studies have looked at long-term follow-up (> 10 years) of MAT, reporting conflicting evidence. Wirth and colleagues performed a follow-up (14 years) analysis of an original series, demonstrating that all allograft and articular cartilage underwent degenerative changes.[30] In contrast, Verdonk et al. suggested that MAT has a potential chondroprotective effect at follow-up (minimum 10 years, mean 12.1 years) by demonstrating that there was no joint space narrowing in 52% of patients.[31] The relatively young field of meniscal transplantation is characterized by a limited body of retrospective cohort literature, suggesting success rates between 12.5-100%.[26] However, it is important to note that these studies are limited in the capacity that they fail to provide a control group undergoing conservative management following a meniscectomy.[11]

Rehabilitation is an important component in the success of many orthopedic surgeries, but very little research has been conducted on the most appropriate method when dealing with MAT. This has led there to be confusion and a lack of consensus among professionals with regards to tissue loading and progression. Lee and colleagues have suggested a progressive approach to facilitate functional return without compromising the healing tissue.[26] It has been proposed that within two months post-surgery a patient should have the progressive ability to bear weight while achieving full ROM to allow for return to sport in 6-9 months. ROM exercise should begin immediately post-operatively focusing on full extension while limiting flexion to 90 degrees for the first 6-weeks as increased flexion has been associated with elevated stress on the meniscus, particularly at the posterior horn.[32] Further, pivoting and weight bearing should be minimized to prevent compression and shearing of meniscal tissue during the initial stages of rehabilitation.[26] During the first 4-weeks, initial rehabilitation is characterized by progressive closed kinetic chain exercises (i.e. standing toe-touch with full knee extension or passive knee extension) and patellar mobilizations to promote functional tissue loading (Figures 2-4).[26,32] Early open kinetic chain exercises, such as seated leg curl, are not advised. It has been suggested that knee flexion increases activation of the semimembranosus and popliteus cause posterior translation of both the medial and lateral meniscus respectively, potentially dislodging meniscal tissue.[26,32] Recommendations suggest that gentle jogging can begin between 4-6 months, but running is not advised before 6-months post-surgical.[26,32] Finally, return to play is likely to occur between 6-9 months.[26] In the case that concomitant ACL reconstruction occurs, rehabilitation protocol should be modified to address the meniscus

Figure 2
Standing toe-touch with full knee extension

Figure 3
Passive knee extension

Figure 4
Patellar mobilization

as the primary concern. Typically, ACL rehabilitation is characterized by progressive strengthening of the hamstrings through either concentric or eccentric loading to prevent anterior translation of the tibia during dynamic movements. The principals addressed during ACL rehabilitation if addressed too early are likely to have detrimental effects on the success of a meniscal transplant.[32] In this case an appropriate rehabilitation protocol for both the ACL and meniscus was followed. The rehabilitation program was carefully developed based on suggestions from the surgeon, while taking into consideration patient tolerance and mastery of previous exercises before progression could take place.

Conclusion

Meniscal injuries are a common injury among the athletic population, resulting from a non-contact mechanism of injury where rapid acceleration and deceleration in conjunction with twisting causes meniscal tissue to become impinged between the tibia and femur. The menisci serve to dissipate loading, increase joint congruency and aid in lubrication of the femorotibial articulation.[13-15] It has been well documented in the literature that significant trauma or excision of the menisci are associated with degenerative changes in the knee, suggesting that preservation of the menisci is of crucial importance in the prevention of early DJD. Traditionally, meniscal lesions have been addressed through surgical correction or removal, with less emphasis on conservative management as early surgical repair are associated with better outcomes. However, not all surgical procedures are successful leading to continued symptoms and disability. Meniscal allograft transplants have become a recent surgical innovation in the management of meniscal injuries. This relatively new procedure is characterized by meniscal transplantation using one of four forms of an allograft (cryopreserved, fresh-frozen, fresh, freeze-dried), with most success coming from those using fresh-frozen specimens.[11,25] Currently, due to the limited amount of surgeons performing these surgeries worldwide literature regarding the chondroprotective effects is limited, suggesting that this intervention should remain a last resort when patients have continued symptoms. Future research should be focused on the long-term success as well as the chondroprotective effects of meniscal allograft transplants, while addressing rehabilitation protocols that could promote return to function following surgery.

References

1. Maffulli N, Longo UG, Spiezia F, Denaro V. Sports injuries in young athletes: long-term outcomes and prevention strategies. The Physician and Sports Medicine. 2010; 2(38): 29-34.
2. Klenerman L. ABC of sports medicine. Musculoskeletal injuries in child athletes. BMJ. 1994; 308(6943); 1556-1559.

3. Swenson DM, Collins CL, Best TM, Flanigan DC, Fields SK, Comstock RD. Epidemiology of knee injuries among U.S. high school athletes, 2005/2006-2010/2011. Med Sci Sports Exerc. 2013; 45(3); 462-469.
4. Kraus T, Svehlik M, Singer G, Schalamon J, Zwick E, Linhart W. The epidemiology of knee injuries in children and adolescents. Arch Orthop Trauma Surg. 2012; 132; 773-779.
5. Levy IM, Torzilli PA, Warren RF. The effect of medial meniscectomy on anterior-posterior motion of the knee. J Bone Jt Surg Am. 1982; 64A(6); 883–888.
6. Cavanaugh JT, Killian SE. Rehabilitation following meniscal repair. Curr Rev Musculoskelet Med. 2012; 5; 46-58.
7. Barber-Westin SD, Noyes FR. Clinical healing rates of meniscus repairs of tears in the central-third (red-white) zone. Arthroscopy. 2014; 30(1); 134-146.
8. Vanderhave KL, Moravek JE, Sekiya JK, Wojtys EM. Meniscus tears in the young athlete: results of arthroscopic repair. J Pediatr Orthop. 2011; 31(5); 496-500.
9. Pengas IP, Assiotis A, Nash W, Hatcher J, Banks J, McNicholas MJ. Total meniscectomy in adolescents: a 40-year follow-up. J Bone Joint Surg Br. 2012; 94(12); 1649–1654.
10. Boyd KT, Myers PT. Meniscus preservation; rationale, repair techniques and results. The Knee. 2003; 10; 1-11.
11. Lubowitz JH, Verdonk PC, Reid JB, Verdonk R. Meniscus allograft transplantation: a current concepts review. Knee Surg Sports Traumatol Arthrosc. 2007; 15; 476-492.
12. Messner K, Gao J. The menisci of the knee joint. Anatomical and functional characteristics, and rational for clinical treatment. J Anat. 1998; 193; 161-178.
13. Helfet AJ. Mechanism of derangements of the medial semilunar cartilage and their management. J Bone Joint Surg Br. 1959; 41; 319–336.
14. Levy IM, Torzilli PA, Gould JD, Warren RF. The effect of lateral meniscectomy on motion of the knee. J Bone Joint Surg Am.1989; 71; 401–406.
15. Walker PS, Erkman MJ. The role of the menisci in force transmission across the knee. Clin Orthop. 1975; 109; 184– 192.
16. Bellisari G, Samora W, Klingele K. Meniscus tears in children. Sports Med Arthrosc Rev. 2011; 19; 50-55.
17. Rath E, Richmond JC. The menisci: basic science and advances in treatment. Br J Sports Med. 2000; 34(4); 252-257.
18. Chivers MD, Howitt SD. Anatomy and physical examination of the knee menisci: a narrative review of the orthopedic literature. J Can Chiropr Assoc. 2009; 53(4); 319-333.
19. Willis RB. Meniscal injuries in children and adolescents. Oper Tech Sports Med. 2006; 14; 197-202.
20. Arnoczky SP, Warren RF. Microvasculature of the human meniscus. Am J Sports Med. 1982; 10; 90-95.
21. Baratz ME, Fu FH, Mengato R. Meniscal tears: the effect of meniscectomy and of repair on intra-articular contact areas and stress in the human knee. A preliminary report. Am J Sports Med. 1986; 14; 270-275.
22. Getgood A, Robertson A. (v) Meniscal tears, repairs and replacement – a current concept review. Orthop Trauma. 2010; 24(2); 121-128.
23. Venkatachalam S, Godsiff SP, Harding ML. Review of the clinical results of arthroscopic meniscal repair. Knee. 2001; 8; 129-133.
24. Allen CR,Wong EK, Livesay GA, Sakane M, Fu FH, Woo SL. Importance of the medial meniscus in the anterior cruciate ligament-deficient knee. J Orthop Res. 2000; 18; 109-115.
25. Cole BJ, Carter TR, Rodeo SA. Allograft meniscal transplantation: background, techniques, and results. Instr Course Lect. 2003; 52; 383–396.
26. Lee SR, Kim JG, Nam SW. The tips and pitfalls of meniscus allograft transplantation. Knee Surg Relat Res. 2012; 24(3); 137-145.
27. Noyes FR, Barber-Westin SD. Prospective evaluation of allograft meniscus transplantation: a minimum 2-year follow-up. Am J Sports Med 2006; 34; 2038–2039.
28. Noyes FR, Barber-Westin SD. Irradiated meniscus allografts in the human knee: a two to five year follow-up study. Orthop Trans. 1995; 19; 417
29. Verdonk PCM, Demurie A, Almqvist KF, Veys EM, Verbruggen, Verdonk R. Transplantation of viable meniscal allograft: survivorship analysis and clinical outcome of one hundred cases. J Bone Joint Surg Am. 2005; 87; 715– 724.
30. Wirth CJ, Peters G, Milachowski KA, Weismeier KG, Kohn D. Long-term results of meniscal allograft transplantation. Am J Sports Med. 2002; 30; 174–181.
31. Verdonk PCM, Verstraete KL, Almqvist KF, De Cuyper K, Veys EM, Verbruggen G, Verdonk R Meniscal allograft transplantation: long-term clinical results with radiological and magnetic resonance imaging correlations. Knee Surg Sports Traumatol Arthrosc. 2006; 14; 694-706.
32. Rodeo SA. Meniscal allografts – where do we stand?. AJSM. 2001; 29(2); 246-261.