Knee Menisci: Structure, Function, and Management of Pathology

CARTILAGE
2017, Vol. 8(2) 99–104
© The Author(s) 2016
Reprints and permissions:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1947603516654945
journals.sagepub.com/home/CAR

James Kevin Bryceland¹, Andrew John Powell¹, and Thomas Nunn²

Abstract

The menisci of the knees are semicircular fibrocartilaginous structures consisting of a hydrophilic extracellular matrix containing a network of collagen fibers, glycoproteins, and proteoglycans maintained by a cellular component. The menisci are responsible for more than 50% of load transmission across the knee and increase joint congruity thereby also aiding in fluid film lubrication of the joint. In the United Kingdom, meniscal tears are the most common form of intra-articular knee injury and one of the commonest indications for orthopedic intervention. The management of these injuries is dependent on the location within the meniscus (relative to peripheral blood supply) and the pattern of tear. Removal of meniscus is known to place the knee at increased risk of osteoarthritis; therefore repair of meniscal tears is preferable. However, a significant proportion of tears are irreparable and can only be treated by partial or even complete meniscectomy. More recent studies have shown encouraging results with meniscal replacement in this situation, though further work is required in this area.

Keywords

meniscus, tissue, meniscal injury, diagnosis, knee, joint involved

Introduction

Meniscus is derived from the Greek word *meniskos* meaning crescent moon.¹ A meniscus is a crescent shaped fibrocartilaginous structure which part divides a joint,² usually while adding concavity. Menisci (plural) are present in many joints throughout the body, most notably the knee. This article aims to describe the structure and function of the menisci within the knee and to summarize current concepts in the management of pathologies affecting the menisci.

Anatomy

The knee consists of 2 menisci, 1 medial and 1 lateral. They lie between the femoral condyle and the tibial plateau on the corresponding side of the knee as shown in **Figure 1**.

Macroscopically there are differences between the medial and lateral menisci. The medial meniscus is semicircular, 40 to 45 mm long, approximately 27 mm wide, and covers 51% to 74% of the medial articular surface.³⁻⁵ The posterior horn of the medial meniscus is firmly attached to the posterior intercondylar area of the tibia⁶ directly anterior to the insertion of the posterior cruciate ligament. The anterior horn has a more variable insertion commonly 7 mm anterior to the anterior cruciate ligament. The medial meniscus is relatively immobile because of its firm attachment to deep surface of the medial collateral ligament⁷ and is continuously attached to the joint capsule peripherally.

Figure 1. Menisci as viewed in situ on tibia.

The lateral meniscus displays greater variety in size, shape, and thickness than the medial meniscus. The lateral meniscus is shorter at 32 to 35 mm^{3,4} and almost circular in

¹Queen Elizabeth University Hospital, Glasgow, UK

²Royal Alexandra Hospital, Paisley, Renfrewshire, UK

Corresponding Author:

James Kevin Bryceland, Queen Elizabeth University Hospital,
1345 Govan Road, Glasgow, G51 4TF, UK.
Email: j.bryceland@nhs.net

Figure 2. Vascular zones of the menisci.

shape. The lateral meniscus covers a larger area of the tibial articular surface at 75% to 93%.⁵ The posterior horn of the lateral meniscus is attached to the intercondylar area of the tibia adjacent and anterior to that of the medial meniscus. The posterior horn of the lateral meniscus is also attached to the medial femoral condyle near the insertion site of the posterior cruciate ligament by the meniscomfemoral ligaments. These are known as the ligament of Humphrey, which lies in front of the posterior cruciate ligament and the ligament of Wrisberg, which lies posterior to the posterior cruciate ligament. Though only 46% of people have both of these ligaments, 100% of people have at least one of them.⁸ Unlike the medial meniscus, the lateral meniscus does not have any direct attachment to the corresponding collateral ligament. There is only loose peripheral attachment to the joint capsule which is interrupted by the popliteus tendon at the popliteal hiatus⁹ thereby allowing greater mobility of the lateral meniscus.

Vascular supply to the menisci originates predominantly from the inferior and superior lateral and medial geniculate arteries¹⁰ via the perimeniscal capillary plexus. Following birth, the menisci become increasingly avascular, so by maturity only the peripheral 10% to 25% of the tissue is perfused.⁵ This gives rise to 3 distinct regions of the menisci (**Fig. 2**): the peripheral relatively vascularised region called the red-red zone (Zone 1) and the completely avascular inner zone known as the white-white zone (Zone 3). There is a zone of transition between the 2, which is called the red-white zone (Zone 2). There is a direct relationship between the vascularization and capacity of the tissue to heal, predisposing the white-white zone to permanent posttraumatic and degenerative lesions.¹¹

Microstructure

The microstructure of the medial and lateral menisci is similar. They are fibrocartilaginous structures with an extracellular matrix which is 72% water by weight.¹² The remaining extracellular matrix is an interlacing network of collagen

Figure 3. Meniscus in cross-section.

fibers, proteoglycans, and glycoproteins.¹³ This extracellular matrix is synthesized and maintained by the cellular component of the menisci. The precise cellular and extracellular content of the menisci varies depending on the region within the tissue. Within the red-red zone, type I collagen is predominant similar to ligaments, tendons and other fibrous connective tissues. Most cells in this region are therefore akin to fibroblasts and fusiform in shape. Conversely, the extracellular matrix of the white-white zone contains an abundance of type II collagen fibers, which are more similar to hyaline articular cartilage. The predominant cell type here is therefore fibrochondrocytes,^{14,15} which are anaerobic cells with few mitochondria giving a low metabolic rate suited to the poor vasculature of this area of tissue.

Collagen fibers within the menisci are arranged in 3 distinct layers as shown in **Figure 3**. The majority of fibers lie in the middle layer and are orientated circumferentially offering resistance to hoop stresses.¹⁶ This layer is sandwiched between 2 surface layers in which there are radially arranged shorter fibers acting as ties, providing structural rigidity against compressive forces and preventing longitudinal splitting¹³ as well as resistance to shear forces.

Proteoglycans are heavily glycosylated molecules¹⁷ making them highly hydrophilic. They serve the important function of absorbing water, which supports the tissue under compressive forces.^{17,18} Adhesion glycoproteins are present in small amounts but serve as an important link between the cellular component of the meniscus and the extracellular matrix and include fibronectin, thrombospondin, and collagen VI.^{19,20}

Function

Both menisci are crucial to the healthy knee and perform several functions. Perhaps most notably, they are responsible for >50% of load transmission across the knee.²¹⁻²³ The percentage of force transmitted varies with the position of the knee. For every 30° of knee flexion, the contact surface between the 2 knee bones decreases by 4%.²⁴ When the knee is in 90° of flexion the applied axial load in the joint is 85% greater than when it is in 0° of flexion.²³ In full knee

flexion, the lateral meniscus transmits 100% of the load in the lateral knee compartment, whereas the medial meniscus takes on approximately 50% of the medial load.²⁵ In the knee following complete meniscectomy, the contact area is reduced by approximately 50% resulting in a dramatic increase in load per unit area. Even partial meniscectomy of as little as 15% to 34% has been shown to increase contact pressures to in excess of 350%.²⁶

The menisci also have the important function of increasing the congruity between the femoral and tibial condyles, increasing joint conformity, which is a requirement for fluid film lubrication and normal circulation of synovial fluid within the knee.²⁷ They are able to achieve this through a full range of normal movement by deforming as the knee flexes and extends. The medial meniscus performs a role in anteroposterior stability of the knee through the range of movement as evidenced by increased *in situ* forces of 33% to 55% on the anterior cruciate ligament in the knee after medial meniscectomy.²⁸ Energy dissipation, or shock absorption, by the menisci is the result of high frictional drag caused by low permeability of the matrix, which is about one-sixth as permeable as articular cartilage.²⁹

Injury

Meniscal tears are the most common form of intra-articular knee injury with an incidence of 60 to 70 per 100,000 per annum in the United Kingdom.³⁰ In the United States, meniscal tears are the commonest reason for orthopedic surgical intervention.^{31,32} It has been shown that men are more prone to meniscal injuries by a ratio of between 2.5:1 and 4:1 and a peak incidence between 20 and 29 years of age.^{33,34} In young patients, sports-related injuries account for more than one-third of meniscal tears^{33,34} and are usually the result of high energy twisting or hyperextension forces.³⁵ When associated with sport, meniscal injuries have a high rate of concomitant anterior cruciate ligament rupture.³⁶⁻⁴⁰

Classification

Meniscal injuries can broadly be described in terms of pattern and location. Tear pattern can be subdivided into vertical, horizontal and complex as shown in **Figure 4**. Vertical tears can be longitudinal, often involving the periphery of the meniscus in the commonly known “bucket handle” lesion, or radial, which is often asymptomatic when small. Horizontal tears can be complete cleavage, separating the meniscal edge into 2 layers, or partial cleavage which results in the most commonly seen pattern known as a “flap tear.” Complex tears have a vertical and horizontal component and are usually related to a degenerate knee.⁴¹⁻⁴³

Location of meniscal tears with reference to the zones of vascularization as described previously is key to deciding the best course of management. Location can be divided into

Figure 4. Patterns of meniscal injury.

zone 1—0 to 3 mm from the meniscosynovial junction, zone 2—3 to 5 mm from the periphery, and zone 3—> 5 mm.⁴⁴ These zones correspond with the red-red, red-white, and white-white zones, respectively, as demonstrated in **Figure 4**. Healing rates for meniscal injuries have been shown to be high in the vascularized red-red zone.⁴⁵⁻⁴⁹ With respect to the anatomical location of a tear, it has been suggested that the posterior horn of the medial meniscus carries rates of failure to heal when repaired.⁵⁰

Meniscal Repair

Understanding of the functions and importance of the menisci to the knee highlights the need to preserve the meniscus where possible. Meniscal repair therefore presents an attractive solution to treating meniscal tears. However, recent meta-analysis has demonstrated failure rates of around 23%.⁵¹ Failure rates are demonstrably higher >5 mm from the meniscosynovial junction and in degenerate tissue or complex tears. Vascular supply 3 to 5 mm is variable^{52,53} and clinical judgment must be exercised as to appropriateness of repair based on the condition of the tissue and pattern of tear. Furthermore, higher success rates have been demonstrated in meniscal tears repaired within 6 weeks of injury compared with late repairs.⁵⁴ Unsuccessful meniscal repair carries morbidity in the form of articular damage, tear extension, loose bodies, and requirement for reoperation.⁵⁵ Clinical judgment must therefore be exercised. There are 4 techniques for meniscal repair: open, outside-in, inside-out, and all-inside. Technological advances have led to most surgeons now preferring the all-inside technique because of decreased risk of neurovascular damage and reduced surgical time.⁵⁶ Tears in the anterior and middle thirds of the menisci can be difficult to address with this technique and this situation is often easier managed by the inside-out or

outside-in technique. Additional techniques have been shown to increase the probability of a meniscal repair healing and include rasping adjacent synovium to stimulate a healing response,⁵⁷⁻⁵⁹ creating channels in the meniscus using a needle to encourage fibrovascular healing in avascular areas⁵² and the addition of a fibrin clot to a meniscal repair has been shown to substantially reduce failure rates.⁶⁰ Meniscal repair performed at the same time as anterior cruciate ligament reconstruction has also been shown to have healing rates of 93% when compared with 50% when repair is performed as an isolated procedure in a stable knee.⁶¹

Meniscectomy

Clearly not all meniscal tears are repairable and there is no clear guidance from the published literature as to what percentage of tears should be repaired, certainly rates of partial meniscectomy are higher than that of meniscal repair. Resection of the entire meniscus results in significant increases in load transmitted through the articular cartilage and has been shown to be associated with a 14-fold increase in rates of osteoarthritis after 21 years.⁶² For this reason, removal of the least amount of meniscus possible will result in the best long-term outcome.^{63,64} When partial meniscectomy is performed it is important, where possible, to preserve the circumferential collagen fibers,⁵⁵ which are essential to the load-bearing and shock-absorbing function of the meniscus in dissipating hoop stresses. Partial meniscectomy holds the short term advantage over repair of quicker rehabilitation. This probably does not outweigh the potential long-term benefits of repair in reduction of development of osteoarthritis, shown by one study to be 19.2% for repair compared with 60.0% following partial meniscectomy at 8.8 years.⁶⁵ Other studies have suggested that while radiographic signs of osteoarthritis are significant at 8 to 16 years following arthroscopic partial meniscectomy, clinical symptoms of knee arthritis were not observed so frequently.⁶⁶

Meniscal Substitution

A problem exists for patients with meniscal tears that are irreparable or in which repair has failed and partial meniscectomy is impossible, necessitating complete meniscectomy. In this situation, replacement of the removed meniscus may reduce long-term wear of the articular cartilage. Different types of meniscal substitutes, including allografts, collagen, and synthetic and biodegradable scaffolds have been used in experimental and clinical studies.⁶⁷ Encouraging results have been shown with fibrin clot allografts that eventually modulated into fibrocartilaginous tissue in animal models.⁶⁸ The fibrin clot appeared to act as a chemotactic and mitogenic stimulus for reparative cells and to provide a scaffolding for the reparative process. In clinical practice, this technique has mixed results with success rates of 64% reported.⁶⁹ Synthetic

or collagen meniscal scaffold implants are gaining favor and support the in-growth of new "meniscus like" tissue with the aim of alleviating post-meniscectomy knee pain and preventing further articular cartilage degeneration. Success rates as high as 91% have been demonstrated with this technique⁷⁰ but studies have small numbers and lack long-term follow-up past 1 year.

Conclusion

The menisci are essential to the function of the healthy knee and an understanding of their structure and function is crucial to managing pathology. Preservation of as much healthy meniscus as possible, while managing symptoms, is the core principle of treatment. Meniscal repair techniques are improving and success rates are higher when performed early. Unfortunately a substantial proportion of meniscal tears are not repairable necessitating partial or even complete meniscectomy. Evidence has reliably demonstrated that meniscectomy leads to a significantly increased risk of developing osteoarthritis in the knee and that the minimum amount of meniscus possible should be removed only. However, a small number of patients still require complete meniscectomy for complex and recurrent tears. Early results looking at meniscal replacement in this situation are encouraging but evidence is limited and more work is required in this particular area.

Acknowledgments and Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Pring JT. The Oxford dictionary of modern Greek: Greek-English, English-Greek. Oxford, England: Clarendon Press; 1982.
2. Platzer W. Color atlas of human anatomy, vol. 1: locomotor system. 5th ed. New York: Thieme; 2004.
3. McDermott ID, Sharifi F, Bull AM, Gupte CM, Thomas RW, Amis AA. An anatomical study of meniscal allograft sizing. *Knee Surg Sports Traumatol Arthrosc.* 2004;12:130-5.
4. Shaffer B, Kennedy S, Klimkiewicz J, Yao L. Preoperative sizing of meniscal allografts in meniscus transplantation. *Am J Sports Med.* 2000;28:524-33.
5. Clark CR, Ogden JA. Development of the menisci of the human knee joint. Morphological changes and their potential role in childhood meniscal injury. *J Bone Joint Surg Am.* 1983;65:538-547.
6. Drake RL, Vogl AW, Mitchell AWM. Gray's anatomy for students. 2nd ed. Philadelphia, PA: Churchill Livingstone; 2010. p. 558-60.

7. Stein G, Koebke J, Faymonville C, Dargel J, Müller LP, Schiffer G. The relationship between the medial collateral ligament and the medial meniscus: a topographical and biomechanical study. *Surg Radiol Anat.* 2011;33:763-6.
8. Kusayama T, Harner CD, Carlin GJ, Xerogeanes JW, Smith BA. Anatomical and biomechanical characteristics of human meniscofemoral ligaments. *Knee Surg Sports Traumatol Arthrosc.* 1994;2:234-7.
9. Cohn AK, Mains DB. Popliteal hiatus of the lateral meniscus. Anatomy and measurement at dissection of 10 specimens. *Am J Sports Med.* 1979;7:221-6.
10. Wheelless CR III. Wheelless' textbook of orthopaedics: vascular anatomy of menisci. http://www.wheellessonline.com/ortho/vascular_anatomy_of_menisci.
11. Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med.* 1982;10:90-5.
12. Herwig JU, Egner EB, Buddecke EC. Chemical changes of human knee joint menisci in various stages of degeneration. *Ann Rheum Dis.* 1984;43:635-40.
13. Ramachandran M. Basic orthopaedic sciences: the Stanmore guide. London, England: Hodder Arnold; 2007. p. 80-4.
14. Melrose J, Smith S, Cake M, Read R, Whitelock J. Comparative spatial and temporal localisation of perlecan, aggrecan and type I, II and IV collagen in the ovine meniscus: an ageing study. *Histochem Cell Biol.* 2005;124:225-35.
15. Hellio Le Graverand MP, Ou Y, Schield-Yee T, Barclay L, Hart D, Natsume T, et al. The cells of the rabbit meniscus: their arrangement, interrelationship, morphological variations and cytoarchitecture. *J Anat.* 2000;198:525-35.
16. Jones RS, Keene GC, Learmonth DJ, Bickerstaff D, Nawana NS, Costi JJ, et al. Direct measurement of hoop strains in the intact and torn human medial meniscus. *Clin Biomech (Bristol, Avon).* 1996;11:295-300.
17. Yanagishita M. Function of proteoglycans in the extracellular matrix. *Pathol Int.* 1993;43:283-93.
18. Scott PG, Nakano T, Dodd CM. Isolation and characterization of small proteoglycans from different zones of the porcine knee meniscus. *Biochim Biophys Acta.* 1997;1336:254-62.
19. McDevitt CA, Webber RJ. The ultrastructure and biochemistry of meniscal cartilage. *Clin Orthop Relat Res.* 1990;(252):8-18.
20. Miller RR, McDevitt CA. Thrombospondin in ligament, meniscus and intervertebral disc. *Biochim Biophys Acta.* 1991;1115:85-8.
21. Noyes FR, Heckmann TP, Barber-Westin SD. Meniscus repair and transplantation: a comprehensive update. *J Orthop Sports Phys Ther.* 2012;42:274-90.
22. Fukubayashi T, Kurosawa H. The contact area and pressure distribution pattern of the knee: a study of normal and osteoarthrotic knee joints. *Acta Orthop Scand.* 1980;51:871-9.
23. Ahmed AM, Burke DL. In-vitro measurement of static pressure distribution in synovial joints—part I: tibial surface of the knee. *J Biomech Eng.* 1983;105:216-25.
24. Walker PS, Hajek JV. The load-bearing area in the knee joint. *J Biomech.* 1972;5:581-589.
25. Walker PS, Erkiuan MJ. The role of the menisci in force transmission across the knee. *Clin Orthop Relat Res.* 1975;(109):184-92.
26. Seedhom BB, Hargreaves DJ. Transmission of the load in the knee joint with special reference to the role of the menisci: part II: experimental results, discussion and conclusions. *Eng Med.* 1979;8:220-8.
27. Hamrock BJ, Schmid SR, Jacobson BO. Fundamentals of fluid film lubrication. Boca Raton, FL: CRC Press; 2004.
28. Papageorgiou CD, Gil JE, Kanamori A, Fenwick JA, Woo SL, Fu FH. The biomechanical interdependence between the anterior cruciate ligament replacement graft and the medial meniscus. *Am J Sports Med.* 2001;29:226-31.
29. Fithian DC, Kelly MA, Mow VC. Material properties and structure-function relationships in the menisci. *Clin Orthop Relat Res.* 1990;(252):19-31.
30. Maffulli N, Longo UG, Campi S. Meniscal tears. *Open Access J Sports Med.* 2010;1:45-54.
31. Morgan CD, Wojtys EM, Casscells CD, Casscells SW. Arthroscopic meniscal repair evaluated by second-look arthroscopy. *Am J Sports Med.* 1991;19:632-638.
32. Salata MJ, Gibbs AE, Sekiya JK. A systematic review of clinical outcomes in patients undergoing meniscectomy. *Am J Sports Med.* 2010;38:1907-16.
33. Baker BE, Peckham AC, Puppato F, Sanborn JC. Review of meniscal injury and associated sports. *Am J Sports Med.* 1985;13:1-4.
34. Steinbrück K. Epidemiology of sports injuries—25-year-analysis of sports orthopedic-traumatologic ambulatory care [in German]. *Sportverletz Sportschaden.* 1999;13:38-52.
35. Greis PE, Bardana DD, Holmstrom MC, Burks RT. Meniscal injury: I. Basic science and evaluation. *J Am Acad Orthop Surg.* 2002;10:168-76.
36. Rubman MH, Noyes FR, Barber-Westin SD. Arthroscopic repair of meniscal tears that extend into the avascular zone: a review of 198 single and complex tears. *Am J Sports Med.* 1998;26:87-95.
37. Kimura M, Shirakura K, Hasegawa A, Kobuna Y, Nijima M. Second look arthroscopy after meniscal repair: factors affecting the healing rate. *Clin Orthop Relat Res.* 1995;(314):185-91.
38. Horibe S, Shino K, Nakata K, Maeda A, Nakamura N, Matsumoto N. Second-look arthroscopy after meniscal repair. Review of 132 menisci repaired by an arthroscopic inside-out technique. *J Bone Joint Surg Br.* 1995;77:245-9.
39. Kurosaka M, Yoshiya S, Kuroda R, Matsui N, Yamamoto T, Tanaka J. Repeat tears of repaired menisci after arthroscopic confirmation of healing. *J Bone Joint Surg Br.* 2002;84:34-7.
40. Beaufils P, Bastos R, Wakim E, Cho SH, Petit-Jouvet C. Meniscal injury in the plastic reconstruction of the anterior cruciate ligament. Meniscal suture or abstention [in French]. *Rev Chir Orthop Reparatrice Appar Mot.* 1992;78:285-91.
41. Aichroth P. Degenerative meniscal tears. *Knee.* 1994;1:181-2.
42. Phillips BB. Classification of meniscal tears. In: Canale T, editor. *Campbell's operative orthopaedics*. Philadelphia: Mosby; 2003. p. 2528-9.
43. Outerbridge RE. The etiology of chondromalacia patellae. *J Bone Joint Surg Br.* 1961;43-B:752-7.
44. Beaufils P, Verdonk R. The meniscus. Berlin, Germany: Springer Science; 2010. p. 45.
45. Eggli S, Wegmüller H, Kosina J, Huckell C, Jakob RP. Long-term results of arthroscopic meniscal repair: an analysis of isolated tears. *Am J Sports Med.* 1995;23:715-20.

46. Warren RF. Arthroscopic meniscus repair. *Arthroscopy*. 1985;1:170-2.
47. Hanks GA, Gause TM, Sebastianelli WJ, O'Donnell CS, Kalenak A. Repair of peripheral meniscal tears: open versus arthroscopic technique. *Arthroscopy*. 1991;7:72-7.
48. Miller DB. Arthroscopic meniscus repair. *Am J Sports Med*. 1988;16:315-20.
49. Barber FA, Coons DA, Ruiz-Suarez M. Meniscal repair with the RapidLoc meniscal repair device. *Arthroscopy*. 2006;22:962-6.
50. van Trommel MF, Simonian PT, Potter HG, Wickiewicz TL. Different regional healing rates with the outside-in technique for meniscal repair. *Am J Sports Med*. 1998;26:446-452.
51. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years. *J Bone Joint Surg Am*. 2012;94:2222-7.
52. Arnoczky SP, Warren RF. The microvasculature of the meniscus and its response to injury an experimental study in the dog. *Am J Sports Med*. 1983;11:131-41.
53. Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med*. 1982;10:90-5.
54. Tengroottenhuysen M, Meermans G, Pittoors K, Van Riet R, Victor J. Long-term outcome after meniscal repair. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:236-41.
55. Barber FA, McGarry JE. Meniscal repair techniques. *Sports Med Arthrosc Rev*. 2007;15:199-207.
56. Morgan CD. The "all-inside" meniscus repair. *Arthroscopy*. 1991;7:120-5.
57. Zhang Z, Arnold JA, Williams T, McCann B. Repairs by trephination and suturing of longitudinal injuries in the avascular area of the meniscus in goats. *Am J Sports Med*. 1995;23:35-41.
58. Okuda K, Ochi M, Shu N, Uchio Y. Meniscal rasping for repair of meniscal tear in the avascular zone. *Arthroscopy*. 1999;15:281-6.
59. Uchio Y, Ochi M, Adachi N, Kawasaki K, Iwasa J. Results of rasping of meniscal tears with and without anterior cruciate ligament injury as evaluated by second-look arthroscopy. *Arthroscopy*. 2003;19:463-9.
60. Henning CE, Lynch MA, Yearout KM, Vequist SW, Stallbaumer RJ, Decker KA. Arthroscopic meniscal repair using an exogenous fibrin clot. *Clin Orthop Relat Res*. 1990;(252):64-72.
61. Cannon WD, Vittori JM. The incidence of healing in arthroscopic meniscal repairs in anterior cruciate ligament-reconstructed knees versus stable knees. *Am J Sports Med*. 1992;20:176-81.
62. Christoforakis J, Pradhan R, Sanchez-Ballester J, Hunt N, Strachan RK. Is there an association between articular cartilage changes and degenerative meniscus tears? *Arthroscopy*. 2005;21:1366-9.
63. Hede AD, Larsen EI, Sandberg HE. Partial versus total meniscectomy. A prospective, randomised study with long-term follow-up. *J Bone Joint Surg Br*. 1992;74:118-21.
64. Schimmer RC, Brulhart KB, Duff C, Glinz W. Arthroscopic partial meniscectomy: a 12-year follow-up and two-step evaluation of the long-term course. *Arthroscopy*. 1998;14:136-42.
65. Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jäger A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med*. 2010;38:1542-8.
66. Petty CA, Lubowitz JH. Does arthroscopic partial meniscectomy result in knee osteoarthritis? A systematic review with a minimum of 8 years' follow-up. *Arthroscopy*. 2011;27:419-24.
67. van Tienen TG, Hannink G, Buma P. Meniscus replacement using synthetic materials. *Clin Sports Med* 2009;28:143-56.
68. Arnoczky SP, Warren RF, Spivak JM. Meniscal repair using an exogenous fibrin clot. An experimental study in dogs. *J Bone Joint Surg Am*. 1988;70:1209-17.
69. Henning CE, Lynch MA, Yearout KM, Vequist SW, Stallbaumer RJ, Decker KA. Arthroscopic meniscal repair using an exogenous fibrin clot. *Clin Orthop Relat Res*. 1990;(252):64-72.
70. Spencer SJ, Saithna A, Carmont MR, Dhillon MS, Thompson P, Spalding T. Meniscal scaffolds: early experience and review of the literature. *Knee*. 2012;19:760-5.