REVIEW ARTICLE

Meniscus injuries: Where do we stand?

BR Gelbart
Orthopaedic Surgeon/Knee Surgery Fellow, Honorary consultant, Charlotte Maxeke Johannesburg Hospital Soft Tissue Knee Clinic, Division of Orthopaedic Surgery, University of Witwatersrand, Johannesburg
P Firer
Orthopaedic Surgeon, Netcare Linksfield Clinic, Orange Grove, Johannesburg; Honorary Consultant, Charlotte Maxeke Johannesburg Hospital Soft Tissue Knee Clinic

Reprint requests:
Dr BR Gelbart
PO Box 28985
Sandringham
Johannesburg
2131
Email: bradgelbart@icon.co.za
Tel: +27 11 485-1970
Fax: +27 11 640-1838

Abstract

The role of the meniscus in the knee has previously been grossly underestimated. The last 25 years have produced an enormous amount of research that highlights the importance of the meniscus to the function of the knee. The primary role of the meniscus is load bearing in order to decrease the forces on the articular surface of the femur and tibia. However, the meniscus also functions as a secondary stabiliser of the knee, providing joint lubrication and shock absorption.

The meniscus is also well supplied with nerve endings which explains the pain associated with meniscal injury and the role of the meniscus in proprioception.

The management of meniscal injuries has evolved from open total meniscectomy to arthroscopic partial meniscectomy, meniscal repair, meniscal transplant and attempts at meniscal culture.

This review provides an update on the literature and the current management options for meniscal injuries.

Menisci were once thought to be functionless, vestigial remnants in the knee. Just as we believe that we could live without an appendix, total meniscectomy was once the operation of choice for meniscal injuries.

However, there have subsequently been two major advances that have changed our understanding of the role of the menisci and our ability to treat their injuries.

The first is the understanding of the crucial roles the menisci play in lubrication,[1] shock absorption, stabilisation and load transfer.[2,3]

The second is the rapid advance of biomedical engineering. Menisci can now be repaired through a variety of methods and also transplanted and cultured in a laboratory.

This understanding and ability has led to meniscal preservation.

In the United States of America approximately 1 million meniscal surgeries are performed annually[4] and the most common procedure logged during their part II board certification exam was an arthroscopic meniscal debridement.[5]

This review aims to highlight the current trends in the management of meniscal injury and the progress being made in this field.

Anatomy of the menisci

The menisci are two wedge-shaped semilunar sections of fibrocartilaginous tissue. They are found between the femoral and tibial surfaces of the knee joint, with one meniscus in the medial compartment and one in the lateral compartment. The medial meniscus has a wider radius of curvature than the lateral. They both attach to the tibia at their anterior and posterior horns and are also attached to the surrounding tissue. The medial meniscus is attached to the deep portion of the medial collateral ligament. The lateral meniscus is attached to the femur by the meniscofemoral ligaments. Both menisci are attached to one another anteriorly by the transverse intermeniscal ligament.

These attachments are important as they maintain the position of the menisci, but are also sites which predispose the menisci to injury in an unstable knee.

Microscopically, the menisci are composed of cellular components embedded in an extracellular matrix.

It is unknown whether meniscal cells are chondrocytes or fibroblasts. Since they contain elements of both these cells they have been termed 'fibrochondrocytes'.[6] These cells are responsible for many functions, one of which is to synthesise collagen which decreases with age.

The extracellular matrix of the meniscus comprises four components: water (72%), fibrillar components (collagen – 22%), proteoglycans and adhesion glycoproteins.

- **Collagen type I** is the most predominant fibrillar component within the tissue, but smaller amounts of collagen type II, III, V, and VI have also been found. Collagen consists of three layers[7,8] (*Figure 1*):
  - Superficial layer – thin layer of randomly oriented fibres
  - Lamellar layer – inside the superficial layer. Consists of randomly oriented fibres except at the periphery and anterior and posterior horns. In these zones the fibres are orientated radially or longitudinally
  - The deep zone consists of circumferentially oriented fibres with a few radially oriented fibres called tie fibres
- **Proteoglycans** are responsible for hydration and therefore the compressive properties of the meniscus.
- **Adhesion glycoproteins** are responsible for binding with other matrix molecules and cells.

The **blood supply** of the menisci is from the middle, medial and lateral genicular arteries. These form the perimeniscal capillary plexus at the peripheral attachments to the joint capsule. The outer one third of the adult meniscus is vascularised and is also surrounded by synovial tissue, while the inner third is avascular. The middle third is a watershed zone. The vascularisation is important to consider when discussing management options.

Interestingly the infant's meniscus is fully vascularised.

This peculiar blood supply has resulted in the meniscus being divided into three zones, depending on the vascular status.

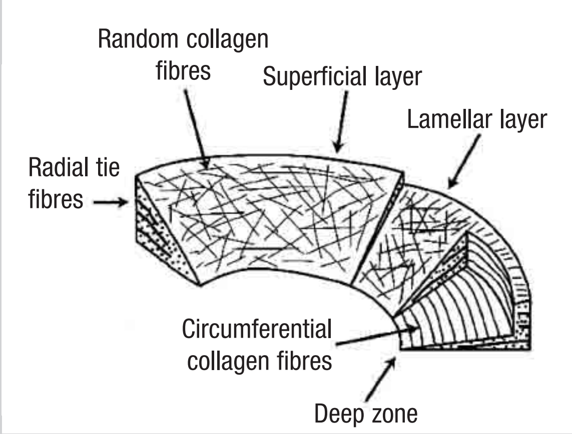

Figure 1: The arrangement of collagen fibrils within the meniscus (reproduced with permission from the authors[8])

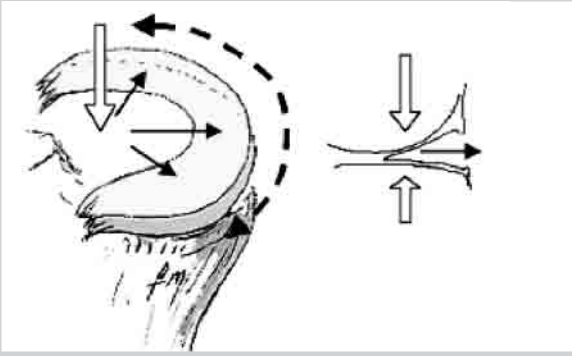

Figure 2: The biomechanics of the meniscus. The conversion of compressive load (white arrow) to hoop stresses i.e. radial force (black arrow) and this acts as a tension force (dotted arrow) (reproduced with permission from the authors[10])

The red-on-red zone refers to the outer third, the red-on-white zone to the middle third and the white-on-white to the inner third. While tears found within the red zones are likely to heal, those in the white zones are avascular and have no potential to heal.[9]

Biomechanics of the meniscus[8,10]

The primary function of the meniscus is load transmission, but the menisci also play a secondary role in stabilisation of the knee and joint lubrication.

The arrangement of the collagen fibres in a circumferential manner with radial ties converts the compressive forces to radial forces. Radial force causes tension along the longitudinal collagen fibres. These are known as 'hoop stresses' and the circumferential collagen fibres are ideally aligned to decrease these forces (*Figure 2*).

A full thickness radial tear of the meniscus disturbs the circumferential collagen fibres and defunctions the meniscus, whereas longitudinal tears will have the two sides compressed together by these forces.

The shape of the menisci with a large radius of curvature at the horns and a smaller radius of curvature at the centre, allows the meniscus to reduce cartilage stresses effectively throughout extension and flexion respectively.[3]

The menisci transmit approximately 50% of the body weight in extension and up to 85-90% in flexion.[11]

The menisci also stabilise the knee. Although the menisci are mobile structures they are tethered at certain points. It is well known that an anterior cruciate ligament (ACL) deficient knee with an intact meniscus will be more stable than an ACL deficient knee without an intact meniscus. However, the meniscus will not provide enough restraint to substitute for the ligament.

The extensive nerve supply in the menisci includes mechanoreceptors and free nerve endings in the peripheral two-thirds, with the highest concentration in the posterior horns.[12] This suggests that the menisci may have an important role in proprioception and protective reflexes.

The improved congruity provided for by the menisci may help joint lubrication and cartilage nutrition.

Classification of meniscal tears[13]

Tears of the meniscus can be divided in to five main types:

1. **Longitudinal tears** – mainly occur in young patients. The meniscus splits due to a shearing force. This split occurs between collagen fibrils. If these occur in the peripheral zone they are usually amenable to repair. A longitudinal tear may comprise part of a bucket handle tear, where the inner portion of the meniscus folds into the joint (*Figures 3 and 4*).
2. **Horizontal tears** – most commonly in a degenerate meniscus. Delamination between the different layers of collagen occurs resulting in separation of the superior from the inferior surface of the meniscus. These usually extend to the inner margin of the meniscus, i.e. the avascular zone, and as such are not amenable to repair.
3. **Radial tears** – run from the meniscus margin towards the periphery. The longitudinal collagen fibres are disrupted and as such the meniscus becomes defunctioned. This injury is indicative of a high energy injury or a degenerate meniscus (*Figure 5*).
4. **Flap tear** – similar to a radial tear in that it extends across the inner margin, but the tear runs obliquely across the meniscus. These may also result in transection of longitudinal collagen fibres indicative of a high energy injury or degeneration. The flap may have a tendency to fold into the joint causing mechanical symptoms.
5. **Degenerative/complex tears** – the majority of degenerate menisci have marked derangement of the collagen architecture. This results in multiplanar tears, which are generally not repairable.

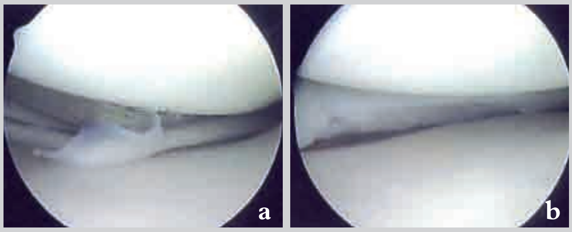

Figure 3a: Top: unstable longitudinal tear of the avascular portion of the lateral meniscus

Figure 3b: Bottom: stable rim post debridement avascular tear lateral meniscus

Figure 4a: 19-yr-old male previous partial meniscectomy for irreparable tear in meniscus. Note early articular damage

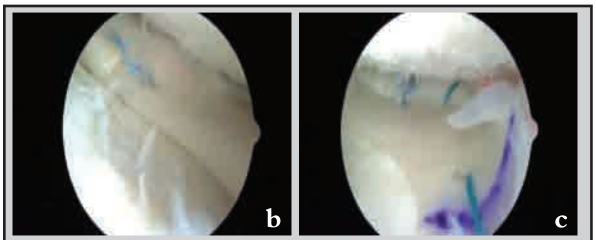

Figure 4b and 4c: Collagen implant inserted into defect and sutured in situ. Combination all inside (4b) and inside out (4c) techniques were used

Clinical evaluation

Symptoms

A careful history is important when assessing for possible meniscal damage. Most patients can recall the mechanism of injury, which is usually a loading, twisting action of the knee with sudden onset pain.

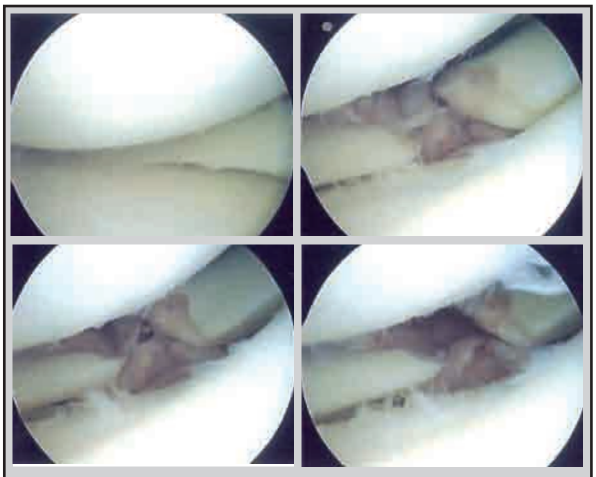

Figure 5: A complete radial tear of the posterior horn of the lateral meniscus in an ACL deficient knee. The two ends were sutured hoping for some healing

A knee that swells immediately (haemarthrosis) may indicate a tear in the peripheral vascular portion of the meniscus. However, in this situation it is important to exclude other more common causes such as osteochondral fracture, disruption of joint capsule or ACL rupture.

More commonly a tear in the central, less vascular, portion will produce delayed swelling – more than 24 hours later.

Patients who present with more chronic injuries may complain about recurrent effusions.

Locking of the knee, i.e. an inability to extend the knee after rising from a crouched position, has been shown to be present in 81% of patients with a bucket handle tear.[14]

Pain is usually localised to the affected joint line. Some patients complain of pain if the knees touch in bed indicative of a medial meniscus injury.

Signs

A subtle sign of chronic pathology is quadriceps muscle atrophy.

The presence of an effusion particularly in a knee with a chronic problem is suggestive of intra-articular pathology.

Patellofemoral disorders often produce symptoms of clicking and may refer pain to the medial joint line. It is important to examine this joint and to attempt to reproduce the pain or clicking that the patient may be experiencing, to differentiate from a meniscal tear.

Meniscal injury is suggested by the presence of joint line tenderness, particularly the posteromedial or posterolateral joint line.

Remember that in a small percentage of cases, the signs and symptoms can present on the opposite side of the knee to which the pathology occurs

This pain is usually reproduced on deep flexion.

Knee stability must be assessed in every patient suspected of having a meniscal injury.

Hip pathology should also be excluded.

A number of eponymous provocative tests have been described.

- **Apley's grind test** – With the patient lying prone, the knee is flexed to 90°. A compression rotation force is placed on the knee through the heel. Pain suggests a meniscal tear.
- **McMurray's test** – The patient lies supine with the knee fully flexed. One hand is placed on the knee, the other under the heel. The knee is flexed and then straightened by the examiner. While straightening, a valgus force and external rotation of the heel will catch the posterolateral meniscus. Pain or clicking is positive for a tear. The manoeuvre is then repeated from hyperflexion using varus force and internal rotation of the heel, which will reproduce symptoms on the medial side.
- **Thessaly test** – The patient stands upright on one foot. Their hands are supported in front of them by the examiner. The patient bends the knee 5° then twists the knee internally then externally three times in each direction. This is then repeated at 20° flexion. The normal side is tested first followed by the side of the suspected injury.[15] Pain is the positive sign.

It must be remembered that in a small percentage of cases, the signs and symptoms can present on the opposite side of the knee to which the pathology occurs, i.e. posteromedial tears can present with lateral/posterolateral symptoms.

Imaging the meniscus

X-ray

Plain X-rays should be performed on all patients with knee pathology to exclude bony lesions. Occasionally chondrocalcinosis of the meniscus can be seen. This may be a clue to the presence of a degenerative tear.

Contrast arthrography

Prior to MRI, arthrography was used to assess for internal derangement in the knee. It was a useful adjunct but symptomatic patients were recommended for arthroscopy despite the arthrography findings.[16]

Ultrasound

This is a relatively cheap, non-invasive investigation. Since the value of this investigation is the dynamic changes noted on screen, ultrasound is very operator-dependent. This is borne out by the variable figures produced in the literature. Ultrasound for meniscal injuries has been shown to have a sensitivity of 60–100%and specificity of 21–100%.[17-20] Higher sensitivity and specificity are achieved with more advanced probes. Of concern is the high number of false positives (low specificity) that are seen. Although practised frequently by many radiology units, it should be 'condemned' to research as it has no clinical relevance.

Computer tomography (CT scan)

CT scanning as been described for meniscus injuries[21] but the poor soft tissue definition relative to MRI make this investigation a poor first choice.

Magnetic resonance imaging (MRI)

The most common indication for MRI of the knee is for the identification of meniscal injuries.[22] Some reports have shown that MRI is more sensitive than clinical examination.[23-25] However, as with most investigations, this depends on the experience of the radiologist. It seems that studies with more patients tend to produce better sensitivities and specificities. MRI for medial meniscus tears shows a sensitivity between 86% and 96%[14] and a specificity of 84–94%.[22]

MRI for the diagnosis of lateral meniscus tears has a lower sensitivity (68–86%), but higher specificity (92–98%[22]). While MRI yields a low false positive rate for lateral meniscus tears, the false negative rate of 14-32% must be considered in the absence of a tear on MRI.

Due to tightly bound protons, short TE sequences are most useful in diagnosing meniscal injuries.

There are two criteria that must be fulfilled on MRI in order to make the diagnosis of a meniscal tear. The first is increased signal intensity within the substance of the meniscus that unequivocally contacts the articular surface of the meniscus. The second is an abnormal meniscal shape in the absence of previous surgery. The presence of one of the above has shown that a meniscal tear will be found 90% of the time at arthroscopy.[22,26]

MRI is also very useful to exclude other causes of knee pain in the absence of a meniscus tear. These conditions include infection, tumour, avascular necrosis of the femoral condyle, articular damage or bone oedema (transient osteoporosis).

Arthroscopy

It is not recommended that arthroscopy should be used as an investigative modality. However, when performing arthroscopy it is important to accurately assess the menisci for tears. This is achieved by ensuring proper visualisation of the entire meniscus and by probing the entire meniscus. Peripheral longitudinal tears are easily missed if not probed.

Management

The key role of the meniscus in the function of the knee and accelerated degenerative changes seen in a meniscus-deficient knee have led us to focus on meniscus preservation. As early as 1948 Fairbank showed that total meniscectomy resulted in accelerated radiological change in the knee.[27] This has improved somewhat, with the advent of partial meniscectomy.[28]

The doyen of partial meniscectomy (through a mini arthrotomy before the days of arthroscopy) was a South African surgeon, Dr Clive Noble, in the 1960s and 1970s.

There are no randomised controlled trials to show that arthroscopic meniscal repair has any long-term benefit in terms of joint preservation. The good results seen to date,[10,29] however, suggest that this may decrease the incidence of early degenerative changes.

The implications of not treating a meniscal tear are not so clear. Experimental animal studies have shown that meniscal tears can result in chondropathy and osteoarthritis.[30,31] Clinical studies though are unable to prove what happens first – the meniscus damage or the articular cartilage damage.[32-35] A recent study by Christoforakis *et al*, evaluated 497 consecutive knee arthroscopies on patients with meniscal tears.[36] They found that the mean age of patients with complex and horizontal tears was 44.8 years compared with 33.6 yrs for the other types of tears. These complex and horizontal tears were also associated with a statistically increased chance of having Outerbridge[37] grade III or IV articular cartilage damage. Furthermore, the complex and horizontal meniscal tears were more likely to be associated with more than one site of articular damage than the other tear types. Again this does not answer what came first: the meniscus tear or the articular degeneration. Interestingly, in their study, 81% of the cohort had at least one site of articular cartilage damage. This means that even simple tears in young patients may result in chondral damage.

Our approach is to actively search for a tear in younger patients with clinical and radiological investigations including X-ray and MRI. If a tear is present or highly suspected, the patient is advised to undergo arthroscopy and meniscus preservation surgery.

In patients who are suspected of having a degenerative tear, the so-called 'middle-aged meniscus', the option of non-operative treatment is employed. This allows the opportunity of settling the knee without surgery. It is well documented that debridement of a degenerate meniscus may not always result in long-term relief.[38]

Non-operative

Small peripheral tears in young patients can be managed non-operatively. The difficulty is to decide without arthroscopy whether the tear is stable or not. Weiss *et al* retrospectively reviewed 3 612 arthroscopic procedures for meniscal lesions. They identified 80 (2.2%) meniscal tears that were deemed to be stable. These were not treated. Six patients returned for repeat arthroscopy due to meniscal symptoms. The authors recommended that stable vertical tears at the periphery have increased potential for healing.[34]

Physiotherapy – This has been shown to be beneficial to patients with degenerative meniscal tears. A recently published randomised control trial followed up patients with degenerative meniscal tears. Patients who underwent surgical debridement in combination with physiotherapy did not show an improved outcome compared to those who received physiotherapy alone.[39]

Corticosteroids – Along with physiotherapy, some patients with degenerative meniscal tears improve after a single corticosteroid injection into the knee. This is our first-line treatment for a degenerative meniscus, in the absence of definitive locking symptoms

Operative management

Total meniscectomy

This was the treatment of choice for meniscal lesions until the 1970s.[10] However, since then arthroscopic techniques and the understanding of the biomechanics and role of the meniscus have led to a shift towards preservation of meniscal tissue. This form of treatment is seldom practised nowadays.

Open repair

This was popularised by De Haven[40] and was one of the early means of repairing meniscal tears. This is now almost always reserved for fixation of the meniscus as part of the management of tibial plateau fractures or as part of a multiligament reconstruction, e.g. a posterolateral corner or midsubstance medial collateral ligament repair. It is only possible on the very peripheral tears.

Arthroscopic repair

Meniscal rasping

Occasionally small, stable peripheral tears of the meniscus are seen at arthroscopy (*Figure 6*). Often these are chronic tears with fibrous tissue in the gap. The meniscal rasp is then used to debride the torn edges of the meniscus to stimulate bleeding.

This is indicated in patients who have a stable, longitudinal tear in the vascular zone of the meniscus. In should only be performed in the presence of complete ligamentous stability or at the time of cruciate ligament reconstruction. Tears in an unstable knee or in the avascular zone are not amenable to this form of treatment.

The 'inside out' technique is still the gold standard and remains our method of choice

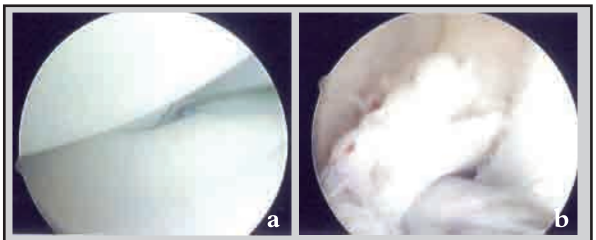

Figure 6a (left): stable longitudinal tear of the posterior horn of the lateral meniscus in an

Figure 6b (right): ACL deficient knee

Meniscal suturing

Tears in the red-red zone (periphery) or red-white zone (up to approximately 5 mm from periphery) may be amenable to repair. Traditionally, longitudinal tears have been the most amenable to suturing and healing. A proviso for good healing is a stable knee. Meniscal repairs in the unstable knee doom the repair to failure. However, a stable knee, with normal kinematics, will not place unnecessary shear force onto the repair. In fact, controlled weight bearing which compresses the meniscus results in 'the hoop stress'. This hoop stress compresses the margins of the tear together. This may assist healing.

Recently reports have emerged about positive results with the repair of full thickness radial tears.[10] These are devastating injuries to the meniscus leading to disruption of all the longitudinal fibres. Results of the repair are not reported in any randomised controlled trials, but case reports seem positive. Post-operatively these repairs should be protected by minimising all stress on the meniscus for four to six weeks. Loading of the knee will place the repair under tension.

Repairs in the avascular zone are at risk for failing.

Meniscal repair in conjunction with ACL reconstruction has consistently shown better healing rates than in the ACL stable knees.[41] We believe two factors play a role:

The stable knee's meniscus may tear because its quality is inferior, whereas the ACL injured meniscus fails because of significant forces.

Secondly, in reconstructing the ACL a large haemarthrosis usually occurs and this may stimulate meniscal healing.

The late Chuck Henning used to advocate the introduction of blood clot to assist meniscal repair.

Techniques

Numerous techniques have been described for meniscal repair. They are based on the technique of passing the sutures.

Outside in

This was the first arthroscopic technique used but is now the least common of the methods used. It involves passing a needle from outside the joint, through the meniscus and then passing a suture through the needle. The suture is then retrieved and knot tied, ideally outside the joint. This technique is primarily used for anterior horn tears.

Inside out *(Figure 4c)*

This is still the gold standard and remains our method of choice. Zone-specific cannulae have been designed allowing the surgeon to arthroscopically pass a long straight needle directly to the injured portion of the meniscus. The sutures are retrieved under direct vision through a medial/lateral incision and the knot is tied outside the joint. The main concern with this technique is damage to neurovascular structures particularly with posterolateral repairs. These need to be protected by a suitable instrument, e.g. a tablespoon.

All inside *(Figure 4b)*

Numerous all inside techniques have been described, such as sutures with a pre-tied slip knot and absorbable meniscal repair devices including meniscal darts, arrows staples and screws. There have been many reported complications with these devices including transient synovitis, inflammatory reaction, cyst formation, device failure, device migration and chondral damage. For these reasons these bioabsorbable meniscal implants are generally out of favour.[41] In addition biomechanical studies have shown that these devices are initially equivalent to suturing techniques; however they are prone to losing strength over time.

The fourth generation all inside meniscal sutures such as Fas-T-Fix (Smith and Nephew), Meniscal cinch (Arthrex) and RapidLoc (Mitek) all have good short term results, with meniscal healing between 80-91% at two-year follow-up.[41]

Rehabilitation

Rehabilitation protocols vary from centre to centre and depend on the type of procedure and tear morphology. However, the principle of limited weight bearing and avoidance of flexion greater than 90° should be adhered to for the first four to six weeks. Thereafter, a gradual increase in activity can be allowed. Squatting should be avoided for approximately five months.[41]

Arthroscopic partial meniscectomy *(Figure 3b)*

Irreparable tears of the meniscus, either due to zone of injury or complexity of the tear, are best treated by this method. Practically, the vast majority of meniscal tears are managed this way. The principle is to debride the loose non-viable edges of menisci in order to produce a stable meniscus. This aims to decrease the number of fragments of menisci that are loose and potentially causing damage to the articular cartilage. These loose fragments may also be a cause of pain.

Results in a cohort of patients followed up between five and 11 years post partial medial meniscectomy in stable knees, showed that the majority of patients had an excellent or good outcome. Patients who had Outerbridge grade III or IV articular cartilage damage were more likely to have a poorer outcome.[38] It is for this reason that one should take care not to automatically 'scope and debride' all patients with degenerative meniscus tears.

Rehabilitation

The post operative rehabilitation protocol following partial meniscectomy should be patient-oriented. Most patients require crutches and remain non-weight bearing for a few days post-operatively. Thereafter they are allowed to weight bear as tolerated. Most patients are crutch-free by ten days. A good physiotherapy programme will probably allow most sportspeople to return to sport in under six weeks (this may be longer depending on the underlying articular cartilage damage).

This truncated rehabilitation protocol and earlier return to sport is a consideration when discussing the management option with a professional sportsperson or patient with limited ability to undergo rehabilitation. Some patients request a partial excision as opposed to repair, when feasible, allowing them to return to their sports and livelihood sooner. This comes at the risk of developing arthritis later in life. However, there are no long-term randomised controlled trials comparing joint status post repair versus post partial meniscectomy.

Meniscus transplant

Meniscus transplantation dates back to 1916, when the first attempt was made to replace the meniscus with an autogenous fat tissue interposition graft.[42] Numerous different techniques of transplanting the tibial plateau or parts thereof were tried. Milachowski *et al* were the first to report on free meniscal transplants.[43]

Subsequently many different types of substitutes have been tried and tested.

The ideal candidate is younger than 50 years old with a stable knee

The current indications for meniscal transplant or replacement are:[42,44]

- Total meniscectomy with early arthritis – slow progression
- Loss of anterior cruciate ligament – provide stabilisation along with concurrent or delayed ligament reconstruction
- Concomitant osteotomy – enhance effect and postpone recurrent deformity
- Prophylactic transplantation – avoid consequences of meniscectomy in young patient due to irreparable meniscus tear or discoid meniscus.

The ideal candidate is younger than 50 years old with a stable knee. Meniscal transplant is contraindicated in the presence of grade IV articular cartilage damage or an unstable knee

Types of graft

Autograft

Interposition autografting of the patella tendon,[45] quadriceps tendon,[45] fat pad[46] and perichondral tissue[47] have been attempted. These experiments were mainly performed on animals. The quadriceps tendon was the only graft that made it to clinical application. Although, at relook arthroscopy, the tendon looked like meniscus, it was soft. The patients did not have any significant improvement in their outcome scores. Based on these limited studies autograft is not recommended for long-lasting meniscus replacement.

Allograft

Meniscal allograft would seem to be a potential answer. The process involves finding a suitable donor. This involves strict monitoring according to the national tissue bank. The donor would need to be screened for infections and blood typing. The recipient then needs to be anatomically matched according to the available meniscus.

The recipient should be investigated by following means:[42]

- Long leg standing X-rays – to assess the alignment of the limbs
- Plain X-rays – to assess the degree of arthritis and bony landmarks to size the meniscus
- Bone scan – to assess status of subchondral bone for disturbed homeostasis
- Computerised tomography scan – this should ideally be performed on the donor and recipient knee to accurately assess the size.
- MRI – provides information on the status of the meniscus, cartilage and ligaments as well as for size matching.
- Arthroscopy – may give more information on status of articular surface

Much debate currently surrounds the best method of graft preservation. Fresh-frozen provides the best tissue but is the most immunogenic and carries the highest infection risk. It is also difficult to store and is not readily available. The donor cells in a deep-frozen meniscus are destroyed but may be stored for longer.

Lyophilised or freeze-dried menisci loose all antigens and enzymes, but the ground substance decays. This leaves a collagen scaffold for growth of host fibrochondrocytes. These menisci also decrease in size, changing the biomechanical properties of the graft.

Cryopreservation using glycerol may partially maintain the fibrochondrocytes for two to four weeks, but this is very expensive.

The menisci can also be secondarily sterilised by tissue banks using gamma irradiation or ethylene oxide. However, the ethylene oxide may induce secondary synovitis and the gamma sterilisation may weaken the collagen structure.

In South Africa we have menisci available from the two main tissue banks. All donors are suitably screened for infection. The menisci are harvested with the tibial plateau and then this is cut to fit the defect size. The specimens are fresh frozen and irradiated and are freely available.

Due to the variability in different methods of preserving meniscus tissue, different methods of implanting it and varying criteria for implantation, there are no randomised controlled trials assessing outcome. It is also difficult to compare different studies. Generally, the reported outcomes show an overall failure rate of around 20%. Most patients can expect pain relief and an ability to increase activity levels. This is supported by midterm studies.[44] Ten-year outcome studies on case series have been reported.[48] Despite significant improvement the patients were still substantially disabled. However, radiographic follow-up did not show advanced degenerative changes.

Meniscal prostheses

Multiple synthetic materials have been considered to be used as menisci, such as Teflon,[49] Silastic,[42] carbon fibre,[50] Dacron[51] and polyvinyl alcohol hydrogel.[52] None of these have proven to be a success and should not be in clinical use.

Currently collagen-based meniscal implants have been produced and trials are currently underway (*Figures 4b and c*).

Tissue engineering

The complex nature of the cells and the extracellular matrix makes the meniscus very difficult to engineer.[8] Various studies have given tissue engineers knowledge on how fibrochondrocytes react to certain growth factors. There still remains a lot of work to be done before menisci can be grown in vitro and then transplanted into patients.

The basis of meniscus engineering is to develop the best scaffold to allow the cells to grow on. This combined with the right growth factors and culturing conditions then presents a possibly good meniscus. Once implanted one needs to able to accurately image the graft and assess viability.

Conclusion

Meniscus injuries comprise a large percentage of the work done by orthopaedic surgeons. Current management has moved towards meniscus preservation. Although much progress has been made in meniscal transplantation this has still not become a routinely performed procedure and probably still has a limited role in our environment. We await the outcome of engineered menisci as perhaps they will be the answer.

No benefits of any form have been received from a commercial party related directly or indirectly to the subject of this article.

References

1. Macconaill MA. The function of intra-articular fibrocartilages, with special reference to the knee and inferior radio-ulnar joints. *J Anat* 1932;**66**(Pt 2):210-27.
2. Shrive NG, O'Connor JJ, Goodfellow JW. Load-bearing in the knee joint. *Clin Orthop Relat Res* 1978;131:279-87.
3. Meakin JR, Shrive NG, Frank CB, Hart DA. Finite element analysis of the meniscus: the influence of geometry and material properties on its behaviour. *Knee* 2003;**10**(1):33-41.
4. Cook JL. The current status of treatment for large meniscal defects. *Clin Orthop Relat Res* 2005;435:88-95.

5. Garrett WE, Jr., Swiontkowski MF, Weinstein JN, Callaghan J, Rosier RN, Berry DJ, Harrast J, Derosa GP. American Board of Orthopaedic Surgery Practice of the Orthopaedic Surgeon: Part-II, certification examination case mix. *J Bone Joint Surg Am* 2006;**88**(3):660-7.
6. Webber RJ, Harris MG, Hough AJ, Jr. Cell culture of rabbit meniscal fibrochondrocytes: proliferative and synthetic response to growth factors and ascorbate. *J Orthop Res* 1985;**3**(1):36-42.
7. Petersen W, Tillmann B. Collagenous fibril texture of the human knee joint menisci. *Anat Embryol (Berl)* 1998;**197**(4):317-24.
8. Sweigart MA, Athanasiou KA. Toward tissue engineering of the knee meniscus. *Tissue Eng* 2001;**7**(2):111-29.
9. DeHaven KE. Decision-making factors in the treatment of meniscus lesions. *Clin Orthop Relat Res* 1990;252:49-54.
10. Boyd KT, Myers PT. Meniscus preservation; rationale, repair techniques and results. *Knee* 2003;**10**(1):1-11.
11. 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**(3):216-25.
12. Assimakopoulos AP, Katonis PG, Agapitos MV, Exarchou EI. The innervation of the human meniscus. *Clin Orthop Relat Res* 1992;275:232-6.
13. DeLee, Drez. *Orthopaedic Sports Medicine: Principles and practice* (First edn). W.B. Saunders: Philadelphia, 1994;1146-62.
14. Shakespeare DT, Rigby HS. The bucket-handle tear of the meniscus. A clinical and arthrographic study. *J Bone Joint Surg Br* 1983;**65**(4):383-7.
15. Karachalios T, Hantes M, Zibis AH, Zachos V, Karantanas AH, Malizos KN. Diagnostic accuracy of a new clinical test (the Thessaly test) for early detection of meniscal tears. *J Bone Joint Surg Am* 2005;**87**(5):955-62.
16. Korn MW, Spitzer RM, Robinson KE. Correlations of arthrography with arthroscopy. *Orthop Clin North Am* 1979;**10**(3):535-43.
17. Najafi J, Bagheri S, Lahiji FA. The value of sonography with micro convex probes in diagnosing meniscal tears compared with arthroscopy. *J Ultrasound Med* 2006;**25**(5):593-7.
18. Azzoni R, Cabitza P. Is there a role for sonography in the diagnosis of tears of the knee menisci? *J Clin Ultrasound* 2002;**30**(8):472-6.
19. Sandhu MS, Dhillon MS, Katariya S, Gopal V, Nagi ON. High resolution sonography for analysis of meniscal injuries. *J Indian Med Assoc* 2007;**105**(1):49-50, 52.
20. Shetty AA, Tindall AJ, James KD, Relwani J, Fernando KW. Accuracy of hand-held ultrasound scanning in detecting meniscal tears. *J Bone Joint Surg Br* 2008;**90**(8):1045-8.
21. Gagliardi S, Mughetti M, Gualtieri G, Gualtieri I. Diagnostic accuracy of CT scan in intra-articular lesions of the knee (arthroscopic confirmation of 100 cases). *Chir Organi Mov* 1995;**80**(3):301-7.
22. Prickett WD, Ward SI, Matava MJ. Magnetic resonance imaging of the knee. *Sports Med* 2001;**31**(14):997-1019.
23. Spiers AS, Meagher T, Ostlere SJ, Wilson DJ, Dodd CA. Can MRI of the knee affect arthroscopic practice? A prospective study of 58 patients. *J Bone Joint Surg Br* 1993;**75**(1):49-52.
24. Rangger C, Klestil T, Kathrein A, Inderster A, Hamid L. Influence of magnetic resonance imaging on indications for arthroscopy of the knee. *Clin Orthop Relat Res* 1996;**330**:133-42.
25. Munk B, Madsen F, Lundorf E, Staunstrup H, Schmidt SA, Bolvig L, Hellfritzsch MB, Jensen J. Clinical magnetic resonance imaging and arthroscopic findings in knees: a comparative prospective study of meniscus anterior cruciate ligament and cartilage lesions. *Arthroscopy* 1998;**14**(2):171-5.
26. Rubin DA, Paletta GA, Jr. Current concepts and controversies in meniscal imaging. *Magn Reson Imaging Clin N Am* 2000;**8**(2):243-70.
27. Fairbank TJ. Knee joint changes after meniscectomy. *J Bone Joint Surg Am* 1948;**30B**(4):664-70.
28. Hulet CH, Locker BG, Schiltz D, Texier A, Tallier E, Vielpeau CH. Arthroscopic medial meniscectomy on stable knees. *J Bone Joint Surg Br* 2001;**83**(1):29-32.
29. Sohn DH, Moorman CT. Meniscal debridement: current concepts. *J Knee Surg* 2008;**21**(2):145-53.
30. Appleyard RC, Burkhardt D, Ghosh P, Read R, Cake M, Swain MV, Murrell GA. Topographical analysis of the structural, biochemical and dynamic biomechanical properties of cartilage in an ovine model of osteoarthritis. *Osteoarthritis Cartilage* 2003;**11**(1):65-77.
31. Janusz MJ, Bendele AM, Brown KK, Taiwo YO, Hsieh L, Heitmeyer SA. Induction of osteoarthritis in the rat by surgical tear of the meniscus: Inhibition of joint damage by a matrix metalloproteinase inhibitor. *Osteoarthritis Cartilage* 2002;**10**(10):785-91.
32. Fahmy NR, Williams EA, Noble J. Meniscal pathology and osteoarthritis of the knee. *J Bone Joint Surg Br* 1983;**65**(1):24-8.
33. Lewandrowski KU, Muller J, Schollmeier G. Concomitant meniscal and articular cartilage lesions in the femorotibial joint. *Am J Sports Med* 1997;**25**(4):486-94.
34. Weiss CB, Lundberg M, Hamberg P, DeHaven KE, Gillquist J. Non-operative treatment of meniscal tears. *J Bone Joint Surg Am* 1989;**71**(6):811-22.
35. Noble J, Hamblen DL. The pathology of the degenerate meniscus lesion. *J Bone Joint Surg Br* 1975;**57**(2):180-6.
36. 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**(11):1366-9.
37. Outerbridge RE. The etiology of chondromalacia patellae. *J Bone Joint Surg Br* 1961;**43-B**:752-7.
38. Matsusue Y, Thomson NL. Arthroscopic partial medial meniscectomy in patients over 40 years old: a 5- to 11-year follow-up study. *Arthroscopy* 1996;**12**(1):39-44.
39. Herrlin S, Hallander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: a prospective randomised trial. *Knee Surg Sports Traumatol Arthrosc* 2007;**15**(4):393-401.

40. De Haven KE, Sebastianelli WJ. Open meniscus repair. Indications, technique, and results. *Clin Sports Med* 1990;**9**(3):577-87.
41. Turman KA, Diduch DR. Meniscal repair: indications and techniques. *J Knee Surg* 2008;**21**(2):154-62.
42. Peters G, Wirth CJ. The current state of meniscal allograft transplantation and replacement. *Knee* 2003;**10**(1):19-31.
43. Milachowski KA, Weismeier K, Wirth CJ. Homologous meniscus transplantation. Experimental and clinical results. *Int Orthop* 1989;**13**(1):1-11.
44. Cole BJ, Carter TR, Rodeo SA. Allograft meniscal transplantation: background, techniques, and results. *Instr Course Lect* 2003;**52**:383-96.
45. Kohn D, Wirth CJ, Reiss G, Plitz W, Maschek H, Erhardt W, Wulker N. Medial meniscus replacement by a tendon autograft. Experiments in sheep. *J Bone Joint Surg Br* 1992;**74**(6):910-7.
46. Kohn D, Rudert M, Wirth CJ, Plitz W, Reiss G, Maschek H. Medial meniscus replacement by a fat pad autograft. An experimental study in sheep. *Int Orthop* 1997;**21**(4):232-8.
47. Bruns J, Kahrs J, Kampen J, Behrens P, Plitz W. Autologous perichondral tissue for meniscal replacement. *J Bone Joint Surg Br* 1998;**80**(5):918-23.
48. Verdonk PC, 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**(8) 694-706.
49. Toyonaga T, Uezaki N, Chikama H. Substitute meniscus of Teflon-net for the knee joint of dogs. *Clin Orthop Relat Res* 1983;179:291-7.
50. Wood DJ, Minns RJ, Strover A. Replacement of the rabbit medial meniscus with a polyester-carbon fibre bioprosthesis. *Biomaterials* 1990;**11**(1):13-6.
51. Sommerlath K, Gillquist J. The effect of a meniscal prosthesis on knee biomechanics and cartilage. An experimental study in rabbits. *Am J Sports Med* 1992;**20**(1):73-81.
52. Kobayashi M, Toguchida J, Oka M. Development of an artificial meniscus using polyvinyl alcohol-hydrogel for early return to, and continuance of, athletic life in sportspersons with severe meniscus injury. I: mechanical evaluation. *Knee* 2003;**10**(1):47-51.

• SAOJ

Guidelines for peer reviewers

Please consider the following questions when reviewing articles:

1. Is the language acceptable?
2. Is the style of the article acceptable?
3. Do you have any suspicion of plagiarism?
4. Are the contents correct?
5. Do the facts come across in such a way that the reader will get the message?
6. Does the article really enlarge present knowledge on the subject?
7. Do the references reflect the Vancouver system?
8. Is the number of references acceptable?
9. Are the conclusions supported by the text?
10. At which level does this article focus?
    a. A subspecialty of orthopaedic surgery
    b. General orthopaedic surgery
    c. Senior registrar level.