Meniscal problems: to repair and to replace

Wal, R.J.P. van der

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The approach to meniscal lesions in The Netherlands - a paradigm shift.

Robert J.P. van der Wal
Samuel K. van de Velde
Ewoud R.A. van Arkel

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THE HISTORY OF MENISCAL REPAIR

The first repair attempts

The concept of repairing meniscal tissue is not new. By 1883, Scottish surgeon Thomas Annandale had described a case of meniscal repair. He called the procedure "an option for a displaced semilunar cartilage". Through an arthrotomy of the knee the displaced meniscus was reduced and stitched into position. The excellent result of the repair encouraged Annandale to proclaim that this proceeding may now become an established means of treatment.[1] In 1908, Katzenstein reported on a series of seven meniscal repairs with a follow-up of up to seven years. He used vertical silk sutures for the meniscal repair. Katzenstein believed that only in a minority of cases resection of the meniscus results in a permanently good function. He further stated that it did not make any sense to try to suture a severely degenerated or malformed meniscus. In all the other cases though, he advised strongly in favor of repairing the meniscus. Interestingly he also believed that a traumatic lesion without dislocation of the meniscus might heal spontaneously.[2]

Meniscal vascularization – from repair to complete resection

Following King's classic paper in 1936 on the healing of semilunar cartilages in the dog many authors have postulated the importance of vascularity to meniscal healing.[3] King demonstrated that meniscal lesions had the potential to heal, provided that the lesions were located in the peripheral vascular zone. Arnoczky and Warren are generally credited as being the first to expose the blood supply for each meniscus. In 1982 they illustrated a microvascular perimeniscal plexus supplied by the vascularized synovial tissue on the periphery of the menisci.[4] However, by 1946 Smillie reported in his book "Injuries of the knee joint" on the study by Poth, which was originally published in 1932 in which an arterial injection with an opaque medium showed that the blood supply of the meniscus was limited to the convex border. In this peripheral area a network of vessels were seen entering the meniscus from the capsule. The central and concave zones had no blood supply.[5] Curiously, these fundamental findings did not steer Smillie to link the importance of vascularization of the meniscus with the possibility of repairing a torn meniscus. On the contrary, the peripheral vascularization of the meniscus was the basis of Smillie's philosophy in which he stated that when the entire meniscus is excised a new meniscus would grow out of the parietal synovial membrane. This new meniscus would have basically the same form and general appearance of the original meniscal structure, although histological examination revealed fibrous tissue only. This altered meniscal structure was not considered problematic, since the only important function of the meniscus was supposed to be lubrication of articular cartilage. Because of the alleged regenerative potential of the meniscus Smillie advocated for total excision of the torn meniscus and was opposed to partial meniscectomy. To help surgeons in performing these total meniscectomies, he

developed the Smillie knife, a knife which has been used until deep in the 1980's at which point arthroscopy was introduced and partial meniscectomy became the standard treatment for meniscal lesions.[5]

Meniscal function – from resection back to repair

The loadbearing function of the menisci in the knee, as well as the consequences of removal of meniscal tissue for the longevity of articular cartilage, started to become clear. In 1948 Fairbank examined post meniscectomy knees and noted that over time these knees developed joint-space narrowing and femoral condylar flattening. He was the first to describe the loadbearing function of the meniscus.[6] Tapper and Hoover confirmed that the late effect of meniscectomy was osteoarthritis; and that the worst results could be expected in those patients who were less than twenty years old at the time of surgery.[7] In the nineteen-seventies it became generally accepted that the meniscectomy could lead to degenerative changes in the knee, and that partial meniscectomy would have less effect on articular cartilage than total meniscectomy.[8-10] In the same period a shift occurred from the traditional open (partial) meniscectomy to arthroscopic partial meniscectomy with better clinical results.[11,12] Gradually became evident how variables such as total meniscectomy, removal of the peripheral rim, lateral meniscectomy, joint instability, degenerative meniscal tears, presence of chondral damage, presence of hand osteoarthritis suggestive of genetic predisposition, and an increased body mass all have negative influence on the outcome of (partial) meniscectomy.[13] Because of the growing understanding of the relationship between loss of meniscal function and degeneration of the knee, combined with the concurrent development of arthroscopic techniques, the technique of meniscal repair was developed to reserve meniscal integrity with encouraging results.[14-19] In 1990 the first paper on meniscal repair was published in The Netherlands.[20] In 2010 the Dutch consensus for meniscal treatment was published in the guideline "Knee arthroscopy; indications and treatment (Table 1).[21] These recommendations are consistent with the French guidelines published in 1999.[22] The implementation of this nationwide guideline may have contributed to a decrease in incidences of meniscus surgeries. However, it is unknown if the amount of meniscal repair procedures increased.[23]

Rationale for maintaining meniscal function

It is now generally accepted that both menisci have important biomechanical functions within the knee joint, and that these functions are to be maintained as much as possible. Meniscal functions include loadbearing, shock absorption, joint stability, joint lubrication, and proprioception.

Table 1: Guideline for Meniscal Treatment. Dutch Orthopaedic Association (Nederlandse Orthopedische Vereniging) guideline "Knee Arthroscopy; indications and treatment".[22]

1.	A meniscal lesion does not necessarily mean meniscectomy. Wait and see or meniscal repair should be given systematic considerations.
2.	If (partial) meniscectomy is performed the peripheral rim should be left intact.
3.	Conservative treatment is preferred in degenerative tears without mechanical obstructions.
4.	In peripheral meniscal tears in the vascular zone, especially in young patients meniscal repair is recommended. A stable knee is indispensable when considering meniscal repair.
5.	A meniscal repair in combination with an anterior cruciate ligament reconstruction (ACL) is preferred over meniscectomy.

Maintaining meniscal loadbearing

During compression the menisci distribute the joint load and protect the articular cartilage by creating a more congruent articulation between tibia and femur, increasing the contact area and subsequently decreasing peak contact pressure on cartilage. The menisci are able to move during knee flexion because they are connected to the tibia through mobile insertion ligaments. The meniscal movement ensures maximal congruency with articular surfaces during flexion, hereby facilitating load transmission, stability, and lubrication.[24,25] Knee motion during rotations demonstrated greater rotations in the lateral compartment compared to the medial compartment. The marked mobility of the lateral meniscus and the limited motion in the posteromedial corner might explain the decreased risk of lateral to medial meniscal injuries.[26] This is fortunate since removal of the lateral meniscus has been shown to be more detrimental to cartilage survival than medial meniscectomy. Pena et al. showed in a finite element study that the maximum shear stresses after total and partial lateral meniscectomies were 288 and 323% higher than the equivalent stresses in the medial counterparts.[27] Studies measuring contact stresses on the tibia plateau have shown that the menisci transmit is at least 50% of the load during the first 90° of flexion.[28] When loaded in vitro 70% and 50% of the loads on the lateral and the medial compartment were transmitted through the corresponding menisci, respectively.[29] After meniscectomy the contact area between menisci and articular cartilage is reduced which leads to increased peek stress and stress concentration on articular cartilage of the femur and tibia, and decreased shock absorption.[29] Partial meniscectomy has less detrimental effect on articular cartilage than total meniscectomy, where degenerative changes are directly proportionally related to the amount of meniscal tissue removed.[9,30] However, even partial meniscectomy significantly alters the loading situation of the meniscus and its attachments. Specifically, the attachment forces decreases with increasing the amount of meniscal tissue loss, which reflects the impaired ability of the meniscus to transform axial load into meniscal hoop stress.[31] In fact it has been shown that simply cutting the peripheral rim of the meniscus causes a complete functional meniscal deficiency equivalent to performing a total meniscectomy.[31] This highlights how only a minor change of menis-

cal anatomy could have major effect in joint biomechanics, and that any effort to repair meniscal integrity is imperative. For example, LaPrade et al. showed that an anatomic repair of the posterior horn of the medial meniscus could produce near intact contact area and resulted in relatively minimal increases in mean and peak contact pressures compared with intact knees.[32]

Maintaining joint stability

The effect of joint instability on outcome of meniscectomy has been elucidated by Burks et al. They found that patients with anterior cruciate ligament (ACL) deficient knees had significantly higher radiographic osteoarthritis grade changes with more medial joint space narrowing after meniscectomy, compared with patients with ACL-intact knees after meniscectomy. Lateral joint space narrowing was not significantly different between both groups.[33] It is postulated that the menisci are not the primary stabilizers of the knee joint, but that in ligament insufficient knees they assist in joint stability. Levy et al. found that isolated excision of the medial meniscus has little effect on the forced anterior-posterior displacement of the tibia on the femur.[34] However, when medial meniscectomy followed resection of the ACL, the displacement was increased significantly at all flexion angles. The greatest increase was at 90° of flexion.[35] The medial meniscus has not only been shown to enhance anteroposterior stability, but also to provide resistance to varus-valgus and internal-external rotational loads in ACL-deficient knees.[36,37] On the other hand, resection of the lateral meniscus in ACL-deficient knees did not change tibiofemoral kinematics compared to those in ACL intact knees.[37] Briefly, in ACL deficient knees, the medial meniscus is of greater importance to knee stability than the lateral meniscus. In contrast, the lateral meniscus is of greater importance to load transmission than the medial meniscus. Hence, for both medial and lateral meniscal injuries, restoring meniscal function is critical.

Clinical results of meniscal repair

Medium and long-term results of meniscal repair have been shown to be successful. The clinical success rates for all meniscal repair techniques combined in stable knees has ranged from 70 to 90%. In unstable knees there is a decrease in meniscal repair success rate to 30-70%.[38] However, when performing an ACL reconstruction (ACLR) in conjunction with meniscal repair, several studies have demonstrated meniscal repair success greater than 90%. Lateral meniscal repairs are expected to heal better compared to medial repairs.[38] Interestingly, the time interval between trauma and meniscal repair had no influence on meniscal healing. Instead the quality of the meniscal tissue as assessed during arthroscopy was the predicting factor for meniscal repair survival.[39] Despite these encouraging results, data from the French Arthroscopy Society showed that meniscal repair was only considered in a minority of meniscal surgeries, not exceeding the 3-5% limit.[40] Unfortunately, it

is not stretching to conjecture that the balance of meniscectomy to meniscal repair in the Netherlands might be very similar to that in France.

DECISION MAKING IN MENISCAL INJURY TREATMENT

Conservative treatment

Not all meniscal injuries require surgery. For example, in patients with meniscal tears and osteoarthritis of the knee no differences in knee function were found after one year between patients treated with surgery compared to patients treated with an exercise program alone.[41] In fact, knee function outcomes in patients with degenerative meniscal tears without locking complaints were no better after partial meniscectomy than after sham surgery.[42] Nevertheless, surgical treatment could be discussed when a patient presents with evident mechanical signs like locking and catching due to a degenerative meniscal lesion. That meniscal debridement should be performed here rather than attempting to repair the degenerative tissue, is self-explanatory, as degenerative tears are associated with chronic damage and could be considered one of the first signs of knee osteoarthritis.[43] Another setting where conservative treatment of meniscal injury might be considered is the setting of a combined non-displaced lateral meniscal tear and ACL injury. It has been shown that the healing response for lateral meniscal tears left in situ during ACLR could be as high as 74%. For the medial meniscus, however, repair is always indicated in concomitant ACLR to decrease the risk of postoperative pain or subsequent meniscectomy.[44]

Meniscal repair

When surgery is likely to benefit the patient, certain factors should be assessed to determine whether meniscal repair rather than resection might be successful. The vascular supply is the most important factor in meniscal healing. Therefore, most meniscal repairs are traditionally performed in the red-red or the red-white zone. However, repair is also recommended for simple or complex meniscal tears that extend into the avascular zone when the conditions are such that a stable repair of a potentially functional meniscus can be obtained. This recommendation is particularly appropriate in young active patients in whom removal of meniscal tissue would result in major loss of function and risk for future knee osteoarthritis.[45] The shape and length of the meniscal tear are other determining factors when contemplating meniscal repair. The length of the tear affects its stability. Tears that are less than 1 cm are considered stable tears and do not require repair.[44] There are vertical longitudinal, horizontal, radial, horizontal flap tears, vertical flap tear and degenerative or complex tears. The root tear, which will be discussed separately, is a special traumatic radial tear of the posterior horn ligamentous fixation. Longitudinal tears, with a

length of more than 1 cm, located in the red-red or red-white zone are most amendable for repair (Table 2). Horizontal tears, on the other hand, are often not repaired and are instead partially resected up to the capsule not sparing the peripheral rim. Theoretically though, it might be considered that only the under layer or only the upper layer should be removed depending on the quality and thickness of the tissue.[46] Pujol et al. showed that open repair of horizontal tears extending to the avascular zone was effective in midterm results in young patients.[47] Radial tears are often located in the avascular zone. There is debate whether these tears should be left alone of treated with partial meniscectomy. Especially in younger patients, though a more substantial radial tear, extending in the red-red zone or to the peripheral rim is amendable for repair.[18] Partial meniscectomy of such radial tear extending to the capsule would have the same functional effect as total meniscectomy.[32] As mentioned above, the time interval between trauma and meniscal repair has no influence on meniscal healing. Instead the quality of the meniscal tissue as

Table 2: Indications for Meniscal Repair.

Longitudinal tear <10 mm
Tears in red-red zone
Vertical tears
Radial tears extending to the capsule in younger patients
Posterior horn root tears
Horizontal tears extending in the avascular zone in younger patients
Concurrent ACL reconstruction in ACL deficient knee

assessed during arthroscopy is the predicting factor for meniscal repair survival.[39]

Meniscal repair techniques

Menisci could be repaired using an open technique.[15,48] Nowadays, arthroscopic repair has become the standard, consisting of inside-out, outside-in, or all inside techniques. The inside-out suturing technique was the first one used for arthroscopic meniscal repair, and is still being considered the gold standard for meniscal repair.[49] After a complete arthroscopic assessment of the knee and evaluation of the tear, both margins of the tear are debrided using a rasp. Next, the surgeon has to decide which repair technique is most suited for the meniscal tear; inside-out, outside-in, all-inside, or a combination of those. In the inside-out technique, needles with sutures are passed from inside the joint through the meniscus on either side of the tear through an arthroscopic cannula. Vertically placed sutures have shown to provide stronger fixation than horizontally placed sutures.[50] On the outside of the knee, a small skin incision is then made through which the needles are passed and the sutures are tied down to the capsule. The inside-out technique is difficult to use for posterior horn tears.[51] Care has to been taken to protect the neurovascular

structures posterior in the knee. Nonetheless, the inside-out technique remains commonly used and has been proved very effective. In the outside-in technique, sutures are passed through the meniscus from the outside. These repairs are limited mostly to the anterior horns.[52] All-inside devices were developed to reduce surgical time. They were made of absorbable polymers and consisted of screws, arrows and darts, with unfortunate complications such as breakage and articular cartilage damage.[53-55] The newest all-inside repair devices allow placement of sutures in the meniscus without an external incision. The meniscal repair device is loaded with two small anchors bond together with a suture and a sliding knot. First, one anchor is pressed through one side of the tear, after which the device is repositioned and the second anchor is put into place. Finally, the suture with the sliding knot is tensioned. Biomechanical properties of these newer meniscal repair devices were as strong as outside-in sutures and significantly stronger than previous generation all-inside fixation devices.[56] Our preferred technique consists of debridement of both sides of the meniscal rupture. For posterior horn fixation we use an all-inside device, for the midportion of the meniscus we use the inside-out technique, and for the anterior horn we use the outside-in technique. In case of an isolated meniscal repair we perform micro-fracturing in the notch to provide cellular elements and biochemical mediators that are essential for the repair responses. In case of a meniscal repair during a concomitant ACL reconstruction there will be sufficient bone marrow derived cells postoperatively in the knee joint and therefore micro-fracturing of the notch is not performed.[56]

Root tears

Meniscal root tears are specific tears with a profound effect on meniscal biomechanics and kinematics. Injuries of the posterior meniscus root attachments include root avulsions and full-length degenerative tears, and radial tears adjacent to the root, and have been linked to clinically significant meniscal extrusion, defined as displacement of the meniscus with respect to the margin of the tibial plateau. Meniscal extrusion may dramatically impair hoop stress force transmission, leading to accelerated degenerative changes within the knee joint.[57,58] The torn meniscal root is fixed to the tibia plateau with sutures attached to a suture anchor or with trans osseous tibial fixation using an ACL like aiming device. Both techniques have shown good results when the root tear is fixed in anatomical position.[32] In recent years, great insight in the biomechanics of meniscal root tears and subsequent reconstruction has been gained by the research group under the direction of LaPrade. Meniscus root avulsion and all radial tear conditions resulted in significantly decreased contact area and increased mean contact pressure compared with the intact knees. Anatomic repair of the posterior root of either medial or lateral meniscus significantly reduced the increased compartment joint contact pressures seen after posterior horn root avulsions.[32,59] Anterior root tears have been described as well. Anterior root tears can be seen,

for example, after intramedullary nailing of a tibial fracture.[60,61] The clinical consequences of anterior root tears remain unknown.

Complications

Arthroscopic meniscal repair surgery is considered to be minimal invasive, and is conducted relatively safely with low complication rates. Nevertheless, the surgeon needs to be aware of the rare but serious risk of damaging the neurovascular structures during surgery. The most severe complication recorded has been sectioning of the popliteal artery, leading to amputation at the level of the knee joint.[62] Less dreaded but serious complications such as hematoma, aneurysm, and pseudoaneurysms of the popliteal artery have been described not only after meniscal repair but also after meniscectomy.[63] Salzler reported 2.8% and 7.6% complication rates for meniscectomy and meniscal repair, respectively, with surgical complications being more common than medical or anesthetic complications.[64] The difference in the complication rate between repair and meniscectomy has been related to the use of older generation rigid all-inside meniscal repair devices. These devices could break, cause articular cartilage damage and aseptic reactive synovitis.[52,54] The third and fourth generation all-inside repair devices are more self-adjusting with anchor placement behind the capsule and with a sliding knot tensioning the suture on the meniscus. In lateral meniscal repair, complications involving the peroneal nerve have been reported using an inside-out technique.[65] If peroneal nerve injury is suspected postoperatively, immediate re-operation should follow, starting with an arthroscopy for cutting of the intra-articular portion of the suture, followed by a posterolateral exploration of the peroneal nerve and removal of the suture. At the medial site, the saphenous nerve is at risk and medial meniscal repair can lead to complications such as transient paresthesia or complete neuropathy.[66] Symptomatic thromboembolism and septic arthritis are more general complications after arthroscopic knee surgery, not specifically related to meniscal repair. The risk of severe complications has to be acknowledged.[67]

Rehabilitation

Rehabilitation guidelines differ among surgeons and with the lack of an evidence based rehabilitation protocol after meniscal repair it remains controversial. It is undisputable though that rehabilitation after meniscal repair has more postoperative restrictions than the rehabilitation after partial meniscectomy.[68] In our postoperative rehabilitation protocol, we distinguish between the types of meniscal tears which are repaired. All patients will have a pressure bandage two to three days after meniscal repair. For repaired longitudinal or dislocated bucket handle tears, the rehabilitation protocol entails six weeks of walking on churches and partial weight bearing up to 50% as tolerated by pain. One could debate, whether or not weight bearing is allowed after meniscal repair. Based on several studies using an all-inside repair only, it appears that there is no notable difference

between an accelerated rehabilitation regime with full weight bearing allowed as soon as tolerated and a standard postoperative rehabilitation program with partial weight bearing.[69] The compressive loads applied during weight bearing in full extension in case of a vertical, longitudinal repair or bucket-handle repair can reduce the meniscus and stabilize the tear and may favour meniscal healing.[70] Flexion is limited to 90-100° during the first six weeks. Morgan et al. demonstrated that extension appears to reduce the meniscus to the capsule, whereas flexion causes tears in the posterior horn to displace from the capsule.[71] Becker et al. have reported that weight bearing flexion from full extension to 90° increases the pressure on the posterior horn.[72] Thus, consideration is given to limiting flexion to 90°-100° during the early period of healing. Closed chain exercises including cycling on a stationary bike for 10 minutes are allowed daily when 90° of knee flexion is reached easily during this period. After six weeks postoperatively, open chain exercises and running on a cross trainer or treadmill is advised. Until three months postoperatively, patients are not allowed to perform deep squats (more than 120°). For radial and root tear repair, we prescribe six weeks of walking on crutches of which the first 3 weeks are non-weight bearing and the second three weeks weight bearing to 25% bodyweight. Weight bearing should be delayed because the hoop stresses would distracts the tear margins and compromise healing. Flexion is allowed to between 0-90° during the first six weeks and closed chain exercises are commenced. After six weeks, range of movement is increased to 120°. Nine weeks after surgery, the patient is allowed full weight bearing, open chain exercises, and running on a cross trainer or treadmill. Until three months postoperatively, patients are not allowed to perform deep squats (more than 120°). Tibial rotation causes large excursions of the meniscus within the first 30° of flexion and, as already mentioned, with increasing flexion pressure on the posterior horn.[73] For that reason, deep squats and movements involving pivoting should be avoided in the first phase of rehabilitation. Programs can or even should be individualized to the type of surgical procedure performed and the type of meniscal tear repaired.

CONCLUSION

Based on our current knowledge of the function of the meniscus, and the deleterious biomechanical and long-term clinical effect of removing part of the meniscus, we argue that the meniscus should be preserved whenever possible. Especially in the younger patient, we believe that the risk of failure of a meniscal repair outweighs the predictable immediate outcome, but long-term deleterious results of partial meniscectomy. Therefore we believe that paradigm shift is needed. If a meniscal lesion is diagnosed always consider: can I leave the meniscus alone? If not, is meniscal repair possible? If repair is not possible or fails after all, a partial meniscectomy can still be performed, as a last resort. In complex

tears in young patients where fully repair is not possible, consider partial meniscectomy in association with meniscal repair.

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