*Acta Orthop. Belg.*, 2014, **80**, 403-413

*ORIGINAL STUDY*

# Meniscal transplantation : still experimental surgery ? A review

Kris MOENS, Aad DHOLLANDER, Peter VERDONK, Rene VERDONK, Karl FREDRIK ALMQVIST, Jan VICTOR

*From the Department of Orthopaedics, University Hospital of Ghent, Belgium*

***Introduction :*** **the objective of this review is to give a state of affairs of meniscal transplantation, with the accent on preservation and surgical techniques.**
***Materials and methods :*** **All articles were selected by performing a search on the literature by using relevant keywords. The most relevant articles were selected with close attention to the publication date.**
***Results :*** **When a meniscal tear is diagnosed, suture can be an option in the vascular zone, whereas the more frequently affected avascular zone heals poorly. A meniscectomy however is not without consequences, wherefore meniscal transplantation can be seen as a therapeutic option for pain reduction and improvement of function when the meniscus is lost. The meniscal scaffold, allograft and autograft can be currently withheld as possible grafts, where the meniscal scaffolds hold great promise as an alternative to the allograft. Various fixation techniques are therefore developed, where viable, deep frozen as well as cryopreservated allografts seem to give the most promising short term results.**
**The transplantation can be performed using an open as well as an arthroscopic technique, using soft tissue fixation, bone plugs or blocks. De primacy of one technique can't be proven. In general meniscal transplantation can be considered as an acceptable procedure.**
***Discussion :*** **Since the outcomes of different studies are difficult to compare, an attempt should be made to limit new studies to the comparison of one aspect. We can conclude that larger, more comparative randomised controlled long-term studies are necessary to resolve which techniques can give the best long-term results.**

*No benefits or funds were received in support of this study.*
*The authors report no conflict of interests.*

**Keywords** : meniscus ; transplantation ; graft ; surgical technique ; indication ; outcome.

## INTRODUCTION

The goal of this review is to attempt to give a state of affairs of the concept of meniscal transplantation, with the accent on meniscal damage, preservation techniques and the outcome of different surgical techniques. By reading the literature on meniscal transplantation we try to give answers on some important present questions about meniscal transplantation. To do so we confronted various sources with each other and we tried to find similarities and differences between studies.

■ Kris Moens, MD.
■ Aad Dhollander, MD.
■ Karl Fredrik Almqvist, MD, PhD.
■ Peter Verdonk, MD, PhD.
■ Rene Verdonk, MD, PhD.
■ Jan Victor, MD, PhD.
*Department of Orthopaedics, University Hospital of Ghent, Belgium.*
Correspondence : Kris Moens, Department of Orthopaedics University Hospital of Ghent, De Pintelaan 185, 9000 Ghent, Belgium. E-mail : kris.moens@ugent.be
Study performed at UZ Ghent.

## SUBJECTS AND METHODS

In order to create this review, we performed an extensive search on the relevant literature concerning meniscal transplantation. The keywords we combined to find relevant articles, were the following : meniscus, transplantation, indications, preservation technique, scaffold, open technique, arthroscopic, fixation, bone plugs, complications, outcome. Related articles that were relevant were also viewed, in order to compare statements of different authors and give a more extensive view on the concept of meniscal transplantation.

An inclusion criteria which was closely kept an eye on, was the publication date, since the objective of this review is to present the most recent state of affairs of meniscal transplantation, since the preservation, operation and fixation techniques and their outcomes are in full development.

## RESULTS

### Indications for meniscal transplantation

Patients under the age of fifty with a history of total meniscectomy and pain at the meniscus deficient compartment, are candidates for meniscal transplantation (*21*). A normal axial alignment and a stable joint are mandatory, since an untreated mal alignment and a deficiency of the anterior cruciate ligament correlate with failure of the meniscal allograft (*9*). Furthermore no damage to the joint cartilage higher than grade three can be present (*14*) and the joint space narrowing has to be limited to grade zero (no narrowing) or grade one (less than fifty percent) (*20*). The cartilage defects have to be focal and not generalised (*21*).

Besides this, patients with deficient anterior cruciate ligaments, who have already undergone a medial meniscectomy in combination with a concomitant anterior cruciate ligament reconstruction, are possible candidates. These patients would benefit from the higher stability, supported by the medial meniscus. Long-term follow-up data of anterior cruciate ligament reconstructions confirm the importance of a functional meniscus to the residual laxity as well as to the degenerative process. These data would justify a more aggressive approach for meniscal replacement in combination with an anterior cruciate ligament reconstruction in meniscectomised anterior cruciate ligament deficient knees.

Finally, a meniscal transplantation can be considered before symptoms arise in young patients who have undergone a complete meniscectomy, in an attempt to prevent early onset knee joint degeneration. A prophylactic meniscal transplantation is not routinely recommended yet. The inherent dilemma is that meniscal transplantation is not without risks and the current evidence suggests only a chondroprotective potential in the patient population as we described above. Early surgery can then result in superior outcomes (*21*). Because mild degenerative cartilage disease is frequently present, these relatively young patients, who long for an active lifestyle, aren't candidates for unicompartment or total arthroplasty (*20*).

### Contra-indications for meniscal transplantation

Advanced cartilage degeneration is in general considered as a contra-indication for meniscal allograft transplantation, however some studies suggest that there isn't a significant risk factor for failure. Articular cartilage lesions, higher than grade three, should be limited and localised. The treatment of these localised (osteo-)chondral defects could take place simultaneously to the meniscal transplantation, because both can have a favorable effect on the healing and the outcome. Patients above the age of fifty often have explicit cartilage disease and are for this reason less optimal candidates. Radiographic evidence of significant osteofyte formation or flattening of the femoral condyle is associated with worse postoperative results, since these structural modifications change the morphology of the femoral condyle (*21*).

Axial mal alignment also exerts an abnormal pressure on the allograft, which can lead to loosening, degeneration and failure of the graft. A corrective osteotomy should be considered for deviations more than two degrees in the direction of the involved compartment, compared with the axis of the other leg. Varus and valgus deformation could be treated with a concomitant or previously performed high tibial or distal femoral osteotomy (*21*). Besides mal alignment, instability of the knee joint is also a

contra-indication, unless the patient is prepared to undergo ligament reconstruction prior to or simultaneously with the meniscal transplantation (*9*). Other contra-indications that are cited in the literature are obesity, skeletal immaturity, synovial disease, inflammatory arthritis (*21*), knee arthrofibrosis, muscular atrophy and previous infection of the knee joint (*9*).

## Graft types

Throughout the years various types of meniscal substitutes have been used in numerous animal models with variable success. The different types are summarised in the table below (Table I). Only the meniscal scaffold, the meniscal autograft and the meniscal allograft have become clinical applications (*15*), with the allograft being the most frequently used type. Therefore we only discuss these three types and the allograft more extensively than the other graft types.

Table I. — The different types of meniscal substitutes (*15*)

| | |
|---|---|
| Meniscus allograft | Fresh<br>Viable<br>Deep-frozen<br>Lyophilized<br>Cryopreserved<br>Glutaraldehyde fixed |
| Meniscus autograft | Patellar tendon<br>Quadriceps tendon<br>Achilles tendon<br>Fat pad<br>Perichondral tissue |
| Meniscus prosthesis | Meniscal scaffold<br>Silastic<br>Carbon fiber<br>Dacron<br>Teflon |
| Genetically engineered tissue | |
| Meniscus xenograft | |

### *Meniscal scaffold*

Synthetic collagen scaffolds that allowed the ingrowth of fibrochondrocytes were already investigated in the nineties. The clinical follow-up after two years was promising, but there wasn't any information on the biomechanical qualities of this material. The scaffolds that were available then had no matrix like the original meniscus, which was the reason for the lack of orientation of the ingrowing fibrochondrocytes (*15*). Thanks to more knowledge and follow-up of these synthetic scaffolds, polyurethanes and polyurethane ureas, based on putrescine, were developed. A special synthesizing method was used to assure a low distribution of hard segments, which resulted in polyurethanes with good mechanical properties. The compression behaviour of the newly formed tissue was comparable to that of native meniscal tissue and protection of the articular cartilage was thought to be possible with this implant (*4*).

Apart from the synthetic scaffolds, scaffolds made of tendons of cattle were also developed as collagen meniscus implant (CMI) (*4*). These scaffolds permit the ingrowth and regeneration of new meniscal tissue and support it. Encouraging results were already obtained in animal studies as well as in the clinical practice, even after six years follow-up. The implant permits the patients to return to physical activity, sports inclusive, without any adverse effect on the knee joint. The possibility of adjusting the CMI to the meniscal defect without compromising the whole meniscal structure, makes it an unique aid that tries to restore the important functions of the meniscus. These scaffolds seem to decelerate the natural evolution of a partially meniscectomized joint on radiography, regarding degenerative joint damage. This finding couldn't be proven until now. Moreover, the CMI also avoids the problems of matching and disease transmission, typical of meniscal allograft transplantation. The further optimization of the mechanical and structural characteristics of the CMI is necessary to make the scaffold more similar to the normal meniscus. Besides, the use of stem cells or growth factors on the implanted scaffold could ameliorate the biological response and the remodelling process, which was already seen in experimental setting (*24*).

### *Meniscal autograft*

The use of autografts rose in the second part of the eighties because of the increasing attention to possible disease transmission, the costs and the

logistical and storage problems of allografts (*7*). Autogenous tissues are, depending of course on the surgical circumstances, free of infection. They are always available and not expensive, but they have an increased morbidity. Moreover the material properties are inferior to those of the allograft. Because the experimental results in animal models were very promising, clinical studies with quadriceps tendon autografts were initiated. Despite the fact that the use of these autografts resulted in pain reduction, only a minority of the autografts had the aspect of a meniscus on arthroscopy. Consequently the total medial meniscus replacement with a quadriceps tendon autograft was abandoned (*15*).

*Meniscal allograft*

The ideal allograft consists of fresh tissue, what leads to some logistical difficulties (*15*). The availability of fresh transplants is limited and a short interval between the death of the donor and the time of transplantation is mandatory, ideally between four and six hours. Additionally, the clinical usefulness of the fresh grafts was diminished at first because of the danger of transmission of infectious diseases and the impossibility to match the meniscal size. Presently however, these problems are minimized by the current work method : two weeks of graft culturing and applying PCR for contagious diseases like HIV, CMV and hepatitis B and C. The impossibility to match is solved by using imaging, amongst other things. Long-term preservation of the grafts allows a more complete donor screening and gives the possibility of creating a bank for menisci (*6*). Throughout the years different preservation techniques were developed. More aggressive preservation and sterilisation techniques however worsen the material properties of the graft (*15*). The morphological and biochemical characteristics of meniscal allografts don't seem to be improved by the viability of the graft, thus most implanted grafts are deepfrozen or cryopreservated. These grafts can be stored for a long period, which makes them immediately available when a graft bank is present (*22*).

Currently mainly allografts are used for a meniscal transplantation, so we will restrict this review to the discussion of several aspects concerning this type of grafts.

**Allograft harvesting**

Donor menisci are harvested in the operation room, after prelevation of other organs (*22*). They are procured within the twelve hours after death or within 24 hours if the body was stored at a temperature of four degrees (*2*). During this period, the meniscus remains viable because of its major avascular properties (*22*). The meniscal tissue is prelevated either with a sterile surgical technique, either in a clean, nonsterile environment, combined with a secondary sterilisation (*2*). By means of an arthrotomy the lateral collateral ligaments and the cruciate ligaments are cut and the knee is anteriorly dislocated. The menisci are inspected on macroscopic tears or degenerative changes, since only macroscopic intact menisci are removed for clinical use. Consequently the maximum age for a donor is set at the age of 45 years and the use of cytostatic drugs and corticoids is set as an exclusion criteria because of the possible negative influence on the viability and metabolism of the cells. Both menisci of each knee are removed with a small synovial rim for manipulation. The meniscus itself is handled in a strictly atraumatic manner. The bone blocks are not removed, but the detachment of the ligament insertion to the bone at the anterior and posterior horn is carefully executed (*22*).

**Preservation techniques**

After harvesting, the meniscal tissue is preserved with one of the following five methods : viable, deepfreezing, cryopreservation, lyophilisation or with the aid of glutaraldehyde fixation. Viable and cryopreserved allografts contain viable cells, while deepfrozen, lyophilized and glutaraldehylde fixed tissues are acellular at the moment of transplantation (*2*).

*Viable*

Viable allografts would be the ideal graft type because they contain a high number of viable cells (*16*). These are advantageous for the long-term preservation of the extracellular matrix, which is dependent of the survival of the fibrochondrocytes (*15*). This has a positive effect on the mechanical integrity of

the allograft after transplantation, since non-viable allografts have shown articular meniscal cartilage changes in the material properties after transplantation (*16*). Consequently we can expect that a viable allograft fulfils a normal cellular function from the moment of implantation, leading to a normal meniscal function, which hypothetically can be an advantage compared to deepfrozen allografts (*22*). Viable allografts can be kept during seven days without loss of viability, if they are stored at four degrees in a sterile culture medium (*16*). Nevertheless the availability of a fresh transplant is rather limited, since the mean waiting time is two months (ranging from fourteen days to six months). When an allograft becomes available, the patient is informed and an operation is planned in the next fourteen days (*20*). Both in terms of quality and quantity, the ideal moment for the implantation of a viable meniscal allograft is set in the period ten to fourteen days after the start of the culture (*22*). The purpose of this culture period is to create time to screen the donor on contagious diseases and to be able to carefully plan the surgical procedure (*20*). Still the risk of disease transmission was higher with this graft type, since serological tests couldn't be completed before the graft implantation. Presently the operation is solely performed when the PCR results are known. Moreover, secondary methods of graft sterilisation can't be used, because they would destroy the viable donor cells (*16*).

The hypothesis that the use of viable meniscal allografts would be more advantageous than the use of other graft types described below cannot be confirmed, since no clear advantage could be demonstrated (*19*). Furthermore, the number of cells that survive the transplantation and the survival duration after transplantation is unknown. Via DNA probe analysis in a goat model all donor cells in a fresh meniscal transplant were found to be replaced rapidly by host cells (*2*). This questions the need for viable cells in an allograft.

*Deepfreezing*

Deepfrozen meniscal allografts have the advantage of easier storage (*15*). They are quickly brought to a temperature of minus eighty degrees, which liquidates the fibrochondrocytes (*2*). Nevertheless this has no important effect on the material properties of the graft, since the freezing process leaves the collagen network intact. Therefore the storage time has no effect on the biological and material properties of the tissue, which means the meniscus can be stored longer (*6*). This simple technique also offers the opportunity to carry out serological tests before the implantation, which makes it a safe procedure (*22*). It also permits secondary sterilisation techniques to be performed (*6*). This increases the safety concerning transmittable diseases. Despite the freezing and storage process, these deepfrozen allografts seem to heal without any problems, to repopulate with host cells in the next four to eight weeks and to remodel in the next six months. Based on these findings deepfrozen grafts aren't inferior to fresh grafts (*22*). When we compare deepfrozen grafts with lyophilized grafts, deepfrozen ones give the best results. They are more comparable to an intact meniscus, while lyophilized grafts have more similarities with meniscectomized knees. Nevertheless, none of these two types reach the strength of normal meniscal tissue (*23*).

*Cryopreservation*

In cryopreservation, the process of freezing is performed progressively, with the use of dimethyl sulfoxide (DMSO) or glycerol as cryoprotector. This process leads to the freezing of the graft at a temperature of -178 °C (*22*). Once this temperature is reached, the graft can be stored for an indefinite period, since all metabolic processes are theoretically stopped at this temperature and cell membrane integrity is kept, so the viability of the fibrochondrocytes can be partly maintained. This makes an extended storage of the graft possible without influencing the biomechanics (*2*). Depending on different conditions, like the solution and the freezing technique used, ten to forty percent of the fibrochondrocytes can survive. This lengthens the time interval for all the required serologic tests and for the selection of the appropriate patient (*15*). The percentage of viable cells drops along with the storage time and this especially after the second week of preservation. Besides the fact that cryopreservation is an expensive technique, the risk of transmitting an infectious disease exists (*6*).

Secondary sterilisation techniques that can influence the cell viability, cannot be applied, which increases the risk of disease transmission (*16*).

The question if the higher cost and complexity of cryopreservation in meniscal transplantation are warranted, is still unanswered today because there aren't any significant differences shown compared to deepfrozen grafts and because these latter are already transplanted with similar results (*16*). This confirms the assumption that the morphological and biochemical characteristics of the graft don't improve, despite the preservation of partial cell viability (*6*). Furthermore deepfrozen grafts are immediately available, not expensive and the storage of grafts of variable sizes is possible (*22*).

*Lyophilisation*

The process of lyophilisation or freeze-drying kills the cells of the graft and can adversely affect the material properties, which frequently leads to shrinking of the graft (*2*). The whole ground substance is affected during lyophilisation, so that only the collagen network remains for implantation and the graft serves as a scaffold for the ingrowth of host fibrochondrocytes (*15*). Despite the fact that deepfrozen and lyophilized meniscal allografts in sheep were equal regarding the tensile strength a couple of months after transplantation, they never reached the values of normal control menisci. Moreover synovitis and effusion were more frequently observed after transplantation with a lyophilized graft than after deepfreezing or viable preservation. Changes like tissue hydration, swelling and size changes could also occur during reconstitution of the lyophilized transplants, which makes sizing quite difficult. These findings suggest that lyophilisation is not an appropriate preservation technique for meniscal allografts (*16*).

*Glutaraldehyde fixation*

Fixation of the allograft with glutaraldehyde is toxic for the donor cells and implies that only the collagen matrix is preserved. Studies on dogs have shown a less satisfying postoperative healing and recurrent joint effusions compared to meniscal auto- and allografts preserved in culture. Articular degenerative changes and shrinking of the graft were also found with this fixation technique. Moreover, the toxic product that remains in the graft can cause a chronic synovitis. Because of these findings, glutaraldehyde fixation for meniscal allografts has been abandoned (*16*).

**Complications of meniscal transplantation**

Besides the general potential complications regarding surgery and anaesthesiology and the risks of the use of allografts which we described above, complications after a meniscal transplantation are rare (*13*). The importance of a good indication cannot be underestimated, since failure of the graft often occurs after an incorrect indication (*5*). Complications described in the literature are arthrofibrosis, loosening of the bone plug or bone bridge fixation, loosening of the meniscus to the bone plug, meniscal allograft tear or failure of the healing to the periphery, which again demands a repair or a partial meniscectomy of the graft. Also cases of continuous or progressive pain or the progression of degenerative joint damage with the need for allograft removal as result, are described (*13*). Finally, the tension on the graft can be too high or too low due to an imperfect suture (*5*).

**Outcome**

The meniscus can be implanted by means of an open or an arthroscopically assisted technique. In the literature, various surgical techniques are described and the superiority of one against the other is still not proven. In the following we compare the outcomes of the open and the arthroscopic approach and the different fixation techniques.

*Open versus the arthroscopically assisted technique*

In the literature the superiority of arthroscopically assisted implantation to an open technique can't be proven (*14*). Both techniques have their pro- and opponents. Proponents of the open technique state that the postoperative period is equal to that of the arthroscopically treated patients. They report that patients don't need more analgesia, are discharged at the same day and can immediately use their

muscle groups. Moreover no special adjustments regarding revalidation are needed, except the initial protection of the collateral ligament. Certain surgeons also believe that especially at the medial compartment, the open procedure permits a more secure peripheral suture or bone fixation of the graft, which leads to more precision and stability (*13*). Adversely the open technique requires a broader approach with bone detachment and refixation of the relevant collateral ligaments afterwards. This however gives a good overview of the treated compartment, which makes a good evaluation of the position of the graft during control motions possible (*5*). The benefits cited by proponents of the arthroscopically assisted technique, are the diminished operative morbidity without disruption of the collateral ligaments. Moreover a faster revalidation is stated comparing to the open technique. On the contrary the arthroscopically assisted technique is time consuming and technically more demanding (*16*). Because it is difficult to identify the exact localisation of the previous insertions of the anterior and posterior horns (*5*). Therefore this technique should only be exerted after significant practice (*16*).

Open techniques are in general reserved for combined surgery, like a concomitant osteotomy (*15*). In isolated meniscal replacement, the current tendency is to exert this operation arthroscopically, mainly because of the lower surgical morbidity and the faster revalidation (*14*). In table II, a summary of the pros and cons of open and arthroscopically assisted techniques, cited by various authors, is presented.

*Fixation techniques*

Regardless of the decision of an open or an arthroscopically assisted technique, the correct anatomic positioning and the peripheral fixation of the graft are of primary importance (*13*). Research has shown the importance of horn fixation for the extrusion of the meniscus during stress (*14*). A solid fixation of the meniscus at the anterior and posterior horn is consequently necessary to transform the load stress into a tensile force (*15*). The ideal technique for this transformation remains a subject of debate (*10*). In general we can distinguish two groups regarding the fixation techniques : fixation with bone plugs or a bone bridge and soft tissue fixation without bone plugs (*15*).

Table II. — The benefits and disadvantages of the open and the arthroscopically assisted technique of meniscal transplantation

| | |
|---|---|
| | Open |
| Advantages | Good overview of the operation compartment |
| | Good evaluation of the transplant during control motions |
| | More secure peripheral suture or bone fixation |
| | Applicable in combined surgery (for example concomitant osteotomy) |
| | Postoperative period similar to arthroscopically assisted technique |
| Disadvantages | Broader approach with bone detachment |
| | Reinsertion of the collateral ligaments always necessary |
| | cosmetic |
| | Arthroscopically |
| Advantages | reduced surgical morbidity |
| | no disruption of the collateral ligaments |
| | faster revalidation |
| | cosmetic |
| Disadvantages | technically more demanding |
| | time consuming |
| | Difficult identification of the previous insertions of the meniscal horns |

Table III. — The arguments pro and against of soft tissue fixation and bone fixation

| | | |
|---|---|---|
| Soft tissue fixation | Positive | Good healing is demonstrated |
| | | Simpler technique |
| | | Simpler size matching |
| | | Easier anatomic positioning |
| | Negative | Would allow dislocation of the meniscal graft |
| Bone fixation | Positive | Significantly better range of motion |
| | | Superior transmission of the load |
| | Negative | Matching problems |
| | | Close anatomic placement |
| | | Technically more demanding |
| | | Tibial and potential femoral joint surface damaging |

*Soft tissue fixation versus bone plug or bone bridge fixation*

The literature doesn't show a real noticeable clinical difference between soft tissue fixation and the use of bone plugs or a bone bridge is shown (*10*). Moreover there is no implication that bone plug fixation or soft tissue fixation gives superior results (*15*) and both techniques have their benefits and disadvantages (Table III). A recent cadaver study showed that medial meniscal graft fixation doesn't need bone plugs and consequently sutures alone should be sufficient. This would simplify the technicality of the surgery (*11*). Other advantages of soft tissue fixation are more convenience with regards to size matching, the fixation and the anatomical positioning of the graft (*10*), which has to be very accurate, since bad positioning of the horns changes the contact pressure (*15*).

In a couple of other experiments however suture fixation is suggested to allow dislocation of the graft, which doesn't lead to protection of the articular surfaces (*11*).

Proponents of the bone plug technique argue that bone plugs are superior to soft tissue fixation, since a superior transmission of the load is provided when the graft is anchored with bone (*13*). The only detectable clinical difference however was the significantly better range of motion, with a bigger passive extension of four degrees average, compared to soft tissue fixation. The amount of patients in this study yet was too small to be statistically significant (*18*). The bone plug fixation procedure nevertheless causes damage to the tibial joint surface and it can damage the femoral side, following incongruence with the original anatomy (*20*). Moreover problems can arise concerning the graft matching, because accurate anatomic placement of the graft is required to prevent a possible increase in degenerative changes. This procedure is also technically more demanding, especially regarding the posterior horn fixation (*11*).

*Bone plug versus bone bridge fixation*

General consensus exists concerning the bone bridge technique being the preferred method for a lateral meniscal transplantation, because the distance between the anterior and posterior horns of the lateral meniscus is one centimetre of less. The use of bone plugs at the lateral compartment would furthermore produce a higher risk of compromised fixation (*2*). With the medial meniscus, a double bone plug technique is the most frequently used technique because here the horns are placed further apart and a tibial slot could compromise the attachment of the anterior cruciate ligament. Proponents of the bone bridge at the medial site emphasise admittedly that the anatomic relation between the anterior and posterior horns is preserved. Moreover knees with a limited medial joint aperture can benefit from the ease of insertion with the bone bridge technique, if the surgeon can avoid the disruption of the medial collateral ligament. On the other hand proponents of the use of bone plugs at the medial site emphasize the variability of the attachment sites of the anterior horn and the

Table IV. — Arguments concerning the choice of fixation technique in a medial meniscal transplantation

| | |
|---|---|
| Bone plug | Horns are placed further apart |
| | Danger of compromising the anterior cruciate ligament with bone bridge |
| | Variability of the attachment site of the anterior horn |
| | Possibility of minor positional adjustments |
| | Danger of disruption of the medial collateral ligament with bone bridge |
| Bone bridge | Anatomic relation between the horns retained |
| | Simple insertion |

possibility of minor positional adjustments (*13*) (Table IV). We can conclude that, while a bone bridge is generally used at the lateral site, the medial site can be reconstructed with a bone bridge as well as with bone plugs, depending on the preference of the surgeon (*2*).

*General outcome*

When the meniscus is completely lost, all medium and long-term studies have shown that a transplantation is a therapeutic option with good results regarding pain reduction and amelioration of the physical and social function (*21*), which can also be shown clinically (*19*). Despite these good results, substantial inability and symptoms are yet observed after more than ten years follow-up. Also a higher amount of tears are determined. However the clinical outcome in those who had torn their graft and were treated with a partial meniscectomy was positive. This can be due to the concomitant procedure or the fact that a big part of the transplanted meniscus remains in place after a partial meniscectomy (*19*). In addition more recent studies have shown no significant correlation between the initial cartilage status and clinical failure, which questions the contra-indication of severe arthrosis (*21*). Alternative procedures that deal with concomitant pathologic changes, are seen to be successfully combined with a meniscal transplantation to obtain optimal results (*2*). When we compare an anterior cruciate ligament reconstruction combined with a transplantation to a transplantation alone, the outcome seems to be better in those patients that have undergone an extra procedure. This shows the functional advantage of joint stabilisation with an anterior cruciate ligament reconstruction (*19*). Besides that, also the additional effect of a corrective osteotomy in varus mal alignment is clearly demonstrated (*21*). However it remains uncertain if these improvements are mainly the result of the transplantation, the additional procedure or both (*3*). Finally it is encouraging that more recent studies, where more modern methods of graft insertion are used and attention to associated pathology is given, describe more favorable outcomes in approximately eighty five percent of their patients cohorts (*14*).

## DISCUSSION

When the meniscus is completely lost, the transplantation of an allograft is considered a therapeutic option for pain reduction and function improvement. Since this option is not applicable for each meniscectomized patient, indications and contra-indications were formulated in order to minimise the failure percentage. Conditions cited are amongst others the presence of pain, the age (under fifty years old), limited joint damage, normal alignment and a stable joint. Moreover a meniscal transplantation can be considered in young patients after a meniscectomy before symptoms occur in order to prevent early joint damage.

Out of the different graft types, only the meniscal scaffold, allograft and autograft became clinical applications. This last one is however abandoned because of the limited similarity to a real meniscus, in spite of the resulting pain reduction following its use. The meniscal scaffold however holds great promise and could mean an alternative for a meniscal allograft. Thanks to a special synthesis method, the synthetic scaffolds were developed with good mechanical characteristics regarding compression

behaviour, comparable to normal meniscal tissue. We expect that these scaffolds too can provide articular cartilage protection, but this still has to be proven in further research. Regarding the collagen meniscal implants, hopeful results were obtained related to the return to physical activity, including sports. These CMI have the possibility to avoid disease transmission and to adapt to the defect without losing functional quality, which makes it an unique aid. The radiographic delay of degenerative joint damage is also mentioned, but further and more long-term research is needed to confirm this. Also more research on the possibilities to improve his mechanical and structural characteristics and the application of stem cells and growth factors is needed. Because the scaffolds are at the moment secondary to allografts in terms of use, they weren't further discussed in this review. The ideal graft consists of fresh tissue, which can lead to logistical problems regarding the availability and matching as well as the transmission of infectious diseases. These problems are presently minimized by the use of preservation techniques and the application of PCR and sterilisation procedures to make the risk of disease transmission acceptably small. Throughout the years different preservation techniques were developed, like viable, deep freezing, cryopreservation, lyophilisation and glutaraldehyde fixation. Fresh and cryopreserved allografts contain viable cells, while deep frozen, lyophilisized and glutaraldehyde fixed tissues are acellular at the moment of transplantation. Research however has shown that all donor cells in a fresh meniscal transplant are quickly replaced by host cells, which questions the need for viable cells. We can consequently conclude that the role of cell viability in the ultimate outcome of the graft is unclear until now and there is no evidence that the additional cost, associated with fresh or cryopreserved allografts, will be justified by improved results. Until today no significant differences between cryopreserved and deep frozen grafts were shown, while these latter are already transplanted with comparable results. Concluding we can state that meniscal replacement with viable, deep frozen or cryopreserved allografts seems to give the most promising short term results. The use of lyophilized and glutaraldehyde preserved grafts is not recommended in general, because the material characteristics are unfavorably influenced and shrinking, synovitis and effusion were frequently seen.

In the literature different procedures for an open as well as an arthroscopically assisted technique are described and the superiority of one technique cannot be demonstrated, since arguments for both techniques can be cited. In general open techniques are nowadays preserved for combined surgery, while an isolated meniscal replacement is mostly performed arthroscopically, mainly because of the lower surgical morbidity and the faster revalidation.

Independent of the type of surgery, research shows the importance and the need for a firm fixation to avoid the extrusion of the meniscus during stress. The ideal technique also remains a subject of debate. Regarding the choice between soft tissue fixation and bone plugs or a bone bridge, no real discernible difference can be shown clinically as well as in terms of results until now. Both techniques can be motivated, which stresses the need for further research. If the surgeon chooses for a bone fixation, general consensus exists for the use of a bone bridge at the lateral site, while for the medial site both techniques can be used, depending on the preference of the surgeon.

Regardless of the used techniques, a transplantation can be seen as a therapeutic option with good results regarding pain reduction and improvement of the physical and social function when the meniscus is completely lost. Even when concomitant procedures the outcome seems to be better in those patients who underwent an extra procedure. Further research however is mandatory to point out if the transplantation or the additional procedure is the cause of these improvements.

The meniscal transplantation remains an evolving area where consensus is still lacking on different aspects. It is thus difficult to compare the outcome of different studies because of the variation on graft types, preservation, sterilisation, operation and fixation techniques, concomitant procedures, clinical evaluation, follow-up periods, patient numbers and failure criteria. Clinical trials should consequently be limited to the comparison of one aspect, for example the used surgical technique, for which

more simple interpretable data can be obtained. A second problem in current studies is the lack of data with a follow-up of more than ten years, which is one of the reasons why the chondroprotective effect and the long-term outcome of a meniscal transplantation still aren't conclusively proven. In addition the possibility of meniscal repair for extensively displaced ruptures makes that only a limited amount of young patients undergo a meniscal transplantation. This predisposes for a limited patient pool from which we have to interpret and distinguish the best treatment methods. Nevertheless the biggest drawback of all existing studies is the lack of a control group, consisting of conservatively treated symptomatic post meniscectomy patients. The main reason for this shortage of a control group is the difficult feasibility on ethical grounds, since the denial of an allograft transplantation to these patients can mean that the most ideal treatment would not be given. More comparing, larger randomized controlled long-term studies are needed to distinguish for the future which grafts and surgical techniques can give the most favorable long-term results.

## REFERENCES


1. **Chang HC, Teh KL, Leong KL, Mak SL, Karim SA.** Clinical evaluation of arthroscopic-assisted allograft meniscal transplantation. *Ann Acad Med Singapore* 2008 ; 37 : 266-272.
2. **Cole BJ, Carter TR, Rodeo SA.** Allograft meniscal transplantation : background, techniques, and results. *Instr Course Lect* 2003 ; 52 : 383-396.
3. **Cole BJ, Dennis MG, Lee SJ *et al.*** Prospective evaluation of allograft meniscus transplantation : a minimum 2-year follow-up. *Am J Sports Med* 2006 ; 34 : 919-927.
4. **De Groot JH**. Polyurethane scaffolds for meniscal tissue regeneration. *Med Device Technol* 2005 ; 16 : 18-20.
5. **Dienst M, Kohn D.** Allogenic meniscus transplantation. *Oper Orthop Traumatol* 2006 ; 18 : 463-480.
6. **Fabbriciani C, Lucania L, Milano G, Schiavone Panni A, Evangelisti M.** Meniscal allografts : cryopreservation vs deep-frozen technique. An experimental study in goats. *Knee Surg Sports Traumatol Arthrosc* 1997 ; 5 : 124-134.
7. **Goble EM, Kohn D, Verdonk R, Kane SM.** Meniscal substitutes – human experience. *Scand J Med Sci Sports* 1999 ; 9 : 146-157.
8. **Hamlet W, Liu SH, Yang R.** Destruction of a cryopreserved meniscal allograft : a case for acute rejection. *Arthroscopy* 1997 ; 13 : 517-521.
9. **Heckmann TP, Barber-Westin SD, Noyes FR.** Meniscal repair and transplantation : indications, techniques, rehabilitation, and clinical outcome. *J Orthop Sports Phys Ther* 2006 ; 36 : 795-814.
10. **Hommen JP, Applegate GR, Del Pizzo W.** Meniscus allograft transplantation : ten-year results of cryopreserved allografts. *Arthroscopy* 2007 ; 23 : 388-393.
11. **Hunt S, Kaplan K, Ishak C, Kummer FJ, Meislin R.** Bone plug versus suture fixation of the posterior horn in medial meniscal allograft transplantation : a biomechanical study. *Bull NYU Hosp Jt Dis* 2008 ; 66 : 22-26.
12. **Kohn D, Aagaard H, Verdonk R, Dienst M, Seil R.** Postoperative follow-up and rehabilitation after meniscus replacement. *Scand J Med Sci Sports* 1999 ; 9 : 177-180.
13. **Lubowitz JH, Verdonk PC, Reid JB, Verdonk R.** Meniscus allograft transplantation : a current concepts review. *Knee Surg Sports Traumatol Arthrosc* 2007 ; 15 : 476-492.
14. **Matava MJ.** Meniscal allograft transplantation : a systematic review. *Clin Orthop Relat Res* 2007 ; 455 : 142-157.
15. **Peters G, Wirth CJ.** The current state of meniscal allograft transplantation and replacement. *Knee* 2003 ; 10 : 19-31.
16. **Rijk PC.** Meniscal allograft transplantation – Part I : background, results, graft selection and preservation, and surgical considerations. *Arthroscopy* 2004 ; 20 : 728-743.
17. **Sekiya JK, West RV, Groff YJ *et al.*** Clinical outcomes following isolated laterale meniscal allograft transplantation. *Arthroscopy* 2006 ; 22 : 771-780.
18. **Sohn DH, Toth AP.** Meniscus transplantation : *Current concepts J Knee Surg* 2008 ; 21 : 163-172.
19. **Verdonk PC, Demurie A, Almqvist KF *et al.*** Transplantation of viable meniscal allograft. Survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am* 2005 ; 87 : 715-724.
20. **Verdonk PC, Demurie A, Almqvist KF *et al.*** Transplantation of viable meniscal allograft. Surgical technique. *J Bone Joint Surg Am* 2006 ; 88 : 109-118.
21. **Verdonk R, Almqvist KF, Huysse W, Verdonk PC.** Meniscal allografts : indications and outcomes. *Sports Med Arthrosc* 2007 ; 15 : 121-125.
22. **Verdonk R, Kohn D.** Harvest and conservation of meniscal allografts. *Scand J Med Sci Sports* 1999 ; 9 : 158-159.
23. **Wirth J, Peters G, Milachowski KA, Weismeier KG, Kohn D.** Long-term results of meniscal allograft transplantation. *Am J Sports Med* 2002 ; 30 : 174-181.
24. **Zaffagnini S, Giordano G, Vascellari A *et al.*** Arthroscopic collagen meniscus implant results at 6 to 8 years follow up. *Knee Surg Sports Traumatol Arthrosc* 2007 ; 15 : 175-183.