International Meniscus Reconstruction Experts Forum (IMREF) 2015 Consensus Statement on the Practice of Meniscal Allograft Transplantation

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Current Concepts

International Meniscus Reconstruction Experts Forum (IMREF) 2015 Consensus Statement on the Practice of Meniscal Allograft Transplantation

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Investigation performed at the International Meniscus Reconstruction Experts Forum, Lyon, France

Meniscal allograft transplantation (MAT) has become relatively commonplace in specialized sport medicine practice for the treatment of patients with a symptomatic knee after the loss of a functional meniscus. The technique has evolved since the 1980s, and long-term results continue to improve. However, there still remains significant variation in how MAT is performed, and as such, there remains opportunity for outcome and graft survivorship to be optimized. The purpose of this article was to develop a consensus statement on the practice of MAT from key opinion leaders who are members of the International Meniscus Reconstruction Experts Forum so that a more standardized approach to the indications, surgical technique, and postoperative care could be outlined with the goal of ultimately improving patient outcomes.

Keywords: meniscal allograft transplantation; consensus statement; knee

The past 30 years have witnessed an evolution in how the postmeniscectomy knee is treated. Once thought to be vestigial structures and hence removed without thought, the menisci are now understood to be key structures in providing optimal knee function.[22] The loss of the meniscus not only helps to determine the onset of osteoarthritis (OA) but the meniscus plays an important role in providing stability and nourishment of the articular cartilage.[7] The presence of the meniscus has also been significantly correlated with improved outcome after anterior cruciate ligament (ACL) reconstruction because of its joint stabilizing properties, with loss of either meniscus being associated with 5-fold increase in ACL graft failure at 2 years after surgery.[33]

The first animal and then human meniscal allograft transplantation (MAT) studies were performed in the 1980s, with the aim of providing joint stability.[4,24,48] Researchers across Europe, Asia, and North America paved the way in terms of identifying indications and developing surgical techniques that would ultimately result in the trends in current treatment practice.

Because long-term studies have reported satisfactory outcome out to 20 years, the practice of MAT is now no longer thought of as experimental.[6] However, evidence of the provision of chondroprotection and ultimately the prevention of OA remains elusive; therefore, the technique and the associated practice guidelines continue to evolve with the remit of consistently trying to improve patient outcomes.

As such, in 2013 the inaugural meeting of the International Meniscus Reconstruction Experts Forum (IMREF) was held in Toronto, Canada, alongside the International Society of Arthroscopic Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) Biennial Congress. Twenty-five key opinion leaders in the field of meniscal repair and transplantation attended this meeting, the focus of which was on MAT surgical technique. Two years later, at the 2015 ISAKOS congress in Lyon, France, the same group gathered to form a consensus on the practice of MAT, with the purpose of defining current practice and guiding future research so as to continually improve MAT outcomes.

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The purpose of this article is to provide an in-depth overview of the consensus statements developed from the 2015 IMREF meeting, utilizing a previously published approach to gathering consensus.

METHODS

Consensus was determined utilizing the consensus group technique described by List.[17] This technique is a qualitative approach to gathering consensus by means of group discussion statements with a criterion level of agreement set beforehand. The statements are discussed and modified by the group until the criterion level can be met. Before the IMREF consensus meeting held on June 9, 2015, in Lyon, France, an online survey (www.surveymonkey.com) was circulated to all IMREF members and other experienced international surgeons who perform meniscal transplantation. The Appendix (available in the online version of this article and at http://ajsm.sagepub.com/supplemental) shows the specific questions that were posed to the surgeons, building a clear picture of demographics and experience of MAT. Specific questions were then asked around 3 broad areas of MAT:

1. Preoperative assessment and decision making
2. Surgical planning and technique
3. Postoperative assessment

The 15 statements generated were then presented at the IMREF consensus meeting in June 2015, where they were debated and modified by 21 international surgeons, all of whom were experienced in performing MAT, until a criterion level of 70% was met.

CONSENSUS STATEMENTS AND DISCUSSION

The results from the IMREF 2015 survey are shown in the Appendix (available online). Based on the answers to these questions, the following 15 statements were then generated and further debated at the consensus meeting in Lyon. The resulting statements and underlying rationale are discussed below.

Indications for MAT

1. *Based on current clinical evidence showing improvements in outcome after MAT, IMREF recommends the following as primary indications*:
   - I. *Unicompartmental pain in the presence of total or subtotal "functional" meniscectomy*.
   - II. *As a concomitant procedure to revision ACL reconstruction to aid in joint stability when meniscus deficiency is believed to be a contributing factor to failure*.
   - III. *As a concomitant procedure with articular cartilage repair (ACR) in a meniscus-deficient compartment*.

Because of the long-term follow-up and reported clinical results in the peer-reviewed literature, MAT should no longer be considered experimental or investigational surgery.[6] Nonetheless, it is a procedure that is relatively rarely performed (estimated 1/1,000,000 population), and thus careful patient selection is essential to achieve optimal clinical outcomes. Studies show good clinical results when classic indications are adhered to, demonstrating a broad consensus in the literature.[36]

The menisci play an important role in the proper biomechanical function of the human knee joint.[22] The loss of meniscal tissue leads to reduced congruency of the articular cartilage surfaces of the tibiofemoral joint, resulting in a decrease in the intra-articular contact area and an increase in loading pressure. The articular cartilage is unable to compensate for these biomechanical changes in the long term; therefore, the risk of early degeneration is significantly higher in meniscus-deficient knees.

An intact ring structure is essential for proper meniscal function; hence, any interruption of this ring reduces the hoop stresses and leads to insufficient transmission of axial loads.[26] Therefore, it is important to introduce the concept of functional meniscus loss. This situation can arise even if there is no or very little deficiency of the meniscal tissue, for instance, in complete radial tears or root tears.

The goal of MAT is to limit or even preclude the negative effects of meniscus loss, which means relief of pain, restoration of joint biomechanics, improvement in knee function, and prevention of OA. The absence of alternatives in the painful meniscectomized knee has to be considered a strong argument for MAT in selected patients, although the absence of conservative control groups in the published studies makes it impossible to confirm the degree of chondroprotection of this treatment.

Considering these goals, there are 3 main indications for MAT:

I. Unicompartmental pain in a meniscus-deficient knee is the primary indication for MAT. The so-called postmeniscectomy syndrome occurs in the face of a nonfunctional meniscus without significant articular cartilage wear with the patient predominantly complaining of pain. There is some evidence that the treatment of the lateral compartment is of greater importance due to the fact that degeneration appears earlier after a lateral meniscectomy, caused by the incongruence of the joint surfaces of the distal femur and the proximal tibia.[47] Despite inconclusive evidence of chondroprotection and the fact that the meniscus might or could deteriorate after 7 to 10 years, there is strong evidence that those who have postmeniscectomy syndrome have a predictably excellent result after MAT.

II. There is also strong agreement that patients with ACL deficiency and an absent medial meniscus may benefit from a medial MAT at the time of ACL revision reconstruction. The medial meniscus is an important secondary stabilizer of the knee to anterior tibial translation in the ACL-deficient knee. Therefore, the meniscal graft is expected to protect the ACL and vice versa.[18] Clinical studies have shown that knee instability has an effect on MAT results, with van Arkel and de Boer[39] reporting higher failure rates of

medial MAT in ACL-deficient knees. While not every failed ACL in patients who are functionally meniscus deficient requires MAT, comprehensive decision making will often lead to reasonable considerations to perform concomitant or staged MAT in the setting of revision ACL reconstruction.

III. The resultant increase in contact stress and decrease in joint-contact surface after meniscectomy in some ultimately lead to the overloading and breakdown of the articular cartilage.[22] Partial meniscectomy, especially if it involves the posterior horn, can also lead to significant increases in contact stress on the corresponding articular cartilage. The general optimal indications for ACR include the presence of a functional meniscus.[8] Without the presence of a functional meniscus, increased loads will ultimately lead to failure of ACR. There exists a symbiotic relationship between the meniscus and the corresponding articular cartilage, which must be preserved as best as possible for the health of the knee joint. With the development of improved techniques and understanding of MAT, and the ongoing development of methods for ACR, it is possible to improve clinical outcomes and obtain good to excellent functional results that are similar to the results of either procedure performed separately.[10]

2. Meniscus deficiency is an indication for MAT; however, it should not be considered as a routine procedure in the asymptomatic patient.

- *Asymptomatic knee = no symptoms or objective signs of impending joint degeneration.*

The decision as to whether or not to treat a patient prophylactically who has functional meniscus loss is not easy. Logic would dictate that a young patient with posttraumatic meniscus loss, particularly the lateral meniscus, would benefit from MAT with the aim of preventing or slowing the OA process and at least delay the onset of symptoms. Published studies show overall high clinical success rates and low serious complication rates, making MAT a suitable option in the symptomatic patient.[6,36] However, there is a paucity of evidence for the use of MAT in asymptomatic patients. Experimental data show conflicting results for the potential chondroprotective effect of MAT. Rijk et al[31] conducted an animal study in rabbits in which they could not find any radiological difference between MAT and the control group (meniscectomy) at 12-month follow-up. In contrast, McDermott et al[23] were able to show that tibiofemoral contact pressure decreases to normal values after MAT in a human cadaveric model, suggesting a potential chondroprotective effect. Furthermore, a clinical study by Verdonk et al[44] demonstrated the potential chondroprotective effect of MAT. Most recently, a systematic review of the clinical literature by Smith et al[36] suggested that a low level of evidence exists to support the use of MAT as a chondroprotective treatment. However, with several clinical studies showing a reoperation rate after MAT as high as 35%, it is important to balance the risks and benefits of MAT in the setting of an asymptomatic patient after meniscectomy. As such, 42% of surgeons in the IMREF survey stated they would generally not perform MAT in an asymptomatic patient, with 18% saying yes, but only for the lateral meniscus (Figure 1).

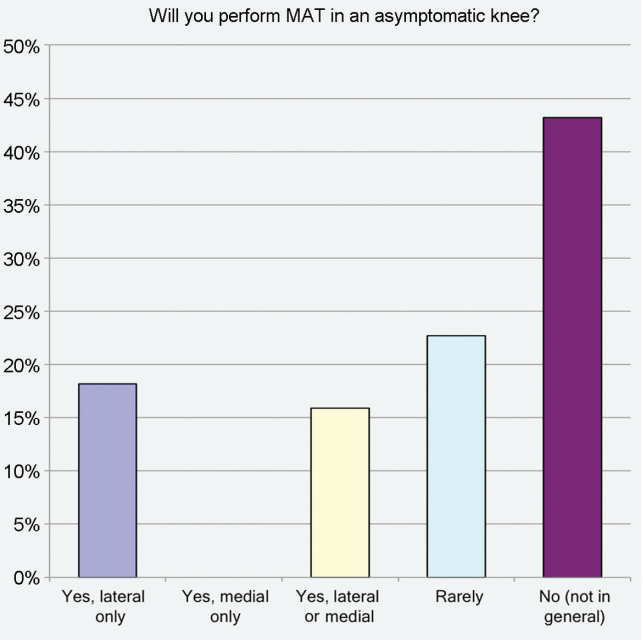

Figure 1. Survey response to treatment of the asymptomatic knee. MAT, meniscal allograft transplant.

Of course, it is paramount to define symptomatic in this patient population. Based on clinical expertise, IMREF defines an asymptomatic patient as one who does not have symptoms (pain) or signs (effusion, radiographic changes) of pending joint degeneration.

Further prospective studies are required to clearly delineate whether MAT is indeed chondroprotective and if it should be routinely offered as a prophylactic measure. Until then, IMREF cannot recommend MAT as a routine prophylactic procedure in the asymptomatic patient who has undergone meniscectomy.

3. When performing an articular cartilage restoration procedure, IMREF recommends performing MAT in the absence of a functional meniscus in the involved ipsilateral compartment.

As detailed previously, numerous studies have highlighted the importance of a functional meniscus when performing ACR. Meniscus loss/dysfunction has been clearly correlated with articular cartilage degeneration[22]; it is therefore understandable that to achieve optimal results after ACR, MAT is recommended if a functional meniscus is absent.[8] To date, there are no randomized clinical studies to show that this is required; the ability to perform such a study would be extremely difficult because of the heterogeneity among this patient population. However, large case series of combined ARC and MAT have repeatedly shown

satisfactory outcomes over the short and medium term and continue to warrant further investigation.[10]

4. *IMREF recommends caution if performing MAT in knees with moderate to severe radiographic OA (ie, Kellgren-Lawrence grade ≥3).*

The chance for clinically successful MAT may be compromised by the presence of OA and should be thought of as a relative contraindication. Some studies report promising clinical and functional results even in arthritic knees. Stone et al[38] reported a mean graft survivorship of 12 years in patients with Outerbridge grade 3 and 4 chondral loss treated with MAT and cartilage repair. There was also a significant mean improvement in preoperative versus postoperative self-reported measures of pain, activity, and function. However, larger series and a number of meta-analyses have all demonstrated that poorer outcomes are expected in the face of OA, with graft survivorship particularly found to be adversely affected.[6,36]

In a select group of younger arthritic patients, in whom nonoperative measures have failed and no other surgical option exists, MAT can be thought of as a bridging solution[12]; however, patients should be aware of the higher reoperation rate and lower graft survivorship.

Graft Procurement and Preparation

5. *IMREF recommends nonirradiated frozen or viable meniscal allografts to be provided with the peripheral meniscotibial ligaments remaining intact.*

Currently, there are 4 storage methods for meniscal allografts: fresh viable grafts, fresh-frozen grafts, cryopreserved grafts, and lyophilized grafts. The IMREF survey found that 68% of surgeons prefer the use of fresh-frozen menisci, with 14% using viable grafts (Figure 2).

Fresh viable meniscal grafts may be the most ideal because they contain live chondrocytes. These cells help maintain the extracellular matrix, which may positively affect the mechanical properties of the meniscus.[46] Verdonk et al[42] demonstrated a high clinical success rate with fresh viable grafts, with a 10-year survivorship for medial and lateral grafts of 74.2% and 69.8%, respectively. On the other hand, the timing of the procurement and transplantation of fresh viable meniscal allografts can be challenging.[43] Verdonk and Kohn[45] have suggested that the "cold ischemia" time should be less than 24 hours, with the graft then stored at 4°C in a culture medium containing antibiotics and the patient's own serum up to 10 to 14 days without seriously affecting cell viability. Clinically, this poses logistical issues, because the short time window makes it difficult to transport and implant the fresh grafts into appropriately matched recipients. Compounding this, fresh viable grafts have been associated with a higher risk of disease transmission, because the foreshortened time window precludes some serological testing and chondrocyte-preservation strategies preclude sterilization.

Fresh-frozen grafts can be stored at −80°C for up to 5 years, which is one of the reasons they are the most commonly used meniscal allografts. This method involves placing the procured meniscus in a physiological solution with an antibiotic agent, followed by rapid freezing.[30] At the time of surgical implantation, the meniscal allograft is usually thawed in another antibiotic solution. A disadvantage of this storage method is that it results in negligible cell viability. However, it has advantages, including a lower risk of disease transmission due to secondary sterilization, simplicity, and relatively lower expense. Interestingly, the lack of cell viability has not been shown to adversely affect meniscal graft survival or clinical outcomes.[6,36]

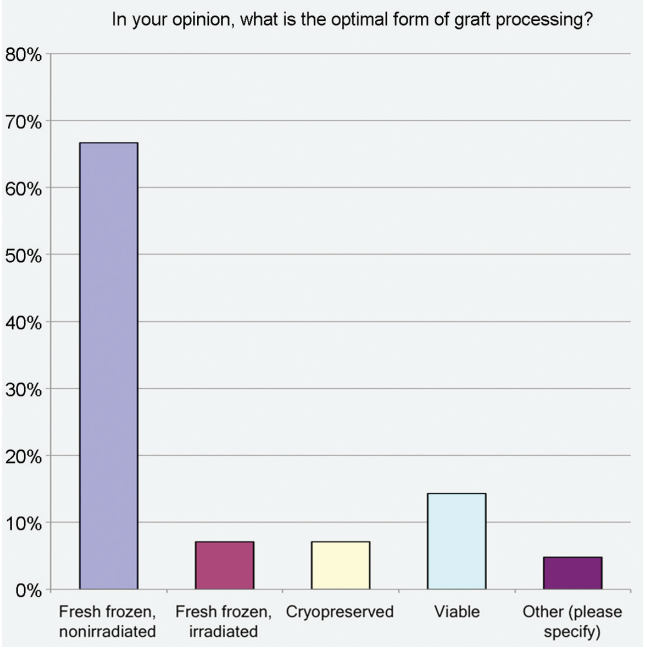

Figure 2. Survey response to optimal graft processing.

There are supporters of both viable grafts and frozen grafts. The importance of cell viability in meniscal allografts is unclear, and to date, no studies have demonstrated a clear advantage between the 2. The lower cost and logistic benefits of fresh-frozen grafts account for their greater popularity at most centers. Inferior clinical results have been reported with both cryopreserved grafts and lyophilized grafts, which may explain the lack of popularity within the IMREF group.[21] Furthermore, there is considerable variability in graft storage and sterilization, as exemplified in a recent systematic review by Matava.[21] In this review of 15 studies, 3 studies used fresh grafts, 7 used cryopreserved grafts, 4 used a mixture of storage methods, and 1 study did not provide the storage method. This review also looked at sterilization methods. In 4 studies, the grafts were sterilized with gamma irradiation, in 5 studies there was no secondary sterilization method used, and in 6 studies the sterilization method was not provided.

Finally, recent anatomic studies have shown the importance of the meniscotibial attachments of the medial meniscus,[35] which are hypothesized to aid in meniscal stability. Fifty-five percent of surgeons expressed a wish to preserve these tissues in the preparation of the allograft to allow for additional peripheral fixation. However, as yet, no study has shown that incorporating the meniscal

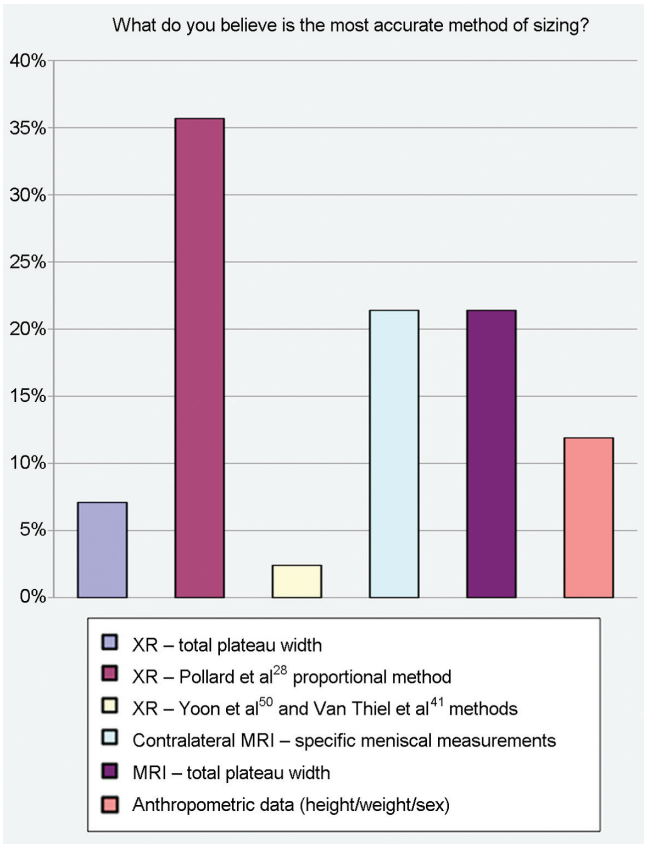

Figure 3. Survey response to graft sizing method. MRI, magnetic resonance imaging; XR, radiograph.

"skirt" tissue improves graft fixation and stability. As a result of the wishes from surgeons, IMREF suggests that tissue banks should preserve the meniscal skirt ligaments where possible, which will then allow the individual surgeons to either preserve them or remove at their own discretion.

6. *IMREF recommends the use of a quantitative method for sizing the patient for MAT, such as magnetic resonance imaging (MRI) or radiographic plateau width (Pollard et al[28]/Yoon et al[50]).*

A number of methods have been proposed to assess recipient meniscal measurements, but it is not clear which methods are the most accurate or reliable. Meniscal measurements obtained from magnification-corrected plain anteroposterior and lateral radiographic films, as proposed by Pollard et al,[28] are the most widely used, with 35% of the IMREF membership currently using this method. According to this method, the width of the meniscus is measured in the anteroposterior view by establishing the distance between 2 vertical lines perpendicular to the joint line: one tangential to the margin of the tibia metaphysis and the other between the medial and lateral tibial eminence in both knees. The length of the meniscus is then measured on the lateral radiographic view by establishing the size of the tibial plateau, and then a line is drawn at the level of the articular line between the anterior surface of the tibia above the tuberosity and a parallel line that is tangential to the posterior margin of the tibial plateau. The medial meniscus corresponds to 80% and the lateral meniscus to 70% of the measurement of the tibial plateau on the sagittal plane. Calibrators for correction of magnification are needed to correctly calculate the size. This method is still widely used; however, it has been shown to be less accurate when sizing the lateral meniscus.

To address this issue, Yoon et al[50] proposed a modification of this method based on a mathematical model to increase accuracy:

$$(0.52 \times \textit{length of the tibia plateau established by the Pollard method}) + 5.2.$$

Only 3% of the IMREF membership surveyed currently incorporates the Yoon et al modification.

A number of more recent studies using MRI have tried to establish a more geometrically accurate allograft size based on specific meniscus measurements.[11] MRI of the contralateral unaffected knee, although costly, may be useful in determining the required size, and it is a reproducible and accurate method of measuring both the width and length of both menisci.[49]

Other authors believe that anthropometric data can substitute for MRI in determining meniscal dimensions. Van Thiel et al[41] have proposed a multivariate regression formula using anthropometric data to establish the meniscal length and width using sex, weight, and height (when height is in centimeters, the coefficient has to be divided by 2.54).

$$\textit{Meniscus size} = [\textit{constant coefficient}] + [(\textit{coefficient of height} \times \textit{height})] + [(\textit{coefficient of weight} \times \textit{weight})]$$

Based on the IMREF survey, MRI is the most popular form of measurement after the Pollard method (36%). Twenty-one percent of surgeons currently use the contralateral MRI, with 21% using total plateau width on MRI. Only 12% of the group used anthropometric data (Figure 3).

Preoperative Planning

7. *Mechanical axis alignment should be evaluated when considering MAT.*
   - *Realignment osteotomy should be considered if there is mechanical axis deviation.*

Ninety-three percent of surgeons in the IMREF survey would elect to perform a realignment osteotomy if the mechanical axis was unfavorable for the ipsilateral compartment (Figure 4).

This is consistent with the literature, with many studies stating the use of concomitant osteotomy to optimize outcomes. Verdonk et al[44] highlighted that full restoration of

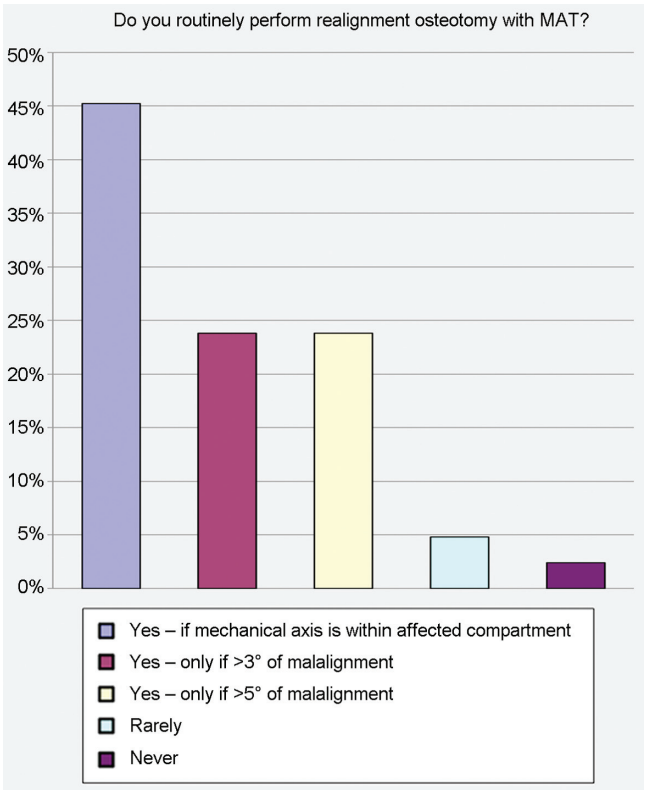

Figure 4. Survey response to performing realignment osteotomy. MAT, meniscal allograft transplant.

contact pressures after MAT has yet to be demonstrated in vitro. Van Thiel et al[40] observed that a 3° valgus correction of a neutrally aligned knee with concurrent medial MAT can decrease the peak and total medial compartment contact pressures significantly. This was seen without a corresponding increase in lateral peak pressures. Thus, this may be the only way to achieve normal contact pressures in MAT and suggests that there may be a biomechanical advantage to even mild degrees of correction, even in the neutrally aligned knee.

It is not clear from current studies whether combining high tibial osteotomy (HTO) with MAT will lead to longer term improvements in outcomes. In a 2011 meta-analysis, MAT was performed as an isolated procedure in only 36% of cases, with osteotomy performed as an associated procedure in 19% of cases, indicating that it is a common procedure in combination with MAT.[6] A number of clinical reports of MAT exist in the literature, the majority of which support the need for alignment correction. In 2002, van Arkel and de Boer[39] reported that patients with preoperative malalignment had poorer results; hence, MAT was then performed only in patients with a normally aligned knee. Verdonk et al[44] showed that MAT associated with HTO can have better outcomes than MAT alone. The overall failure rate within the published cohort was 18%; however, the MAT + HTO group had significantly better Hospital for Special Surgery (HSS) pain scores at final follow-up, while the Knee injury and Osteoarthritis Outcome Score (KOOS) results for all subscales were substantially higher for MAT + HTO compared with MAT (medial or lateral) alone. However, given these clinical benefits, axial alignment did not correlate with progression of cartilage degeneration or signal intensity on MRI.

Parker et al[27] demonstrated in an MRI study that HTO could slow the progression of cartilage loss and, in some circumstances, initiate the recovery of the articular surface. This was hypothesized to be secondary to an improved mechanical environment after HTO. It remains to be seen whether adding MAT could augment this process and add a secondary level of chondroprotection yet to be observed in clinical studies.

However, contrary to the above evidence, a study by Stone et al[37] of patients undergoing MAT with Outerbridge grade 3 or 4 degenerative changes demonstrated no improvement in MAT survival in patients with the addition of alignment correction or chondral procedures at the time of MAT. They found that axial malalignment of less than 7° did not affect MAT survival; however, severe malalignment (>7°) was addressed with osteotomy in the same study. It was acknowledged that the results of this study were contrary to the conventional teaching that osteotomy may reduce cartilage degeneration.

While clinical studies have shown the benefit of realignment osteotomy, no randomized comparative studies have been performed to ascertain whether the perceived benefit in changing alignment corresponds with a direct clinical benefit. Therefore, based on the evidence available, it is the recommendation of IMREF to consider realignment osteotomy in combination with MAT when the weightbearing axis falls within the affected compartment.

Surgical Technique

8. *Based on current evidence, IMREF accepts that there is no superiority of one surgical technique over another (bone vs soft tissue).*

Current practice within the IMREF group observed 74% of surgeons preferring to use bone fixation compared with 26% preferring soft tissue. Of those surgeons using bone fixation, the preference is for a slot/bone bridge technique on the lateral side, with bone plugs for the medial side.

While early biomechanical studies suggested that bone fixation was superior for MAT,[3] McDermott et al[23] showed that lateral meniscal allografts that were fixed only with sutures made for slightly higher articular surface contact pressure than when they had bone fixation—but the difference was small. In effect, therefore, there is possibly only a small advantage from adding bony fixation to suture fixation. Furthermore, other experimental studies have shown good healing of the transplanted allograft when both horns are sutured without bone plug fixation.[32] As a conclusion, no strong evidence currently exists to show the biomechanical advantage of either of the 2 techniques.

Recently, some clinical comparisons between both fixation methods have been published. In a prospective study of 88 MATs with a mean 5-year follow-up, the authors compared 33 of the grafts that were fixed with the suture-only technique versus the remaining 55 cases performed with

the bony-fixation method.[2] Both groups of patients were comparable in terms of age, sex, and radiographic and functional preoperative state. There was a significant improvement in the Lysholm, Tegner, and visual analog scale scores without differences between groups ($P = .28$), while the radiographic evaluation did not show any joint-space narrowing ($P = .34$). In the same group of patients, MRI evaluations were performed to determine the degree of meniscus extrusion.[1] In agreement with more recent data reported by De Coninck et al,[5] a higher percentage of extruded meniscal tissue in the suture-only technique ($P < .001$) was observed. More interesting, they found a complication rate of 33.3% in patients with the suture-only technique (2 arthrofibrosis, 2 infections, 7 graft tears), along with an allograft failure rate of 9%. In the group of patients who underwent MAT with the bony-fixation method, the complication rate was 16.4% (3 arthrofibrosis, 2 infections, 4 graft tears), with an allograft failure rate of 3.6%. It was concluded that MAT with either technique provided similar functional and radiographic results at midterm follow-up, but there was a considerably higher rate of complications in transplantations performed with the suture-only technique compared with those with bony fixation.[2]

In summary, while bony-fixation techniques may be associated with slightly superior biomechanical characteristics and less postoperative complications, no study has shown superiority between the 2 fixation techniques in terms of clinical outcome. As such, IMREF accepts that no single technique is superior to the other based on current evidence.

9. *At present, there is insufficient evidence to support the routine use of biologics during surgery to enhance graft healing and survival in MAT.*

The precise role of biologics for the augmentation of MAT has yet to be fully determined. Myriad possible options exist in the armamentarium for surgeons performing meniscal transplantation, including the addition of growth factors, gene transfer therapy, matrix metalloproteinase inhibition, host response modulation, and cell-based therapy.[9,15] Future work will ultimately need to translate the range of preclinical studies that have evaluated tissue engineering strategies for meniscal repair/regeneration, for possible use in augmentation of meniscal transplantation.

Assessment of Outcome

10. *IMREF recommends the following outcome scores for MAT as a minimum data set*:
    - *Disease specific: Western Ontario Meniscal Evaluation Tool (WOMET)*
    - *Region specific: KOOS*
    - *Activity: Marx Activity Rating Scale*
    - *Quality of life/utility measure: EuroQol 5 dimensions questionnaire (EQ-5D)*

The ideal patient-reported outcome measure (PROM) should be one that has been extensively tested in terms of its psychometric properties. It should be in widespread use to allow comparison and should have minimal respondent and administrator burden.

Like many other reconstructive surgeries of the knee joint, various subjective evaluation methods have been utilized in previous studies of MAT.[6,21,36] Included in these subjective evaluations are the Lysholm score, the KOOS, the Western Ontario and McMaster Universities Index, the International Knee Documentation Committee form, the Cincinnati Knee Rating System, the Tegner Activity Scale, the Knee Outcome Survey, and the Short Form–36.

Because of the wide variety of outcome scores available, IMREF has recommended a minimum data set to be collected so that patient cohorts may be studied and compared in the future. As such, IMREF has recommended 4 different outcome scores that incorporate a global assessment of the condition, including disease- and region-specific questionnaires, as well as an assessment of activity/function and an assessment of quality of life:

a. The KOOS is a region-specific score that is widely adopted and provides a measure of the general status of the knee. This is particularly important as MAT patients often have significant concomitant knee pathology. This instrument has face validity, has demonstrated construct validity and excellent test-retest reliability for each domain (range, 0.75-0.93), and has been shown to be responsive to change in patients with knee OA.[34]
b. The WOMET[13] is a disease-specific score that has been rigorously validated and, as such, is most sensitive to change for patients with meniscal pathology.
c. The Marx Activity Rating Scale[20] is a 4-item activity rating scale. Patients are asked to rate how often they were able to perform each activity (eg, running, cutting, decelerating, and pivoting) in their most healthy and active state.
d. The EQ-5D is a quality of life and utilities tool that is easy to use and becoming more universally adopted internationally.[29]

11. *IMREF suggests surgeons performing MAT consider MRI to assess graft healing and position at 1 and 2 years postoperatively.*

Just over 50% of respondents performed routine MRI in the postoperative assessment of MAT patients. Of those, 72% performed the MRI at 12 months and 43% at 2 years postoperatively. However, this still leaves 48% of surgeons who would not use MRI as a routine assessment tool.

Because of the complexity of concomitant pathology that is often associated with patients undergoing MAT, it can be unclear whether favorable clinical outcomes result from MAT or other procedures such as realignment osteotomy. Therefore, objective evaluation tools such as MRI are important to assess the status of individual anatomic structures. With the development of the high-resolution 3.0-T MRI machines, more accurate and abundant information on intrameniscal signals, morphologic analysis, shrinkage, extrusion, and the degeneration of adjacent articular cartilage can now be obtained.

Graft extrusion is drawing increasing attention because extruded allografts may not normalize or positively affect

load distribution compared with nonextruded grafts. Furthermore, it is an objective measure that can be used repeatedly and compared among different studies. Extrusion is defined with reference to the tibial articular margin and width of the allograft meniscus, with relative percentage extrusion calculated. MRI readily reveals the exact amount of extrusion most effectively in coronal images. Three-dimensional interpretation is also possible with the assistance of sagittal and axial images. However, the clinical importance of extrusion is not yet clear. No studies have demonstrated the relationship between extrusion and clinical outcomes in short- or intermediate-term follow-up. In a longitudinal observational study, subjects who showed extrusion before 6 weeks after MAT remained extruded until 1 year after MAT, and the amount of extrusion did not increase significantly over 1 year.[16] In contrast, subjects who did not show extrusion before 6 weeks remained unextruded until 1 year. This study suggests that extrusion is a consequence of preoperative or intraoperative events, such as the sizing of the allograft or tunnel placement for the allograft, and is probably not related to the postoperative course. It also shows that MRI findings can affect and change clinical practice and surgical techniques, even in short-term follow-up.

IMREF recognizes that MRI also has some drawbacks. First, it is vulnerable to various artefacts, especially metallic debris and implants. Second, it is difficult to interpret various intrameniscal signal intensities, and their clinical relevance remains unknown. As seen after the repair of torn native menisci, various intrameniscal signal intensities can be observed after MAT. Third, MRI cannot provide the dynamic evaluation of allografts allowing range of motion or weightbearing conditions. Finally, MRI is an expensive evaluation method with remaining concerns for how imaging may affect clinical decision making independent of the presence or absence of symptoms. It may therefore be difficult to justify in an asymptomatic patient. However, the use of an objective measure to assess structural properties of the graft after implantation and at follow-up can be seen as essential to continue to improve surgical technique and ultimately improve graft function and longer term outcomes.

12. *IMREF does not recommend routine second-look arthroscopy after MAT.*

As described above, the use of an objective measure of graft morphology is an important surrogate of graft function. While the MRI is safe and noninvasive, second-look arthroscopy confers a perioperative risk to the patient with limited benefit to the asymptomatic patient. As a result, IMREF does not recommend second-look arthroscopy as a routine method of analyzing graft integrity.

13. *IMREF has defined mechanical failure of MAT as complete removal of the graft including arthroplasty. No consensus was reached on the definition of clinical failure but should include MRI and PROMs.*

Different definitions of MAT failure have been used in the literature when describing graft survivorship. Hard endpoints such as graft removal or conversion to arthroplasty are easy to define; however, no consensus could be reached as to the definition of clinical failure. A return to the presurgery status or worse, as measured by PROM, may be an option. The use of MRI as an objective measure can also be used, such as the presence of graft extrusion. However, given the lack of clinical correlation between MRI and PROM, this remains contentious. Interestingly, only 20% of IMREF surgeons felt that the presence of extrusion equated to a failed MAT, as often patients continue to report good clinical outcome even in the face of an extruded graft.[2]

14. *IMREF supports the development of an international MAT registry.*

It is clear that while MAT has been in clinical practice for more than 30 years, there is still much to learn to optimize patient outcomes and graft survivorship. Because of the heterogeneous population that requires MAT, and the relatively low numbers of cases being performed in individual centers, it is paramount that a registry be developed so that a larger data set may be captured, collecting the same prospective, objective clinical data and PROMs so that indications and nuances of surgical technique and rehabilitation may be examined.

The utilization of international registries, such as the Norwegian, Swedish, and Danish ligament registries; the Multicenter Orthopaedic Outcomes Network prospective cohort; and the national joint registries of Scandinavia, United Kingdom, and Australia, has illustrated how powerful a tool this can be.

The IMREF members were poled on whether they would support a registry for MAT and voted with a 98% positive vote in favor. Plans are therefore ongoing to generate a registry database with funding support from allied organizations.

Rehabilitation and Return to Sport

15. *IMREF recommends an individualized return-to-sport prescription based upon functional assessment by a multidisciplinary team and advises caution with regard to return to contact sport.*

The principle behind rehabilitation after MAT is to facilitate the return of knee function while respecting the healing process of the allograft tissue. It is accepted that a meniscal allograft is unable to completely restore the native biological and biomechanical properties of the meniscus, and it is also accepted that the exact loading and shear forces on a meniscus during activities are not fully quantified.[25] Consequently, there is variability between different rehabilitation programs regarding the safety and timing of early weightbearing, range of motion, and the long-term ability to return to high-impact sports.[14] Specific rehabilitation guidelines are outside the scope of this particular consensus document. However, it is generally agreed upon that rehabilitation after MAT requires a personalized, goal-oriented approach, recognizing that the main objective is the avoidance of wear-related

problems in the future. The desired level of functional activity needs to be considered against the expected durability and longevity of the meniscal graft. Patients will regain strength and limb control and acquire functional skills at a different rate to one another. Flexibility of the rehabilitation program to account for this variation, while respecting the normal healing process of the meniscal allograft, ensures that a successful outcome can be achieved.

A rehabilitation program and return-to-sport prescription are designed to consist of 4 stages, with each stage requiring specific goals to be met before progression to the next stage is allowed. Approximate time frames may be provided for guidance, but it should be stressed to patients that the length of their individual rehabilitation may differ, particularly if additional surgery has been performed. The 4 main stages of rehabilitation and return to sport are as follows:

Stage 1: Early restorative phase (0-8 weeks)
Stage 2: Strength and conditioning phase (2-6 months)
Stage 3: Functional rehabilitation progression phase (6-9 months)
Stage 4: Sport-specific training and return to sport ($\geq$9 months)

Thus far, MAT in athletes has been recommended with caution because of concerns for high failure rates and long recovery times. Traditionally this has been particularly important in professional athletes. However, Marcacci et al[19] recently reported a series of 12 professional soccer players who underwent MAT either in isolation or in a combined procedure, in which 92% returned to playing soccer professionally. At 36-month follow-up, 9 players (75%) were still playing professionally (Tegner, 10) and 2 were playing semiprofessionally (Tegner, 9). The mean time for returning to competition was 10.5 months. All clinical scores improved. These data may allow us to extend the indications in competitive sportsmen, even though the risk for mid- or long-term failure may be higher. High-level clinical data to evaluate the long-term results of MAT in athletes are still not available.

CONCLUSION

The recommendations from IMREF have been generated and debated among an international group of key opinion leaders in the field of MAT. While they are not prescriptive in terms of how an individual should perform MAT, they were designed to provide a reference point for surgeons with the aim of optimizing current practice and setting a benchmark for future research. MAT has been in clinical practice for more than 30 years, and the indications and techniques have evolved accordingly. While no longer believed to be investigational or experimental, it is clear that significant improvement in clinical outcome may be achieved with a coordinated and integrated approach from interested clinicians currently practicing in this field.

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