Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 8 Issue 11 November 2025

Research Article

Surgical Treatment of Symptomatic Young Patient with Total Meniscectomy. Does Meniscal Allograft Transplantation can Improve Function, Pain Relief, Return to Sports and will it Survive? A Retrospective Study About 56 Cases

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Received: August 25, 2025

Published: October 16, 2025

Abstract

Young patients who underwent total or subtotal meniscectomy can leads to a painful, stiff, and incommoding knee. Those patients could suffer from early onset osteoarthritis. When medical treatment can't achieve awaited results, a surgery can be needed. We choose to study 56 patients with painful meniscectomized knees who underwent arthroscopic meniscal allograft transplantation. A total of 45 lateral and 11 medial meniscal allografts were transplanted. Follow up was done between 1 to 10 years (between 2012 and 2022). The studied outcomes where functional scores (Lysholm, IKDC), visual analogic scale (VAS), return to sport (RTS) range of motion (ROM), rate of reintervention and imaging survivorship (MRI or ArthroCT). Main patients had an improvement of function, a better ROM, pain relief, high RTS and a good survivorship was found. We performed an isolated MAT in 35,7% of the cases. The MAT was associated in 37,5% of the cases with external condylar microfractures, 7,1% with internal condylar microfractures, 3,7% with MACI procedure of the external condyle, 1,8% with MACI procedure of the internal condyle, 5,4% with ACL reconstruction, 3,6% with mosaicplasty and 5,3% with hardware removal. IKDC score at 1 year was 72,3 (SD 7,4), at 2 years was 78,6 (SD 6,4), at 5 years was 72,1 (SD 14,2) and at 10 years was 63,4 (SD 17,2). Lysholm score at 1 year was 83,4 (SD 6,1), at 2 years was 88,9 (SD 6,9), at 5 years was 86,4 (SD 14,7) and at 10 years was 72,8 (SD 25,3). Mean VAS was 2,4/10 (SD 2,8) while 50% of the patient had a VAS at 1/10 or lower. We compared function results of isolated MAT and associated procedures. Isolated MAT provided slightly better results that associated surgeries. Mean IKDC for isolated MAT was 71,2 while mean IKDC for associated surgeries was 69,6. Mean Lysholm for isolated MAT was 88 while mean Lysholm for associated surgeries was 80,8. Reintervention was needed in 5 patients and 1 patient was converted to total knee arthroplasty. Following a Kaplan- Meier curve, survivorship at 10 years was 9,57 +/- 0,25 years. Mean increased ROM was 6,3° and 69,6% patients returned to sport. Isolated MAT had 80% RTS while combinate MAT had 63% RTS. Comparation of meniscal survivorship depending on the presence or absence of chondropathy has shown no significant difference. Despite a substantial improvement of the MAT in all fields, some patients had residual symptoms and disabilities. MAT is an encouraging treatment for the young meniscectomized patient. It provides favorable improvement of function, pain and RTS in well selected patients.

Keywords: Meniscal Allograft Transplantation; Painful Total Meniscectomy; Arthroscopic Surgery; Sport Surgery

Abbreviations

ACL: Anterior Cruciate Ligament; JBJS: The Journal of Bone and Joint Surgery; MAT: Meniscal Allograft Transplantation; MEEXL: Eternal Left Meniscus; MEEXR: External Right Meniscus; MEING: Internal Left Meniscus; MEINR: Internal Right Meniscus; MSC: Mesenchymal Stem Cells; OA: Osteoarthritis; PCL: Posterior Cruciate Ligament; PROMs: Patient-Reported Outcomes Measures PRP: platelet-rich plasma; RTS: Return to Sport; TKR: Total Knee Replacement; VAS: Visual Analogic Scale

Introduction

Definition and background

The meniscus is a C-shaped fibrocartilaginous structure that plays an important function by increasing the contact surface, reducing peak stress, harmonizing load distribution, absorbing forces, but also lubricating the joint and nourishing the cartilage [1]. Through its attachment to the tibia and femur, it plays a role in stabilizing the joint surfaces. The medial meniscus plays a secondary role by opposing the anterior translational movements of the tibia. The lateral meniscus plays a role in joint alignment. From a microscopic point of view, the meniscus has numerous randomly arranged channels that allow the passage of fluid and nutrients from depth to the surface. All this helps maintain homeostasis of a healthy joint. The main problem with meniscectomy is cartilage deterioration and progression to osteoarthritis that causes pain. Considering all these essential functions, the orthopedic community put emphasis on meniscus preservation techniques [2]. Despite the famous "save the meniscus" adage, several young patients can find themselves with a symptomatic meniscal deficient knee compartment.

Anatomy and histology

The medial meniscus is divided into five anatomical zones (Figure 1a), ranging from the anterior root to the posterior horn. Each zone has specific characteristics and ligament attachments, contributing to the stability and load distribution within the medial compartment of the knee. Zone 4, located between the medial collateral ligament (MCL) and the posterior horn, is particularly prone to injuries due to the orientation of fibers in its structural organization. As for the lateral meniscus, it starts beneath the tibial attachment of the anterior cruciate ligament (ACL) and continues to its posterior horn. Its important attachments include the menisco-fibular ligament (MFIB ligament) and the meniscofemoral ligaments (MFL), which help stabilize the meniscus during knee flexion and extension movements (Figure 1b).

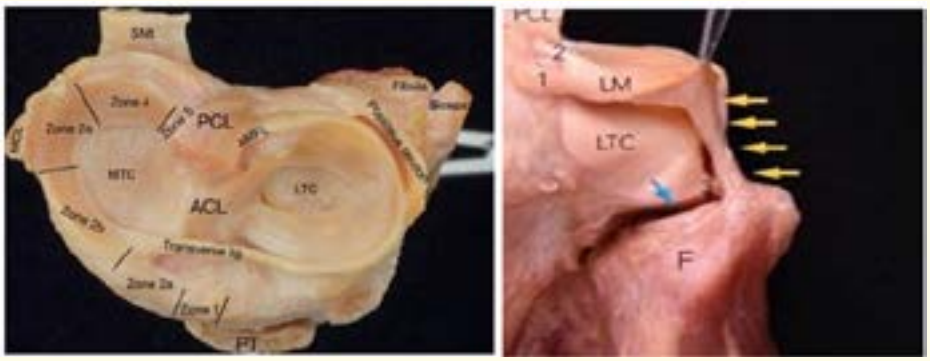

Figure 1: a: Cadaveric left knee with meniscal anatomy [3]; b: Cadaveric right knee, MFIB ligament.

The menisci are primarily composed of water (65 to 75%) and type 1 collagen (20 to 25%), with additional elements such as proteoglycans, glycoproteins, and elastin. This composition endows the menisci with elastic and viscous properties, thus facilitating an adaptive response to pressure, with the ability to initially withstand and subsequently reduce pressure. The extracellular matrix of the menisci is synthesized by fibro chondrocytes, which are essential for the normal function and maintenance of the tissue. The outer surface is mainly made up of fibroblasts, while the interior is dominated by chondrocytes. The structure of the menisci is also characterized by the orientation of its collagen fibers, divided into three layers: a superficial layer with randomly oriented fibers to reduce friction, a middle layer of radial fibers that help disperse axial loads, and a deep layer of circumferential fibers to support tension (Figure 2). The radial fibers are crucial as they connect the circumferential fibers, thus preventing longitudinal tears.

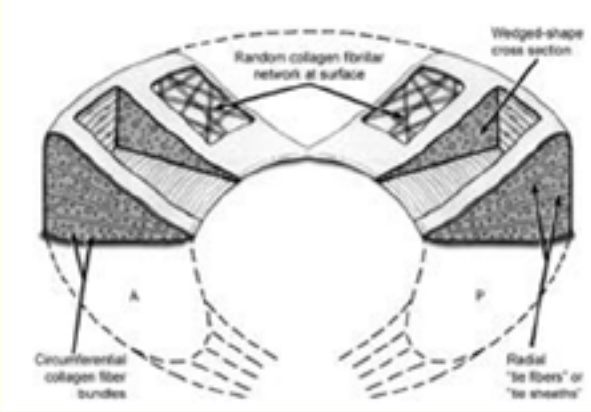

Figure 2: Collagen fiber ultrastructure and orientation within the meniscus [4].

Vascularization is supplied from medial, lateral, and middle geniculate arteries thanks to a capillary plexus which infiltrates the meniscus at the periphery and forms anastomoses with the popliteal artery (Figure 3). It is divided into three zones: the peripherical "red-red" zone, which is well irrigated, the central "red-white" with intermediate irrigation and the central avascular "white-white", also very prone to lesions [5].

Meniscal injuries

Meniscal injuries represent 11% of all knee pathologies, being particularly common among young athletes, often due to non-contact injuries such as cuts, decelerations, or landings from jumps. These lesions required a precise diagnosis and appropriate treatment [7,8]. Practicing sports such as basketball, skiing, rugby or running increases the risk of these injuries, underlining the importance of prevention programs. Other risk factors include older age (over 60), male gender and certain physical occupations involving deep flexion [9]. Meniscus tears occur most commonly in those aged 20 to 39, with a prevalence of lateral tears in younger people and medial tears in older people, indicating a possible degenerative origin. There is also a strong association between anterior cruciate ligament (ACL) injuries and lateral meniscus injuries. In children, meniscal injuries are usually caused by sports trauma, discoid meniscus, or meniscal cysts [10].

Consequences of meniscectomy

Literature has shown that total meniscectomy leads to premature development of osteoarthritis. The JBJS published in 2012 a prospective 40 years (the longest follow-up by 2024) follow-up study over 313 adolescents who had total meniscectomy [11]. They all were symptomatic as defined by the KOOS score. The clinical findings were also confirmed by the X-ray joint narrowing.

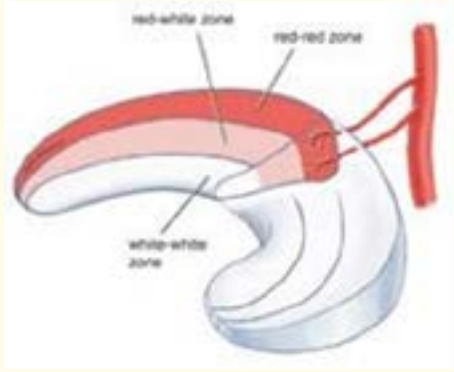

Figure 3: Vascular distribution in the meniscus [6].

The frequency of TKR represents à 132-fold increase in comparing with the age- ethnicity matched population. This long-term study confirms that meniscectomy will almost certainly lead to OA and that the meniscus is therefore chondroprotective [11-13]. In medial meniscectomy we observe an 50% increased load associated with majorated internal rotation and translation of the tibia [12,14]. In lateral meniscectomy we observe an 70% increased load associated with loss of congruency and increased (Figure 4) [7,12,14]. Women who undergo meniscectomy had lower satisfaction, more pain and worse recovery than men [15-18].

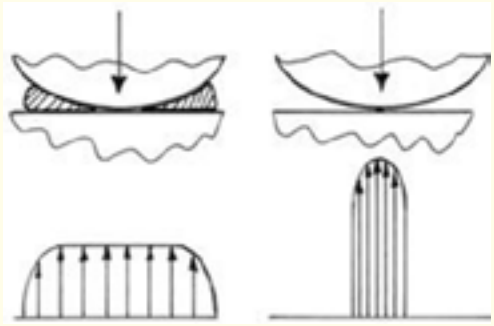

Figure 4: Demonstration of the focally increased peak contact pressures resulting from meniscectomy [14].

Treatment options for post-meniscectomy pain

Predisposing factors as frontal deformations, ligamentous laxity or existing chondropathy can also worsen osteoarthritis development and need to be treated as well [19]. The non-operative modality of treatments is limited in terms of its results (such as physiotherapy, injections, NSAIDs, unloading braces, weight loss or insoles) [12]. Injection of Hyaluronic acid, corticosteroids, PRP or MSC showed no evidence at this time [20-22]. Non-surgical management of a symptomatic meniscectomized knee has also very low evidence. Those treatments cannot slow down nor prevent progression of osteoarthritis. Osteotomies around the knee should be done when indicated. This is a treatment that must be considered complementary and can be combined. Surgical treatments include MAT and meniscal scaffolds. Scaffolds are meniscus-like fibrocartilaginous tissue made for segmental defect. Two options are available: CMI (collagen meniscus implant, Stryker, USA) which is

made of bovine collagen and the Actifit (Orteq Sports Medicine, UK) which is made of synthetic polyurethane. They are only made for "horns and rim preserved" cases. Very few clinical studies showed a 5-year follow- up with short term pain relief and function improvement [23]. Implant extrusion was very high within 4 years (8 of 14) in a prospective study [24]. However, there are no RCT's nor longer follow-up to evaluate the effect of those scaffolds and further studies are necessary [12]. Historically Lexer in 1916 performed an autogenous fat tissue interposition giving poor results [25]. The first MAT was done in 1984 by Milachowski in Munich. Recently the JBJS published a pilot RCT (which is the only one at this time) comparing MAT versus personalized physiotherapy. This is the first study, best evidence quality, that argues in favor to the effectiveness of MAT [12,26]. Our study aimed to assess arthroscopic MAT as it seems to be one of the unique options to prevent osteoarthritis, improve function and pain so as return to sports on those patients. Chondroprotective effect of the MAT seems to be a plausible hypothesis by presumably recreating native meniscus role even it is unlikely protecting it as the native meniscus.

Material and Methods

Patients and methods

56 young patients (<50 years) patients were treated with arthroscopic MAT. All surgeries were performed by one senior knee surgeon (AD) from 2012 to 2012 with a minimal follow-up of 2 years and maximal follow up of 10 years. We performed an isolated MAT in 35,7% of the cases. The MAT was associated in 37,5% of the cases with external condylar microfractures, 7,1% with internal condylar microfractures, 3,7% with MACI procedure of the external condyle, 1,8% with MACI procedure of the internal condyle, 5,4% with ACL reconstruction, 3,6% with mosaicplasty and 5,3% with hardware removal. Meniscal allografts were deep frozen and provided by KUL bank tissue (Leuven, Belgium) and UCL bank tissue (Brussels, Belgium) universities. The study was approved by the Ethical committee of the Saint-Luc University Clinics in Brussels, CHIREC Delta hospital in Brussels and Saint Jean clinic in Brussels (Registration No. B403201523492). Indications for surgery were young patients (<50). They had more than 1 year history of painful knee after total or subtotal meniscectomy with failure of non-operative treatment. Their knees were all stable and had physiological HKA angle. We included only focal Outterbridge (from grade I to IV). We analyzed the following data to describe our results: age at transplant, lateral or medial meniscus, gender, side, stage of focal chondropathy (according to Kellgrene and Lawrence) and sporting demand (high, amateur and no demand). The analysis also considers preoperative amplitude and etiology of the lesion (meniscectomy, discoid meniscus…). We specified the surgical history carried out on the knee and whether there was an associated procedure with this transplantation. Preoperative assessment included a goniometry, an anteroposterior weight bearing radiographic view, tomodensitometry for graft sizing, MRI or arthrotomodensitometry for meniscal, cartilage and subchondral evaluation. The sizing was calculated based on the size of the corresponding tibial plateau: 80% of the tibial plateau for medial meniscus and 70% for the lateral meniscus. Exclusion criteria were high BMI > 35, extended and plurifocal cartilage damages and infection history. We chose as scores the "international knee documentation committee" (IKDC) questionnaire, Lysholm, RTS and a VAS scale. We analyzed the scores collected at the last follow-up: 1 year, 2 years, 5 years, and 10 years. The Lysholm score is categorized into 4 groups: excellent (95-100), good (84-94), satisfactory (65-83) and poor (<65). MRI analysis at last follow up was performed by 2 different viewers. Our radiological criteria were two binary outcomes: absence or presence of the graft and extrusion or not of it.

Surgical procedure

All patients had full arthroscopic with soft tissue technique surgery. "Bone plugs" is also a technique that uses 2 bone plugs at the horns insertions. No patient was operated on using the bone block technique. Patient is positioned in dorsal decubitus with motorized knee holder. Two classical antero lateral and antero medial portals were performed with a 2cm extension depending on external or internal transplantation to facilitate the graft insertion. The recipient site (meniscal rim) is shaved until bleeding is obtained. The meniscus is marked with "Anterior, medial and posterior" signalization (Figure 5).

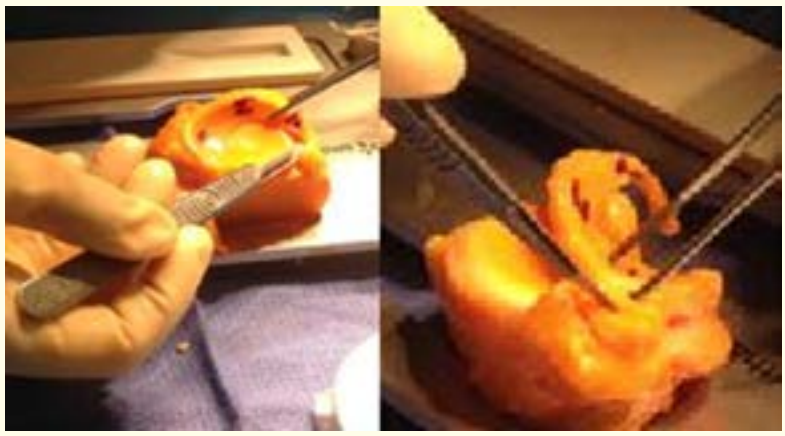

Figure 5: Preparation of the meniscal allograft.

The surgeon puts 2 traction sutures on the anterior and posterior meniscus's horns (Figure 6).

Two 4,5mm tunnels are drilled at the anatomic horn insertion as in a "double root lesion repair". The graft is inserted and pulled down by the 2 horns traction sutures (Figure 7).Then we perform 3 or 4 outsides sutures (medial and anterior horn) and 10 to 12 all inside sutures (Fasftix 360°, Smith and Nephew, USA). Micro fracture in the notch is done to provide a better healing (Figure 8).Rehabilitation protocol was 6 weeks of non-weight bearing period with a 4-week period limited to 90° of flexion physiotherapy. Isolated surgery lasts between 60 to 90 minutes and requires 1 night of hospitalization. Physiotherapy consisted of active mobilization, joint range of motion recovery, proprioception and strengthening of the knee muscles. Sport activities were allowed after 9-12 months depending on the evolution.

Figure 6: Marked allograft with 2 traction sutures at anterior and posterior horn.

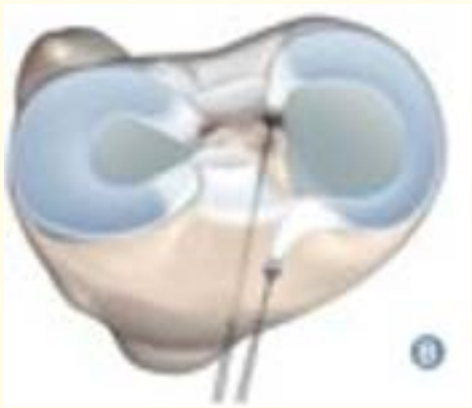

Figure 7: Schematic description of horns fixation.

Statistical analysis

SPSS version 27 (IBM, Armonk, USA) and the Microsoft Excel were our software for the statistical analysis. All our data were subject to univariate/multivariate analysis to establish predictive criteria for success. We choose to analyze the PROMs with boxplots. We used a Kaplan-Meier for MAT survivorship analysis.

Results

We have 76.8% men (43) and 23.2% women (13) so a ratio of 4/1. The average age is 32.4 years with a standard deviation of 8.5 years (between 15 and 49 years). The average follow-up was 6.5 +/- 3.6 years. All patients presented as their main complaint knee pain at rest or during exercise, most of which occurred after meniscectomy. Lateral meniscus transplantation predominated with 80.4% (45) compared to 19.6% (11) for the medial meniscus. Concerning the operated side there is a slight predominance for the right side 57.1%. Among these patients, 25.5% (14) had a high sporting demand, 54.5% (30) had a so-called recreational sporting demand and 20% (11) had no sporting demand. Concerning the etiology, 92.9% (52) of the patients had undergone successive meniscectomies, 3.6% (2) resulted from a discoid meniscus, 1.8% (1) the consequence of a chronic torn of the ACL and 1.8% (1) degenerative meniscopathy. 30% (17) of patients presented a slight valgus morphotype (2° to 7°), 14.2% were in slight varus (2° to 6°) and 55.8% had no axial deformity. The average preoperative flexion amplitude was 128.8° with a standard deviation of 4.9°. The known history of the knees and the etiology are given more precisely in table 1.

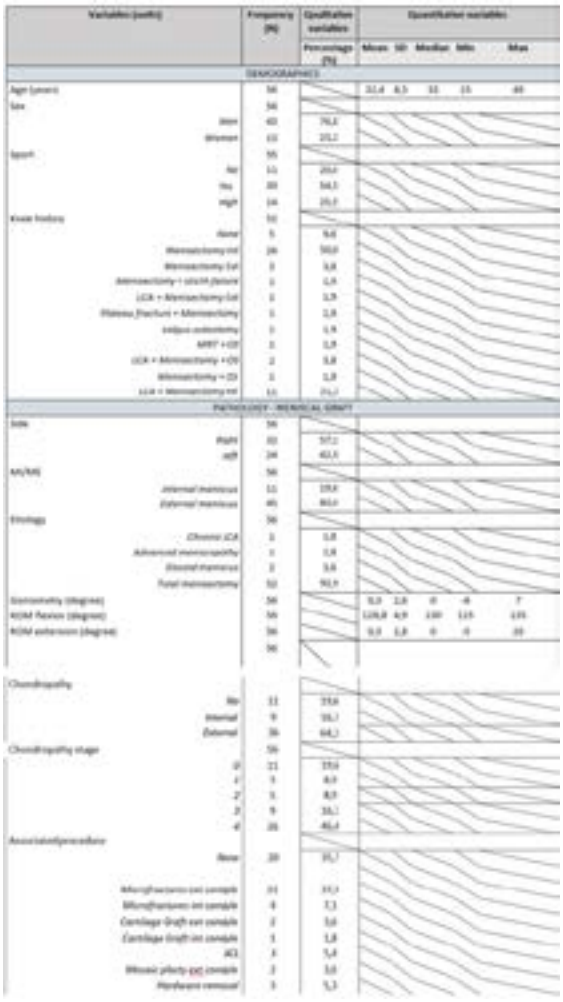

Table 1: Descriptive statistics.

The stage of chondropathy was classified according to the Kellgren and Lawrence classification, described in table 1. Most patients (46.4%) presented with stage IV focal chondropathy, explaining the painful symptoms. The compartment most often concerned was the external compartment (64.3%) rather than the internal (16%). 19.6% did not have preoperative chondropathy, 8.9% had grade I focal chondropathy, 8.9% had grade II focal chondropathy and 16.1% had grade III focal chondropathy. We observed an improvement in knee ROM after the MAT equivalent to 6.3° (135.1-128.8) in flexion and 0.7° in extension. The graft was isolated in 35.7% of cases. In 37.5% of cases there was a micro-fracture of the external condyle. This finding is logical given most external grafts. Here are the other associated procedures and their frequencies: 7.1% of micro-fractures of the internal condyle, 3.6% of cartilage graft of the external condyle, 1.8% of cartilage graft of the internal condyle, 5.4% of anterior cruciate ligament reconstruction, 3.6% mosaicplasty and 5.3% material removal. Kaplan-Meier curve analysis was performed to visualize the graft survival rate. The definition of survival was established as the number of years after which reoperation was necessary. The average graft survival is 9.57 +/- 0.25 years. In 5 patients, reoperation was necessary after extrusion of the graft. For one, it involves a TKR at 10 years and for another, it involves a review of ACL plasty at 5 years after the transplant. For other patients, these are interventions linked to trauma experienced on the knee but not linked to the graft. The comparison between the graft survival rate in patients with chondropathy and patients with intact cartilage does not show a significant difference (p-value 0.223). The same is true when comparing graft survival in patients with internal chondropathy compared to the external compartment (p-value 0.071). The overall survival rate and the survival rate according to chondropathy were illustrated in the table 2 as a Kaplan-Meier curve (Table 2-4).

The data collected are based on patient self-assessment of the function found in the operated knee, the pain felt and the level of activity they can carry out since the transplant. Also, when they wished, they were allowed to testify about their personal feelings since the operation. For the IKDC, Lysholm, VAS and RTS, patients were asked to answer the questionnaires at the last follow-up (Table 5).

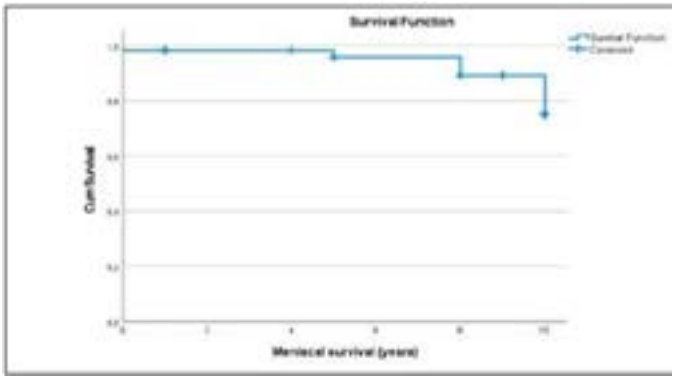

Table 2: Kaplan-Meier graft survivorship.

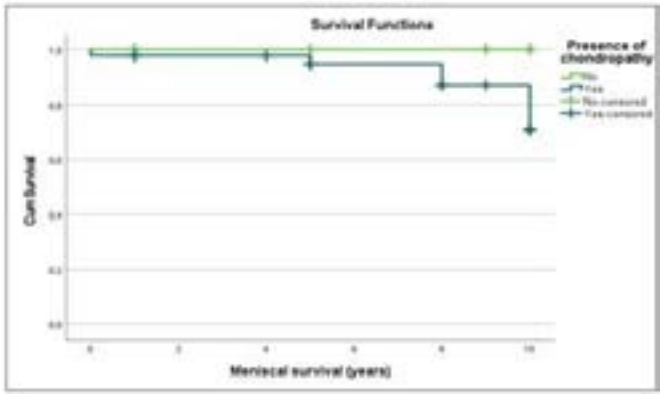

Table 3: Kaplan-Meier survivorship depending on pre-operative chondropathy.

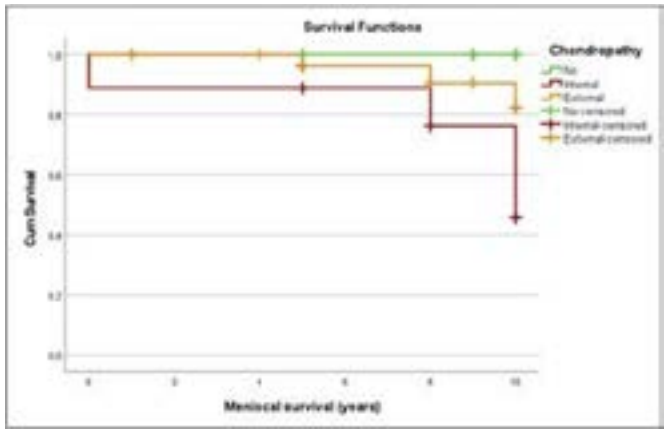

Table 4: Kaplan-Meier survivorship depending on pre-operative lateral or medial chondropathy.

Variables (units)	Frequency (N)	Qualitative variables	Quantitative variables				
		Percentage (%)	Mean	SD	Median	Min	Max
FOLLOW-UP							
ROM flexion post-surgery (degree)	56		135,1	6,8	135	100	145
ROM extension post-surgery (degree)	56		-0,4	1,3	0	-5	0
IKDC 1 year	10		72,3	7,4	73,0	59,0	80,0
IKDC 2 years	8		78,6	6,4	78,0	71,0	88,0
IKDC 5 years	14		72,1	14,2	69,0	42,5	91,0
IKDC 10 years	26		63,4	17,2	67,4	26,4	95,0
Lysholm 1 year	12		83,4	6,1	85	71	94
Lysholm 2 years	7		88,9	6,9	90	81	98
Lysholm 5 years	14		86,4	14,7	95,0	56	100
Lysholm 10 years	26		72,8	25,3	82	22	99
VAS	55		2,4	2,8	1	0	10
RTS	56						
No	17	30,4					
Yes	39	69,6					
Meniscal_survival (years)	53		6,5	3,6	8	1	10
Redo	56						
No	54	96,4					
Yes	2	3,6					

Table 5: Score IKDC, Lysholm and VAS at 1, 2, 5 and 10 years.

The IKDC at 1 year was was 72,3 (SD 7,4), at 2 years was 78,6 (SD 6,4), at 5 years was 72,1 (SD 14,2) and at 10 years was 63,4 (SD 17,2) (Table 6). Mean IKDC at last follow-up was 70 +/- 11. However, it appears that there is a large variability between patients. It should be noted that for the group of results at 2 years, the average is better (IKDC 78.6 +/- 6.4 and Lysholm 88,9 +/- 6,9). This is also the group with the least data. Three groups of patients tend to dissociate from each other. In one group, patients who no longer feel any pain. In another group, patients who maintain constant pain but who describe it as bearable or rather as a nuisance. And then, there are patients who describe the inconstant occurrence of pain and which they describe as very severe or even unbearable. For the first groups, pain tends to decrease and remain low for up to 10 years post-transplant. On the other hand, for patients who feel severe pain, it does not improve or even gets worse at 1, 5 and 10 years. The pain score nevertheless remains largely encouraging with an overall VAS of 2.4/10 with a median of 1/10. Concerning the function of the knee before and after the transplant, 42 patients described regaining better function of their knee allowing them to perform most activities of daily living, 8 maintained mild to moderate discomfort in activities of daily living and 5 retain significant and disabling discomfort. However, some patients say they avoid squatting, squatting, and jumping because this could cause pain and don't feel at ease doing it.

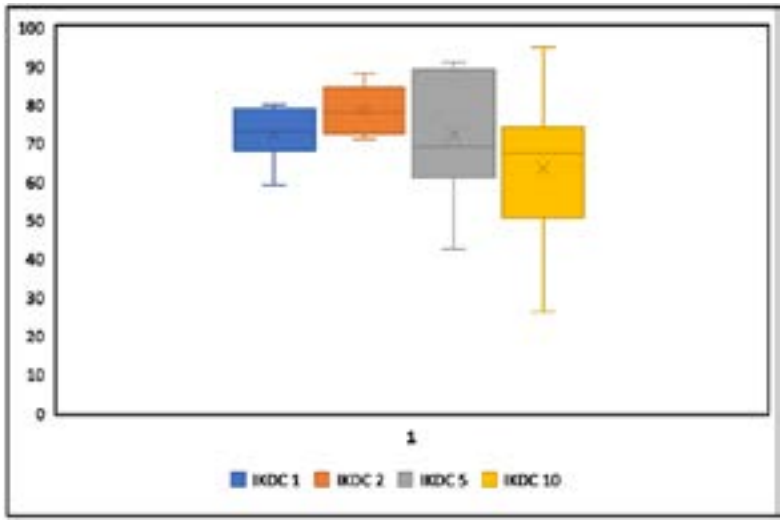

Table 6: Boxplot score IKDC (1 year, 2 years, 5 years, 10 years).

Lysholm score at 1 year was 83,4 (SD 6,1), at 2 years was 88,9 (SD 6,9), at 5 years was 86,4 (SD 14,7) and at 10 years was 72,8 (SD 25,3) (Table 7). Mean Lysholm was 84,4 +/- 13 at lats follow-up. As for the IKDC score, it remains similar between the groups except for the 2-year group where it is higher but for which there is less data. It also appears that the variability of results within the same group is significant. The collection of data makes it possible to clarify that most patients can walk without using crutches or aids very early. Most report knowing how to go up and down stairs without problems. Few patients report sensations of swelling or blockage. The common complaint among dissatisfied patients relates to pain and the inability to perform extreme flexions. Here again 3 different groups are formed, those who have never had pain after the transplant, those who have residual discomfort and those whose pain has never improved.

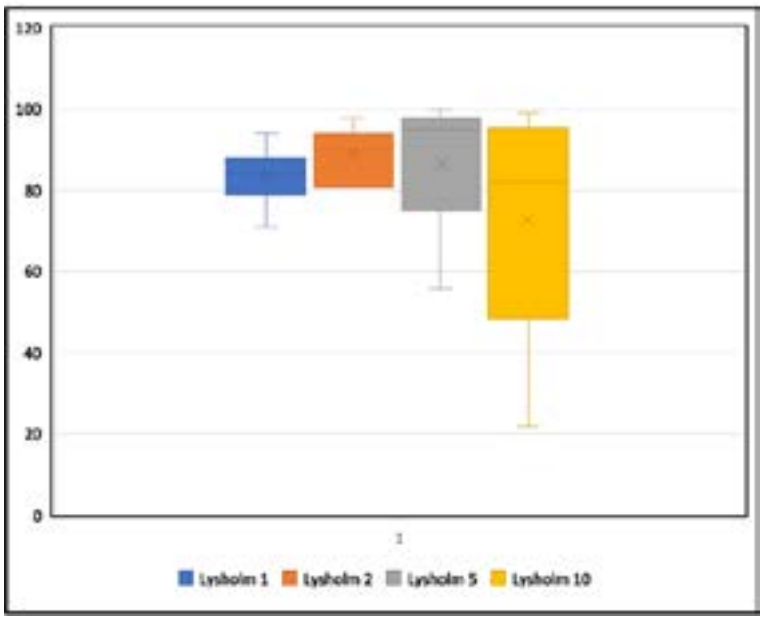

Table 7: Boxplot score Lysholm (1 year, 2 years, 5 years, 10 years).

The RTS shows that 70 % of patients were able to resume their sporting activity. As said previously, 14 of the patients had a high sporting demand and decided to have surgery to continue their sporting activity and all were able to resume it. Among them we include a competitive tennis player, a high-level padel player, a patient who enjoys running and obstacle courses, a patient who was able to complete the 20km of Brussels after MAT as well as other who were able to continue swimming and skiing. For intermediate level athletes, many had to adapt the type of sport they practiced. Running and football remain the sports posing the most problems because they are impact sports. However, most patients reported taking the time to practice a regular activity such as indoor sports or fitness. Regarding survival, we were able to analyze 18 images with follow-up of 10 years. 1 patient had to be converted to TKR. 2 patients in whom the graft had almost completely disappeared with poor functional results. The 8-year survival rate is 83,3% at 10 years. Results comparable to the literature. On 26 images (MRI and ArthroCT) > 5 years of follow-up we observed 8 cases of extrusion with no links to poor results. The VAS was collected at the time of the last follow-up and shows that the average pain is 2.4 +/- 2.8. Half of the patients had a pain level at 0 and below 1. Patient testimony reveals that many have pain caused by their work. Most often it is prolonged standing that remains problematic. A patient who was a baker and pastry chef had recourse to professional retrain-

ing and now does office work. Two patients continue their work despite the pain: a bookseller and a pharmacist who had no other choice but to work on their feet all day. One patient was a cleaning technician and is currently unable to work due to pain. Several exceptions should be noted, a mover and an STIB employee who were able to return to work thanks to MAT despite the physical nature of their job. We also wanted to compare the functional results, pain and RTS depending on whether the graft was isolated or combined with other procedures. The average IKDC for an isolated TMA was 71 vs 69 for an associated procedure. The average Lysholm for an isolated TMA was 88 vs 81 for an associated procedure. Regarding the RTS, 80% of isolated MAT returned to sport vs. 63% for associated actions. Pain was also on average lower (1.8) in the isolated MAT group vs (2.8) in the associated procedure group. Isolated MAT provides best results when performed alone. This may be an argument in favor of early intervention before the damage secondary to meniscectomy is too advanced.

The following images are pre-operative and post-operative MRI'S (Figure 9).

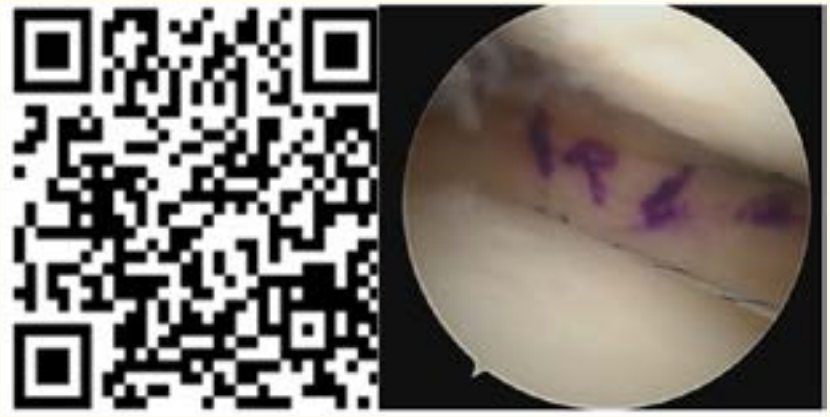

Figure 8: Meniscal allograft after transplantation.

Please scan this QR-code for viewing an illustrating video of MAT (all credits to: Lourdes medical associate, (2019, November 11). Arthroscopic Medial Meniscal Transplant Using Multiple Fixation Techniques [Video]. YouTube. https://www.youtube.com/watch?v=Nypt_DqCs5c

Figure 9: a: Failure of discoid meniscus suture (16y old). b: Follow up at 2 year. c: Arthroscopic view of this lateral MAT. d: Lateral meniscectomy, preoperative. e: Arthroscopic view after MAT. f: 1,5 year follow up (ACL combined). g: Cyclops removal and 2nd look arthroscopy.

Discussion

Even if MAT no longer appears to be an experimental surgery [15,19,27-32], it is difficult to establish clear guidelines. Indeed, we lack very long-term studies (>15 years). The comparison becomes perilous as there are so many variables to consider: many associated procedures, different preservation techniques, different surgical techniques, and different PROMS.

If meniscus is chondroprotective, is the MAT also chondroprotective?

Studies have largely proven that the meniscus is chondroprotective [7,11-13]. Meniscectomy almost always resulted in rapid destruction of the cartilage. This destruction was most documented by the reduction of the joint space. If we assume that MAT improves function and reduces pain, then it is likely that the logical link between this intervention and this outcome is cartilage protection. A systematic review was published by ESSKA in 2015 with the question: does MAT protect the cartilage? The review analyzed 38 studies with 1056 MAT as well as its influence on the joint space in MRI and standard radiography [13]. During an average follow- up of 4.5 years in 11 studies there was 0.0032mm of joint spacing loss (Table 8). The hypothesis of the protective role of MAT on cartilage remains unestablished but plausible. Nuance is made on its probable inferiority compared to the native meniscus, which seems logical.

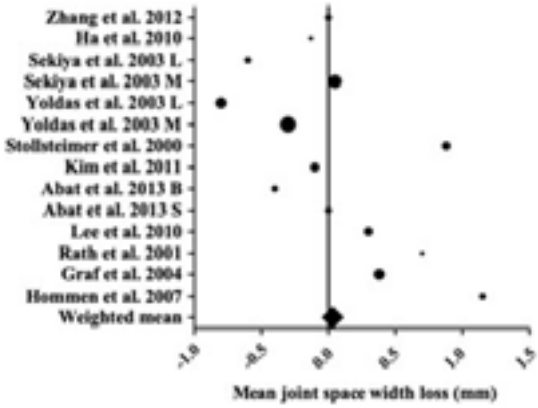

Table 8: Mean joint space loss, systematic review, ESSKA 2015.

Fresh versus frozen MAT?

This topic is also highly dependent on the availability of tissue banks. Frozen grafts are more widely available because they can be stored for up to 5 years and can be of several sizes. Fresh grafts are available approximately 14 days after collection and can only be stored for a maximum of 1 month. Fresh transplants pose serious challenges (availability, difficult conservation method and significant cost). Their supposed superiority due to a higher number of viable cells at the time of transplantation remains controversial [33]. A systematic review published by ESSKA in 2014 concerning the biological properties of the allograft, of which here are the highlighted points. Regardless of preservation, donor cells decline and are recolonized by host cells from the synovium. Freezing alters the collagen structure and causes apoptosis. Here too, an important bias is that we do not choose the quality of the graft before even preserving it. The evolution of these therefore becomes highly unpredictable [34]. In vitro, it was demonstrated that fresh menisci incubated for 15 days in a cell culture solution (with donor serum) continued to synthesize their extracellular matrix [35]. A Japanese team is currently analyzing the effect of cell-based injection therapy [36].

Graft shrinkage and extrusion

Extrusion and shrinkage of the graft is very often noted during medium and long-term follow- up of MAT. This finding is more often present in deep frozen and gamma-irradiated grafts but less in

fresh grafts [32]. It has been shown that there is no clinical correlation to a poor outcome [13,32,37]. Our study also draws a parallel with this observation without predicting a bad result in the event of extrusion/shrinkage. Indeed, on 26 images > 5 years of follow-up we observed 8 cases of extrusion. Recently, a technique called capsulodesis was described reducing this meniscal extrusion, making the menisco-capsular junction more rigid using two tunnels fixing the capsule to the tibial plateau (Figure 10) [38]. In terms of functional results, there were no differences between groups at a 7-year follow-up.

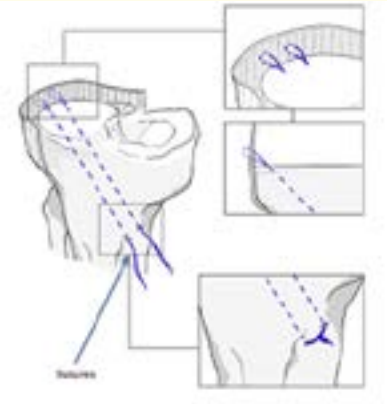

Figure 10: Capsulodesis technique described in tissular MAT [38,39].

Biological considerations

Most biological and histological studies on meniscus transplantation concern animals [32]. Those studies demonstrated adequate graft healing, incorporation, and highly important role of the synovium responsible of repopulation. The analogy to humans is difficult mainly because of our bipedal nature and the increased load on our lower limbs compared to quadrupeds. Two studies were able to perform biopsies (meniscus and synovial) 16 and 12 months respectively after MAT. The anatomopathological and histochemical results showed an incomplete repopulation of viable fibroblasts (from synovium) active in the remodeling of the extracellular matrix [6]. Incorporation of the graft was normally done at the junction. However, there was almost no chondrocyte colonization in the graft [32].

Graft sizing and graft fixation

There are two techniques for MAT fixation. Note that there is also a technique called bone bridge which is only appliable for the external meniscus because its medial version would hinder the ACL. The first where the meniscal allograft is fixed via two bone tunnels, as described above, a technique that we favor. The second, called bone plugs, or two bone cores, are taken and then incorporated into two corresponding tunnels in the recipient knee. The bone plugs technique reports less extrusion (26%) than the tissue method (38%) [32]. However, we saw that this extrusion had no clinical significance. The bone plug restores biomechanics closest to normal in cadaveric studies [40,41]. The tissue method has the advantage of better adaptation of the graft to the recipient site, it is more manageable and allows it to be applied as we see fit, if the size is approximatively correct. Indeed, the menisci that we receive are never perfectly adapted to the patient, the bone method does not forgive in the event of a non-anatomical position of the horns, and it becomes difficult to adapt this meniscus to the patient. However, systematic reviews and a prospective study have not shown superiority of one technique over another in terms of functional results or resistance to force [31,32,42]. Regarding size, most surgeons use CT scans or MRIs. Standard radiography also allows transplant planning but with less precision than other modalities [43]. An im-

portant planning parameter is the width which is more important than the length. The length of the meniscus corresponds to 80% and 70% of the medial and lateral tibial plateau, respectively [44]. It has also been described that height can be accurately predicted by considering height, weight and sex using regressive models [45].

Middle and long-term outcomes

Through meta-analyses, systematic reviews, and clinical studies it appears that MAT is an effective intervention in young meniscectomized symptomatic patients. An RCT has currently been underway since 2018 and its preliminary results have been published [26]. This study published in the JBJS compared on the one hand young meniscectomized patients who were treated with a personalized physiotherapy protocol and on the other hand those who benefited from MAT. The results have argued in favor of MAT in the short and medium term to date. We will have to wait for long-term results and multicenter RCTs. A meta-analysis investigated medium and long-term survival in 2017 [28]. Regarding medium- and short-term survival we find between 85.8 (medial meniscus) and 89.2% (lateral meniscus) between 5 and 10 years of follow-up. These figures decrease to around 50% when the follow up reaches 15 years. The associated gestures were not necessarily predictive of failure and poorer results, but the literature lacks data [46,19]. Concerning RTS, a majority, i.e. 2/3, of operated patients return to their sporting activity [30]. Our study also reports a similar rate with an RTS of 70%. Let us remember the nuance that 30% were unable to return to sport and that patients report a certain apprehension with extreme flexions as well as discomfort which can be significant. The total conversion rate into TKR in the long term (10-15 years) varies between 10 to 29% [19]. MAT can be considered as an effective treatment in young meniscectomized patients who are refractory to medical treatment [13,15,19,27,28,30,46].

MCID (the minimal clinically important difference)

The minimal clinically important difference (MCID) is important for evaluating the clinical significance of surgical interventions through PROMs. MCID represents the smallest change in outcome measures perceived as minor or insignificant score variations. By setting MCID thresholds, researchers and clinicians can more precisely assess surgical treatment effects, guiding evidence based clinical decisions and enhancing patient-centered care. Additionally, MCID facilitates clear communication with patients, aiding in shared decision-making based on meaningful outcome results. In the era of modern medicine where many pathologies are completely cured, it can be difficult for the patient to understand whether they remain in pain or discomfort. The notion of MCID is particularly important in TMA. In fact, the indications and these surgeries remain rare. The rarity of the pathology causes a small volume of data to be analyzed to draw up guidelines. Therefore, these MCIDs represent clinical change, even small ones, that can be significant and improve their daily life. MCIDs in MAT were studied. It was concluded that evaluating PROMs in MAT respecting the MCID is important to evaluate outcome. It is therefore agreed that the results of the PROMs (IKDC, Lysholm and VAS) reflect a real clinical improvement thanks to MAT [29].

Limits

Our study has limitations: no prospective or randomized design, different stages of pre- operative chondropathy.

Conclusion

In the middle to long term, the result of this study shows encouraging and good results in terms of graft survival, reduction of pain, return to sport and improvement of function. Remember that this is a “rescue” surgery for patients for whom therapeutic options have been exhausted. However, good patient selection is strictly necessary to obtain better results. The success of this intervention requires an experienced arthroscopist (learning curve), the availability of the graft and a rigorous operative indication. In terms of patient selection, the best candidates for MAT are patients under 50 years of age whose knees are normally aligned, stable and with a focal chondropathy stage less than or equal to II. The associated procedures (on the cartilage, the ACL, etc.) are sometimes necessary and can be performed during MAT. When the MAT is isolated, better results are obtained. Which suggests we could consider it before the damage is significant. Let’s keep in mind that this is a rare situation for which MAT is a reasonable solution. Our community emphasizes meniscal preservation techniques (increasing number of meniscal sutures). The main objective being to slow the development of osteoarthritic disease and the use of prosthetic surgery in young patients.

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