Collagen Meniscus Implant: Basic Science, Technique and Results

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Contents

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55.1 Introduction

Menisci are fibrocartilage structures situated in the knee joint between the femoral and tibial condyles. They are made up of collagen fibres, mostly type I, that form a tridimensional net structure combining radial and circumferential fibres, and some cells are inside this net. They have the ability to synthesize the extracellular matrix. The meniscus has multiple functions. It contributes to the nutrition and lubrication of the joint structures, has some role in proprioception, assists in the joint stabilization and is very important for shock absorption and force transmission during weight-bearing [16]. The circumferential fibres resist hoop stresses, while the radial fibres handle shear stresses [17]. All these significant functions explain the importance of the menisci in protecting joint cartilage.

The number of meniscus-related surgeries rises in Western countries every year due to ageing and having a more active population [39]. The total number of meniscal surgeries is estimated to be about 1 million annually in the USA and 400,000 in Europe [38]. Most meniscal lesions affect the white-on-white zone of the meniscus, making them unsuitable for meniscal suturing. These lesions must be treated by partial or subtotal meniscectomy.

Although most of the patients treated for a meniscal lesion with meniscectomy experience pain relief and functional improvement, there is an increase in contact stresses on the tibial plateau [26], which is

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proportional to the amount of removed meniscal tissue [1, 19, 37]. The radiographic signs of joint degeneration after meniscectomy (joint line narrowing and flattened femoral condyles) as well as its long-term adverse effects have been widely recognized since the last century [5]. After meniscectomy, some patients complain of pain in the affected joint line. Hede et al. [13] found that 14 % of the meniscectomized patients have fair to poor Lysholm scores at 7.8 years after surgery. Therefore, surgeons should attempt meniscal repair whenever feasible and resect as little meniscal tissue as possible in irreparable meniscal tears [2]. Over the last decade, the concept of meniscal substitution, either with meniscal allografts or with meniscal implants, has been developed. It has been further refined in an effort to preserve the meniscal's functions in symptomatic postmeniscectomized knees. The aim of this chapter is to review the current concepts and results of the Collagen Meniscus Implant (CMI), the first meniscal implant developed and used.

55.2 Basic Science

55.2.1 Development of the Collagen Meniscus Implant (CMI)

Although allografts used for meniscal substitution have shown good early results [17], information about the long-term effects of this procedure and particularly its protective effect on cartilage is scarce [7, 32]. The accepted indication for meniscal allografts is a complete absence of the meniscus. Therefore, a partial defect is not an appropriate indication for this type of surgery. Furthermore, the limited availability of meniscal allografts and potential infectious disease transmission has motivated some authors to explore the possibilities of scaffold-guided meniscal tissue regeneration.

The CMI (Ivy Sports Medicine, Gräfelfing, Germany) was developed by ReGen Biologics (Hackensack, New Jersey, EEUU). It is a highly porous scaffold (not a prosthetic device) made up of type I collagen fibres from purified bovine

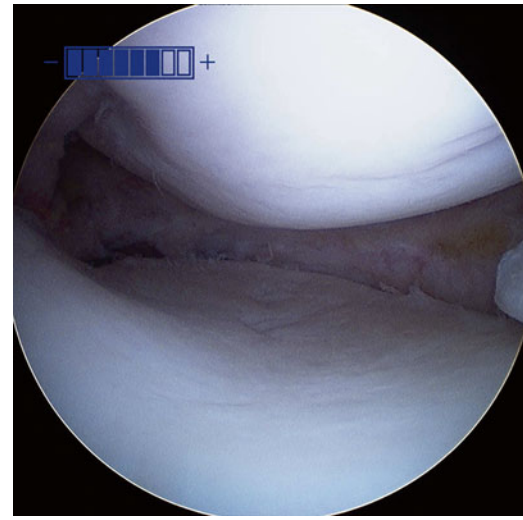

Fig. 55.1 Arthroscopic view of the medial compartment of the right knee. A meniscal defect extending to the red-red zone with the margins trimmed square can be seen

Achilles tendon. The tendon tissue is minced, and the collagen fibres are purified by using various chemical treatments to remove non-collagenous proteins and lipids. Next, the purified collagen fibres are placed in hyaluronic acid and chondroitin sulphate to well and then homogenized. The swollen collagen fibres plus the glycosaminoglycans are co-precipitated with the addition of ammonium hydroxide. The precipitated fibres are dehydrated, manually oriented in a mould, lyophilized and chemically cross-linked. Finally, terminal sterilization is performed with gamma-irradiation [35].

The scaffold is 7.5 cm long and 1 cm wide, which is quite close to the anatomical shape and size of the human menisci, and has a density of 0.20 g/cm^3. The implant is designed to be trimmed and adapted to the meniscal defect during surgery. Based on previous experimental studies, its porosity was planned to favour filling in by host cells [18]. The CMI has no cytotoxicity, pyrogenicity or carcinogenicity. In addition, the product is bioresorbable, and most of the scaffold has been proven to be resorbed over a 12–18-month period [26] (Figs. 55.1 and 55.2).

The medial CMI has been available for use in Europe since the beginning of this century. However, the Food and Drug Administration has

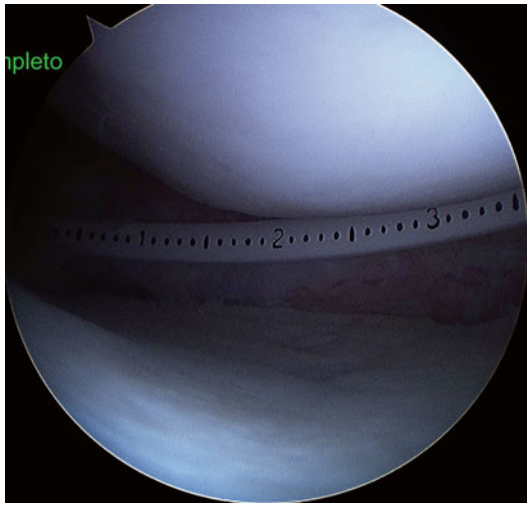

Fig. 55.2 Measurement of the meniscal defect using a graduated Teflon rod

not again granted permission for use in the USA. This was after a short-term approval period in December 2008 and a posterior rescission in October 2010 [16]. More recently, in 2006, the lateral CMI received the CE mark.

55.2.2 CMI Animal Studies

The CMI was first attempted in immature pigs and mature dogs to replace defects caused by meniscectomy. The results demonstrated that the collagen-based scaffold is compatible with meniscal fibrochondrocytes, which are able to grow both in vitro and in vivo, promoting meniscal regeneration in an immature pig. It may also induce regeneration greater than 60 % of the meniscus tissue defect in a mature dog model [35]. Similar results were later found in canine models, with collagen scaffold integration and active angiogenesis in most of the cases [10]. CMI does not cause articular cartilage damage in animal experimentation, unlike other experimental polymer implants [9].

Some animal investigations have suggested that collagen scaffolds could be seeded with cells [15, 25]. In a study done on Merino sheep, the scaffolds seeded with fibrochondrocytes prevented the invasion of the scaffold by inflammatory and reparatory cells, which led to larger and better vascularized menisci with improved biomechanical properties [21]. Furthermore, the seeded collagen scaffolds promoted the generation of meniscal tissue even in experimental lesions created in the white-white zone of the meniscus [27]. Recently, a technique of seeding collagen scaffolds with human bone marrow stem cells has been described [28].

Table 55.1 Contraindications to CMI

Allergies to collagen
Allergies to bovine products
Inflammatory arthritis
Degenerative changes on X-ray greater than Ahlback grade I
Full-thickness chondral lesions (Outerbridge grade IV)
Osteonecrosis in the knee
Obesity
Posterior cruciate ligament insufficiency
Aged patients (older than 50–55 years)
Acute meniscal lesion suitable for meniscal suture
Small meniscal lesions leading to <25 % of the meniscal tissue loss
Malalignment of the lower limb assessed with the weight-bearing axis (unless it is corrected concomitantly with an osteotomy)
Anterior cruciate ligament insufficiency (unless it is treated when the CMI is implanted)
Systemic or local infection
Pregnancy

55.3 CMI Surgical Technique

The indications for CMI are irreparable meniscal tears leading to a meniscal tissue loss greater than 25 % in cases with intact anterior and posterior horn attachments as well as an intact meniscal rim over the entire circumference of the involved meniscus [43].

Contraindications to the use of CMI are shown in Table 55.1.

55.3.1 Medial CMI Technique

The patient is positioned supine on the surgical table. The affected limb is placed with the knee flexed at 90° and the thigh well beyond the table

hinge. This position provides access to the posteromedial corner of the knee, which can be useful in the subsequent suturing procedure. The authors use a lateral post placed some 5–10 cm proximal to the patella and apply a valgus load to open up the medial compartment. The use of a tourniquet is optional although recommended if an inside-out suture technique is used [24].

Standard knee arthroscopy anterolateral and anteromedial portals are established to perform a thorough joint exploration. Accessory portals may be used to obtain a better access for the suturing procedure. In acute cases, meniscal suture repair should be done whenever possible. If it is not possible and/or in chronic cases, the damaged meniscus is debrided until healthy tissue is reached. For that purpose, a combination of straight and angled basket punches as well as a 4.0 mm motorized shaver is useful. Since the objective is to obtain a press-fit meniscus implant, the anterior and posterior horns should be squared off to adjust the CMI with maximum congruence.

When the medial compartment is too tight, a partial release of the medial collateral ligament permits both proper visualization and good access to the most posterior aspect of the compartment. This can easily be done with multiple outside-in needle punctures while applying valgus stress (pie-crusting technique).

The prepared site should extend into the vascular zone of the meniscus to guarantee an adequate blood supply. If the outer limit of the prepared meniscal rim is in the red-white zone, this can be accomplished by making puncture holes in the meniscal rim from the inside with a microfracture awl or with an 18-gauge spinal needle from outside the joint. However, since this technique may impair the collagen network in the remnant meniscus, an alternative method is high-frequency trephination. High-frequency trephination uses radiofrequency to create an area of synovial necrosis (approximately 30 μ) adjacent to the implant that is promptly substituted by a newly formed and more vascular synovial layer at the periphery of the scaffold [24].

After preparation of the anterior and posterior horns and the rim, the length of the meniscal defect is carefully measured using a special Teflon ruler. The anteromedial portal should be enlarged up to 2 cm using a vertical cut in order to facilitate the delivery of the implant.

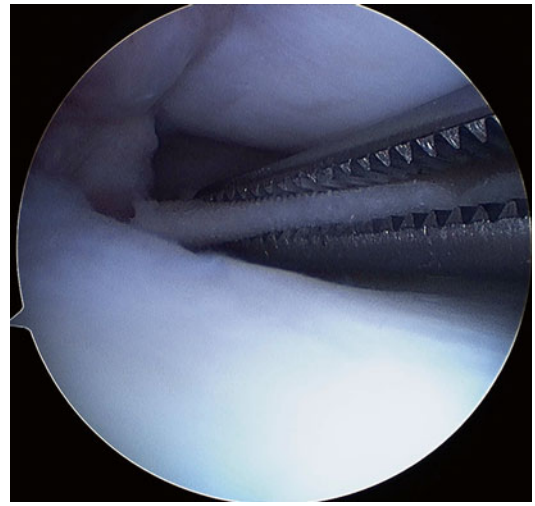

Fig. 55.3 Dry insertion of a medial CMI® using a vascular clamp

The CMI is trimmed to the appropriate size, oversized by 10 %, to achieve a perfect press fit in the meniscal defect. The average length of the required implant ranged from 36 to 48 mm in several previous studies [4, 23, 43]. Although previous rehydration and insertion into a specific delivery cannula was advised in the past, the tailored implant can be simply mounted on a curved vascular clamp and directly inserted into the joint after stopping the inflow to avoid the flip-out of the CMI into the joint (dry insertion) (Fig. 55.3).

When the CMI is in place, it is sutured to the host meniscus remnant with 2.0 nonabsorbable sutures by using an inside-out technique or all-inside sutures. If an inside-out technique is chosen, the sutures are retrieved through a 4 cm long posterior-medial approach made parallel to the posterior margin of the medial collateral ligament. A spoon retractor is placed as deeply as possible between the posterior capsule and the medial gastrocnemius to retrieve the needles. For this purpose, an inside-out suture repair system equipped with zone-specific cannulas, like the SharpShooter® Tissue Repair System (ReGen Biologics, 545 Penobscot Drive, Redwood City, CA), is convenient. The CMI is sutured to the remaining meniscus rim with

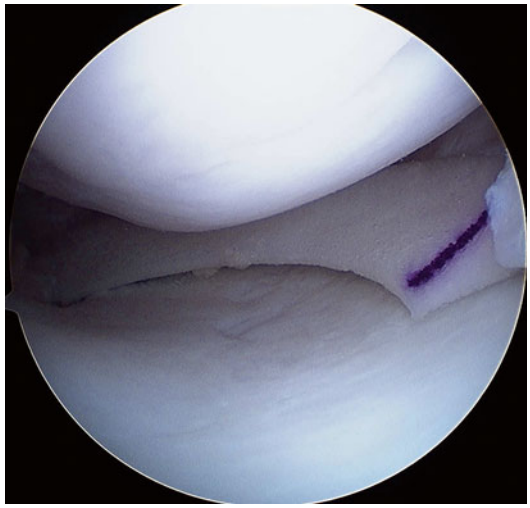

Fig. 55.4 CMI® in place ready for fixation. Note the good press fit achieved at both ends

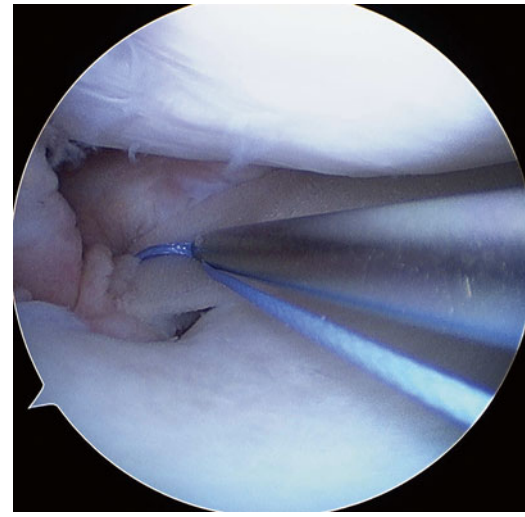

Fig. 55.5 Suturing the implant to the remnants of the posterior meniscal horn using a horizontal stitch

2.0 braided polyester vertical mattress sutures placed approximately 5 mm apart. The anterior and posterior ends of the implant are secured to the meniscal horns with horizontal sutures. All the suture ends are knotted over the capsule outside the joint. Alternatively, all-inside sutures, like the FasT-Fix® Suture System (Smith & Nephew, Inc., Andover, MA), can also be used. They are faster and avoid the need for any additional approach to retrieve sutures. Regardless the suturing technique, vertical mattress sutures are preferred to minimize the risk of implant damage. However, horizontal sutures are chosen for the anterior and posterior fixation points. It is likely that a distance of 10 mm between sutures is adequate to properly fix the CMI when using all-inside sutures [22] (Figs. 55.4, 55.5 and 55.6).

No drains should be placed in the knee joint after surgery, particularly if an isolated meniscus procedure has been performed, as postoperative hemarthrosis might create an appropriate biological environment to start the healing process of the CMI [24].

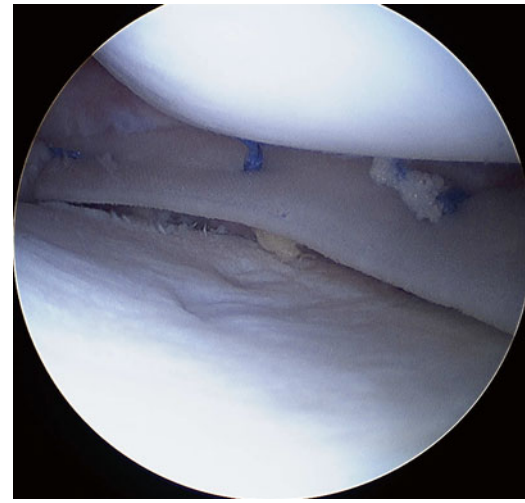

Fig. 55.6 Fixation completed using a combination of vertical mattress sutures placed every approximately 10 mm along the implant and horizontal sutures at the horns

55.3.2 Lateral CMI Technique

The basic sequence of steps for repairing the lateral CMI is similar to that for the medial one. The suitability of the procedure should be carefully considered if there is complete disruption of the meniscal rim at the popliteal hiatus. When no rim is present, the newly formed meniscus tends to extrude under loading conditions. In addition, the use of sutures across the popliteus tendon cannot be recommended in the case of substitution because the physiological micro motion of this tendon might damage the CMI scaffold.

Although, Zaffagnini et al. [42] did not consider a deficient popliteal hiatus as an absolute contraindication for the use of a lateral CMI, an oversized implant that is not fixed at the hiatus seems to be the most prudent recommendation if the surgeon decides to use a CMI in this particular situation.

The patient is placed supine on the operating table. The affected leg is positioned with the knee hanging free at 90° of flexion, with the contralateral leg fully extended on the surgical table. This allows the leg to be flexed over the contralateral knee in a figure-of-four position. This position applies a varus force across the knee, opening up the lateral compartment, and provides easier access to the posterolateral corner.

Standard anterolateral and anteromedial portals are established, and a complete revision of the joint is performed. As in the medial compartment, damaged meniscus debridement is completed if meniscal suturing is not possible. The O-shape of the lateral meniscus might make a square cut more difficult, particularly at the anterior horn. After preparation of the meniscal bed and trephination, the anterolateral portal is enlarged to accommodate the surgeon's index finger [24]. This simple manoeuvre will facilitate the delivery of the lateral CMI. A probe can be used to manipulate the implant into its correct position.

Although an inside-out suture technique is also feasible in this compartment, through a 4 cm longitudinal incision just posterior to the lateral collateral ligament, the all-inside technique is preferable due to the proximity of the peroneal nerve and the popliteal artery. Some inside-out sutures or even the addition of an outside-in stitch to fix the anterior horn might also be useful [24].

55.3.3 Combined Surgeries

Since medial meniscectomy in an anterior cruciateligament (ACL)-deficient knee may lead to asignificant increase in laxity the combined reconstruction of both structures is particularly recommended as it may create a more favourable environment for meniscus healing. Based on the existing literature, the combination of both procedures is very frequent (27 % in the series of [30], 52 % in the series of [23] and up to 67 % in the series of [14]).

When combining both procedures, some especial tips should be considered. When applying a valgus load to an ACL-deficient knee to open up the medial compartment, the tendency of the tibial plateau to glide forward may add some more difficulty. The recommended sequence for combined ACL-CMI reconstruction is as follows: the meniscus bed is prepared first and then the femoral and tibial tunnels for ACL are drilled. Next, the ACL graft is passed and fixed at the femoral site. At that point, the CMI is inserted and sutured, and, finally, the ACL graft is fixed at the tibial site at 20° of flexion [22].

Any angular deformity of the involved knee greater than 5° in the preoperative long-length weight-bearing X-ray (or greater than 3° with respect to the contralateral limb) should be corrected before or, preferably, concurrently with CMI implantation. According to the general guidelines, varus malalignment should be corrected by a high tibial osteotomy (HTO). Linke et al. [20] reported a series of 30 combined CMI and HTO surgeries. Both an opening-wedge and a closing-wedge HTO can be used. When using the open wedge, special care should be taken not to increase the tibial slope. On the other hand, proper release of the medial collateral ligament is necessary so as not to overload the medial CMI. The less common valgus malalignment is usually corrected on the femoral side to avoid an oblique joint line unless the deformity involves the tibial bone. Regardless of the technique used, the authors recommend doing the arthroscopy and implanting the CMI prior to performing the osteotomy during the same surgical session.

55.3.4 Rehabilitation Protocol

In the postoperative period, a knee brace is applied and locked in full extension, and it is worn for 6 weeks. The patient removes the brace three to four times per day to perform self-assisted passive range-of-motion exercises. The

knee brace is unlocked and worn for comfort only after 6 weeks [30].

Range of motion is limited to a range of 0° to 60° for the first 4 weeks and from 0° to 90° for the fifth and sixth weeks. Unlimited range of motion, with active and passive exercises, is encouraged after 6 weeks.

The patients are not allowed weight-bearing for 2 weeks. Partial weight-bearing is permitted between weeks 3–6 and full weight-bearing is allowed after 6 weeks. The use of crutches is discontinued after 8 weeks.

Stationary cycling and aquatic therapy could be done after 3–4 months [12]. A return to impact sports is not recommended earlier than 6 months after CMI implantation.

If a CMI is implanted concurrently with an ACL reconstruction or a realignment osteotomy, the CMI-specific rehabilitation program should have preference [22].

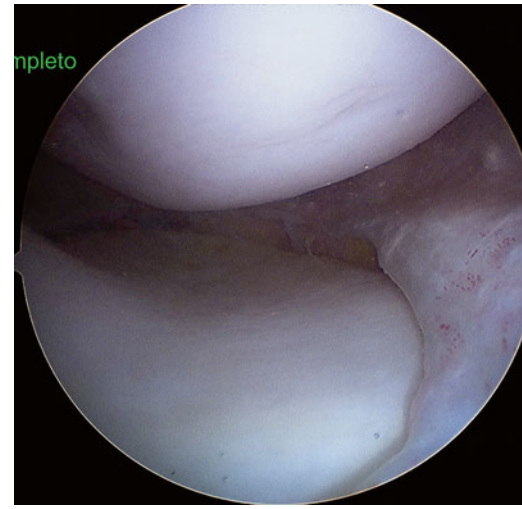

Fig. 55.7 An 8-year follow-up second-look arthroscopy. Most of the implant seems to be resorbed leaving only a small meniscal rim in the posterior area. Note the good aspect of the hyaline cartilage surfaces that suggests some protective functioning of the implant

55.4 CMI Results

55.4.1 Medial CMI Clinical Results

The first series of CMIs in humans was reported in 1997; this study showed no adverse clinical effects, the formation of new tissue and improved clinical scores 3 years after the index procedure [36]. Subsequently, a phase II feasibility study in 8 patients again showed improvement in pain and the subjective scores as well as fibrocartilage matrix formation on biopsies [31]. Some years later, these 8 patients were re-evaluated both clinically and with a second-look arthroscopic examination. The authors found a significant improvement in Lysholm and Tegner activity scores and in VAS pain scores and 69 % of filling of the meniscal defect in a second-look arthroscopy [34].

Zaffagnini et al. [40] prospectively evaluated a group of 8 patients after medial CMI implantation at 6–8 years follow-up. In that series, all the patients were able to return to daily life activities 3 months after surgery. The Cincinnati Knee Rating Scale and the objective IKDC scores improved in all but one case (Fig. 55.7).

Bulgheroni et al. [4] reported on the clinical at results from a series of 34 medial CMI at up to 5 years follow-up. Again, improvements in the Lysholm and Tegner activity scores with respect to the preoperative scores were clearly demonstrated.

Zaffagnini et al. [43], in a nonrandomized study, found better results for several outcome scores (IKDC, Tegner index and SF-36) and a lower visual analogic scale (VAS) for pain in a group of patients treated with medial CMI compared to a group of matched controls treated with partial meniscectomy.

Monllau et al. [23] reported significant improvement in clinical functional scales (Lysholm score) and VAS for pain in 22 patients followed up at a minimum of 10 years. The improvements in the clinical scores were very significant at 1 year and remained almost stable until the final follow-up 10 years after surgery. There were no complications related to the CMI device, and the failure rate was found to be 8 % (2 out of 25).

In a large randomized multicentre prospective clinical trial including 311 patients, the use of medial CMI was compared to a partial meniscectomy [30]. The authors failed to prove significant clinical benefits 5 years after surgery when the

implant was used in acute patients (without previous meniscal surgery). However, they found some improvement in the Tegner index when the implant was used in chronic patients (up to 3 previous meniscal surgeries), meaning that these patients recovered more of their lost activity. Moreover, the risk of reoperation 5 years after surgery was 2.7 times greater in the group treated with partial meniscectomy than in the group of patients in which the CMI was implanted.

In a recent comparative study in patients with combined ACL reconstruction and meniscal surgery, CMI patients have less VAS pain than chronic meniscectomized patients in the long term (9.6 years follow-up in average). Additionally, CMI implantation combined with ACL reconstruction leads to a lesser degree of displacement as measured with the arthrometer KT-2000 when compared to a medial meniscectomy. This last finding highlights the role the reconstructed meniscus plays in knee stability [3].

In a recently reported systematic review of the previous CMI literature, the preoperative Lysholm score of 63.3 improved to an average 90.5 at 6 months after surgery, and this improvement remained almost stable up to 10 years later. The average preoperative VAS pain score of 39.4 improved to 18.3 at 6 months and also remained stable up to 10 years later [8]. Nevertheless, the improvement in the Tegner score from preoperative to 1 year after surgery tends to slowly worsen from 2 to 10 years [8].

The most frequently reported complications after implanting a medial CMI were swelling (50 %) and residual compartmental pain (15.2 %). Some other complications with an incidence of less than 10 % that also have been reported are nerve injuries, infection, deep venous thrombosis and implant failure. However, many of the reported complications might be explained by the high rate of concomitant procedures, mainly the ACL reconstruction and tibial osteotomy [8].

55.4.2 Lateral CMI Clinical Results

There is less knowledge of the lateral CMI evolution than the medial because the lateral design is newer and the accumulated experience is less (only 9.8 % of the cases in the systematic review reported by [8]).

Hirschmann et al. [14] reported the results of a series of 12 patients after lateral CMI, showing significant improvements in VAS for pain, Tegner, Lysholm and IKDC scores, similar to a group of 55 medial CMI.

Zaffagnini et al. [42] reported the 2-year results of a series of 24 lateral CMIs, with significant improvement in the Lysholm scores, VAS for pain, Tegner scores and objective IKDC scores. Knee function was improved in 96 % of the patients, and the Lysholm scores were excellent or good in 87 %.

More recently, Zaffagnini et al. [41, 44] clinically evaluated a multicentric series of 43 patients with a mean age of 30.1 ± 12.0 2 years after implantation of a lateral CMI. All clinical scores significantly improved from preoperatively to final evaluation. At final follow-up, 58 % of patients reported activity levels similar to their pre-injury values, whereas 95 % of patients reported that they were satisfied with the procedure. A higher body mass index, the presence of concomitant procedures and a chronic injury pattern seemed to negatively affect the final outcomes. Serious adverse events with a known or unknown relation to the scaffold, such as pain, swelling and scaffold resorption, were reported in 6 % of patients, leading to CMI explantation, debridement or synovectomy.

Therefore, it seems that in spite of the shorter experience with the lateral CMI, the clinical results are similar to those reported with the medial implant, with significant clinical improvements at 6 months follow-up that are maintained up to 2 years after surgery [8].

55.4.3 Radiographic Results

In the phase II feasibility study, Steadman and Rodkey [34] found no significant radiographic changes from the preoperative up to 5–6 years in terms of joint line height measurements or changes in the mechanical axis.

Bulgheroni et al. [4] found no degenerative changes in 53 % of his series and Kellgren-Lawrence

grade I in 35 %, with grades 2–3 in 26 % and grade 4 in 3 % at 5 years after CMI surgery. However, the preoperative radiographic status was not informed because preoperative radiographs were not available for all patients.

Zaffagnini et al. [43] found less joint space narrowing in a group of patients treated with CMI compared to a group of patients treated with partial meniscectomy.

Monllau et al. [23] reported minimal or no narrowing of the joint line in all but one of the 22 patients followed for a minimum of 10 years.

Unfortunately, radiographic analysis was not done in the largest CMI study because it was a multicentre study with great variability in the radiographic views and techniques used among the involved sites [30].

55.4.4 MRI Results

Several studies evaluated the MRI signal after CMI surgery. Genovese et al. [6] proposed an MRI-based score to analyse the size and signal intensity of the CMI after implantation (Table 55.2).

Several studies recognize a frequent and progressive decrease in size of the implants during the follow-up period compared with the original native meniscus [4, 6, 23, 33]. In a systematic review of CMI MRI evaluations, it has been reported that the size of the implant considered as grade 3 (similar to the normal meniscus) in 87.5 % of the cases at 6 months after surgery decreased to only 36.4 % at 12 months. This figure decreases progressively up to 10 years when only 8.3 % of the cases could be considered grade 3 and 75 % grade 2. On the other hand, the implant was considered absolutely reabsorbed in 16.7 % of the cases [41]. These MRI results seem to be worse for the lateral CMIs.

There was frequently an altered signal intensity of the implant even many years after implantation [23]. The signal intensity according to the Genovese scale seems to mature progressively up to 2–5 years (33 % considered isointense, 56 % slightly hyperintese and 11 % markedly hyperintese). Later than 5 years, the signal intensity could worsen in some cases, as the normal meniscus does (Zaffagnini et al. 2014). In a prospective study, after 10 years of follow-up, the prevalence of signals of myxoid degeneration was found in one third of the implanted CMIs [43].

Table 55.2 Genovese score for MRI size and signal intensity after CMI implantation

Characteristic	Morphology and size	Signal intensity
Type 1	Totally reabsorbed CMI	Markedly hyperintensity
Type 2	Small CMI Regular or irregular morphology	Slightly hyperintensity
Type 3	Shape and size identical to normal meniscus	Isointensity relative to the normal meniscus

MR imaging of the synovial reaction could be seen infrequently during the first year (5 % in the 6-month MRI in the Genovese study). Consequently, the use of intravenous contrast material for the MRI study has no potential interest after 1 year [6].

Hirschmann et al. [14] reported extrusion of more than 3 mm in 72 % of the meniscus including CMI when they analysed MR images 1 year after surgery. This extrusion could cause a decreased load-sharing effect.

The MRI aspect of the tibial and femoral cartilage has also been studied with the Yulish scores. They seem to be stable and show no progression of the cartilage lesions with either the medial or lateral CMI [42]. Overall, more than 60 % of the patients had a normal cartilage signal relative to the Yulish score at both the 2-year and 5-year follow-up.

55.4.5 Histological Results

Rodkey et al. [30] studied 141 CMI biopsies obtained from a second-look arthroscopy 1 year after surgery (as it was part of the protocol of a multicentre randomized trial). They reported macroscopic integration between the meniscus-like

tissue generated over the CMI scaffold and the host meniscus rim. They did not found lack of healing or exuberant tissue growth in the interface or gross tearing in the CMI. Moreover, no chondral damage caused by the CMI was seen. Nevertheless, they found a partial resorption of the implant in many cases, leading to incomplete defect filling. The average of meniscal tissue remaining after meniscectomy was 51 % in the acute group and 37 % in the chronic group and both increased up to 73 % 1 year after CMI implantation.

The histological findings obtained 1 year after surgery with a 14- or 15-gauge needle biopsy demonstrated that host cells (likely derived from the adjacent synovium) migrate into the collagen meniscus scaffold, differentiate into fibroblast-like cells and synthesize the appropriate extracellular matrix, providing a meniscus-like fibrochondrocitic tissue. One year after implantation, only 10–25 % of the original CMI was present, and most of the implant was replaced by the new host tissue [30]. In less than 5 % of the cases, there was inflammation of the synovium in the biopsy specimen, but without clinical findings of synovitis in the arthroscopy [11]. The majority of the scaffold was expected to be reabsorbed over 12–18 months [4, 33]. A complete absorption of the original scaffold was reported in a histologic study done 5 years after the implantation.

The ultrastructure of the CMI 6 months after implantation was studied with a scanning electron microscopy and transmission electron microscopy [29]. CMI sections appeared composed of parallel connective laminae of 10–30 μm, connected by smaller bundles (5–10 μm). This connective network formed lacunae with diameters of between 40 and 60 μm. The lacunae were filled with connective tissue that contained newly formed vessels and fibroblast-like cells, presenting an abundant rough endoplasmic reticulum and several mitochondria. The original structure of CMI was still recognizable 6 months after implantation and no inflammatory cells were detected within the implant. It demonstrated that CMI provides a three-dimensional scaffold suitable for colonization by precursor cells and vessels and leads to the formation of functional tissue.

55.5 Summary

The CMI is a type-I collagen scaffold designed to develop a tissue-engineered meniscus. Both medial and lateral CMI had been developed for this purpose.

The device is placed arthroscopically in the space where a damaged meniscus has been removed, creating a partial meniscal defect, and is anchored to the surrounding tissue. Selecting the suitable candidate is one of the key factors in achieving a successful outcome. The knee must be stable and well-aligned (or the ACL deficiencies and malalignment should be treated concomitantly). Technically, a secure intra-articular attachment is probably the most critical factor in achieving implant stability, so the surgeon should be skilled in performing meniscus repair and reconstruction techniques. Following implantation, the scaffold has been seen to be invaded by cells and undergoes a process of remodelling. The CMI has already been applied clinically for partial meniscus replacement, and some studies with an improvement in clinical scores and VAS pain score with respect to the preoperative status with a 10-year follow-up have been reported. Subsequently, the formation of newly formed meniscus-like tissue was observed in over two thirds of cases, but the size of this is usually smaller than the native meniscus.

Although the CMI is safe for the joint, the clinical benefits of its use seem to appear mainly in symptomatic patients with a previous meniscectomy. However, the supposed chondroprotection effect in reducing the degenerative changes of the meniscectomized knees remains to be proven.

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