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All-arthroscopic technique of biological meniscal tear therapy with collagen matrix

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Summary

Purpose: The number of meniscus surgeries, including partial or complete meniscectomy, has increased considerably with the progress in knee arthroscopy. An analysis of treatment results, carried out at several centres by numerous study groups, showed a development of early degenerative changes in the knees of treated patients.

Methods: This study is aimed at developing a fully arthroscopic technique to treat meniscal tears by suturing and wrapping them in collagen matrix, followed by injection of liquid bone-marrow collected from the tibial proximal epiphysis, into the area of meniscal lesion.

Results: In this paper, we presented arthroscopic technique for wrapping meniscal tears using the collagen matrix sutured with the Fast-Fix sutures.

Conclusions: Proposed surgical technique is not straightforward to perform, but can be learned by adhering to strict arthroscopic principles. The use of collagen matrix and bone marrow aspirate from bone-marrow blood, including stem cells, creates favourable biological conditions for meniscus healing, which may increase the rate of healing.

Level of evidences: V

Key words: meniscal tear • meniscal repair • collagen matrix • marrow blood • stem cells

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Background

The number of meniscus surgeries, including partial or complete meniscectomy, has increased considerably with the progress in knee arthroscopy. An analysis of treatment results, carried out at several centres by numerous study groups, showed a development of early degenerative changes in the knees of treated patients [1,2]. This information indicates the enormous role that the meniscus plays in the normal functioning of the knee and, therefore, should persuade orthopaedic surgeons to make all possible attempts to treat meniscal tears in a way that preserves the meniscus in the knee [1,3–6]. Very good results are achieved after suturing meniscal tears in well-vascularised layers (red) and in longitudinal or transverse lesions (simple tears) [2]. The results of the treatment of meniscal tears of the combined type in less-vascularised layers are not as promising [4,7,8,]. Webber et al. showed that meniscal fibrochondrocytes multiply better and reconstruct the extracellular matrix more actively if they are medium rich in chemotactic and mitogenic factors such as blood thrombi [9]. Arnoczky et al. confirmed this hypothesis in their studies in biological models (dogs), showing an increase in the rate of healing of simple meniscal tears in the white layer (not vascularised) after serum thrombus administration into the site of the lesion [10]. However, complete healing of meniscal tears of the combined type is still difficult to achieve, even after the administration of the chemotactic and mitogenic factors present in serum thrombi [11]. In order to increase the rate of complete healing of meniscal tears of the combined type in less-vascularised layers, Henning et al. proposed a surgical technique involving meniscus-suturing and wrapping the meniscus in a fragment of the patient's own fascia, followed by administration of serum thrombi at the site of the lesion. In their group of patients, such a procedure allowed for an increase in the rate of complete healing, from 75% to 92% [11]. Despite such promising results, the procedure proposed by the aforementioned authors did not find wider application, probably because of serious technical difficulties in performing such a surgery. Barrett et al. attempted to improve this surgical technique and presented their own method of wrapping the meniscus in a fragment of fascia under arthroscopic control and with the use of T-Fix meniscal sutures (Smith & Nephew) [12]. However, the surgery proposed by these authors is still technically challenging and has not found wider application. Partial or complete meniscectomy is still the most frequently employed treatment for meniscal tears of the combined type.

The technique of meniscus-wrapping proposed by these authors is associated with additional tissue traumatisation following graft collection (fragmentation of the fascia). The results analysis of soft-tissue defects treatments with using porcine collagen matrix indicates an excellent integration into the surrounding soft tissues and membrane rebuilding into tissues that are similar in structure to the surrounding connective tissues (fibrous tissue or cartilage) [4]. In a study by Shea et al., comparing the ability of reconstruction and the quality of tissues for various types of matrixs, the authors showed that porcine-collagen matrix are actually the best of the commercially available collagen matrixs [4]. Author (RPJ) proposed and tested the treatment of combined meniscal tears by suturing them and wrapping them in a collagen matrix in a group of 30 patients [13].

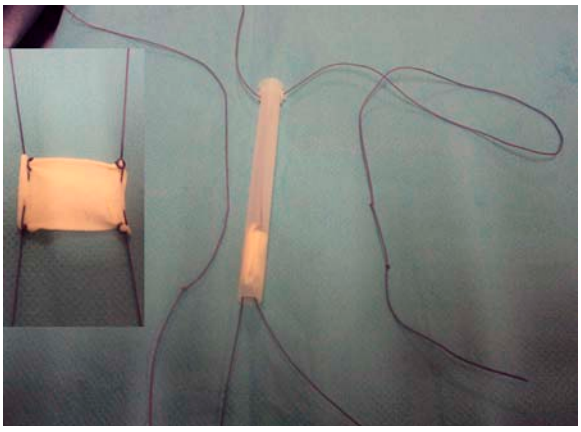


Figure 1. Suturing membrane – sutures location with marking knots and transparent tube with prepared membrane inside.

The results obtained are very promising, but the surgical technique, an inside-out suturing, presents some challenges can also be time-consuming and requires an additional surgical approach.

Objectives

This study is aimed at developing a fully arthroscopic technique to treat meniscal tears by suturing and wrapping them in Chondro-Gide® (Geistlich Pharma AG. Wolhusen, Switzerland) collagen matrix, followed by injection of liquid bone-marrow collected from the tibial proximal epiphysis, into the area of meniscal lesion.

Surgical technique

A diagnostic knee arthroscopy is made to rule out other pathology, such as lesions of ligaments and cartilage. All cartilage lesions are repaired during surgery. For meniscus suturing and wrapping with the collagen membrane, the authors include the types of meniscal tears that so far have been treated with partial meniscectomy. These are tears of the combined type, i.e., horizontal and radial types, involving the white and red-white vascularisation layers, as well as extensive tears of bucket-handle type.

Collagen-matrix preparation

While the surgeon is evaluating the knee joint, his assistant prepares the collagen matrix in the following way: The matrix, usually the size 30/20 mm, is trimmed by Vicryl 1 suture, passing through the surface of the matrix on either side. Such a technique assures that pulling forces exerted on the matrix while placing it onto meniscus, are transferred by the threads and to by the matrix itself. The matrix is than inserted in the applicator (a transparent tube,diameter 10 mm, with two holes on the one end). The way of folding the matrix and the arrangement inside the tube are described in Figure 1.

Meniscus wrapping (in the collagen matrix)

Placing suture shuttle

Using direct arthroscopic vision the loops of threads running through the meniscal posterior horn (Figure 2A) and

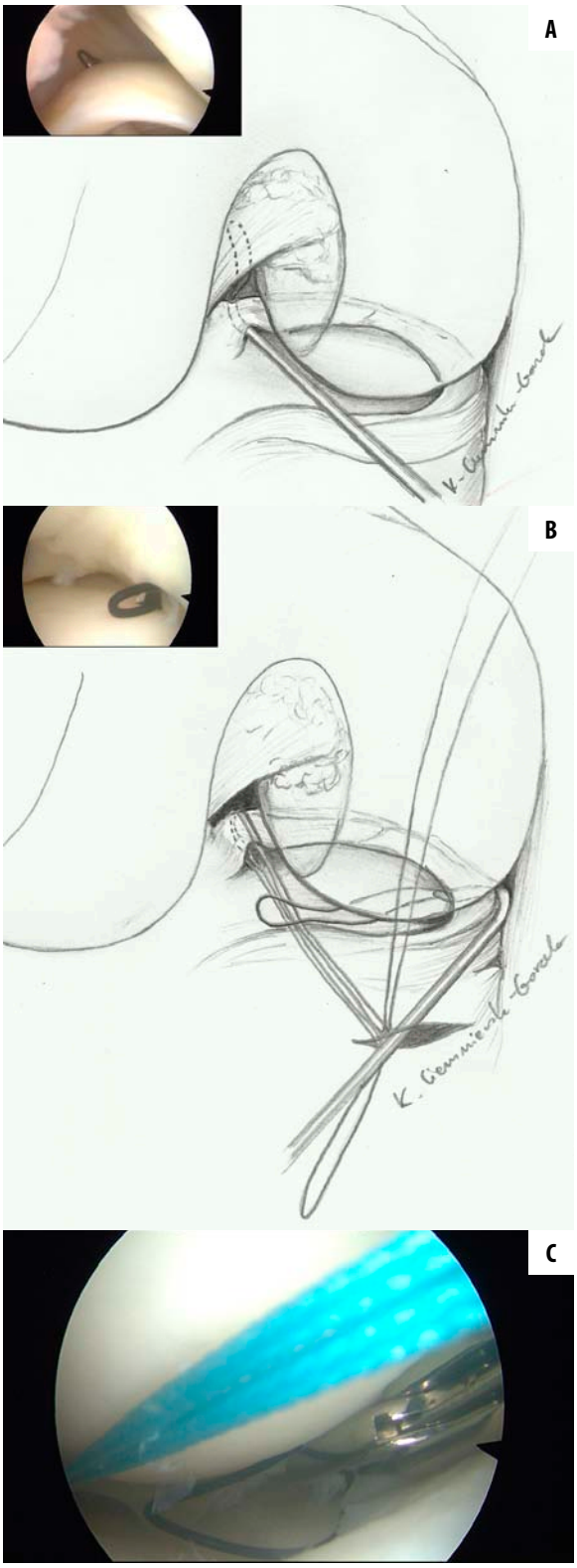


Figure 2. Placing suture shuttle. Suturing posterior horn and the centre part of meniscus body with the Accupass suture device: (**A**) – sharp tip piercing the posterior horn of the meniscus; (**B**) – sharp tip piercing the meniscus body; (**C**) – manipulator gripping loops in the knee joint.

the meniscal body are passed with a special suture shuttle (Accupass – Smith & Nephew, Andover, MA, USA) at

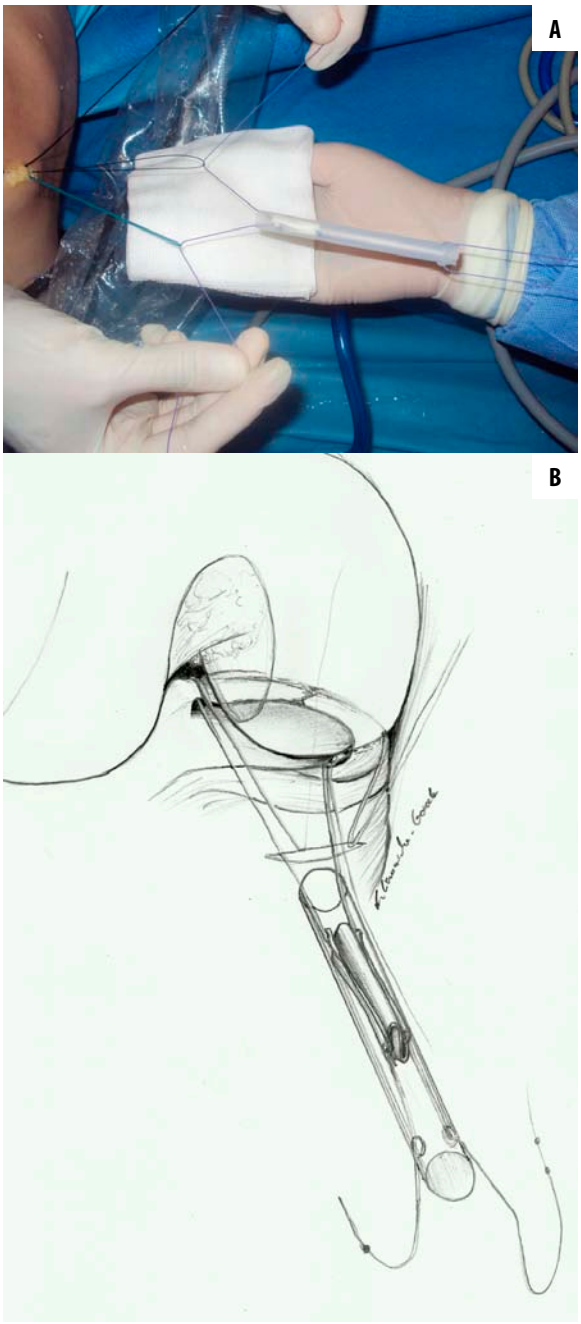


Figure 3AB. Membrane insertion instrument alignment before inserting membrane into the knee joint.

the level of the anterior border of the tear (Figure 2B). Threads should be passed in a way such that their looped ends face the tibial side of the meniscus. An arthroscopic manipulator is used to bring the loops from the knee joint to the outside surface (Figure 2C). If the technical conditions of meniscus suturing require the meniscus' piercing from its tibial-side surface, an additional thread is passed through the loops from the femoral side so that the end with the loop is located on the meniscal tibial side. The surgeon should make sure that the threads are not tangled and are still running through the soft tissues in one canal. The technical pearl is that the surgeon must retrieve the posterior horn and anterior border membrane-passing sutures from the AM arthroscopic portal at the same

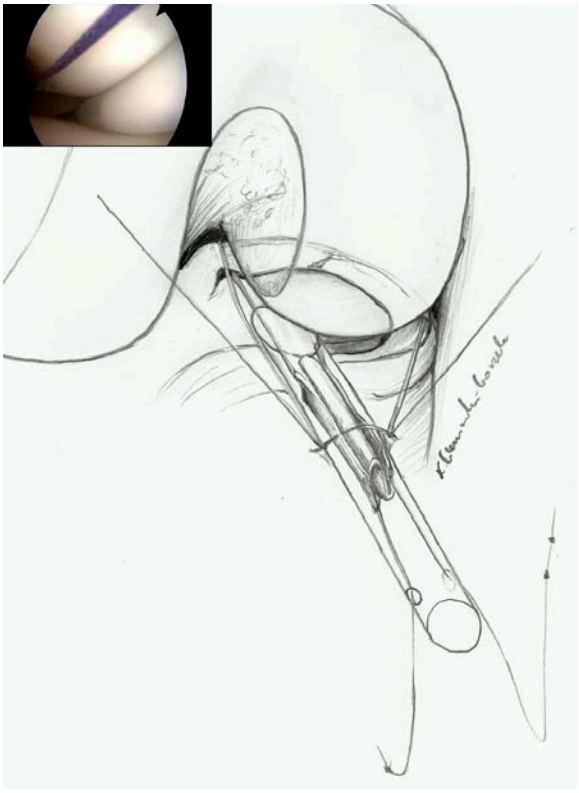


Figure 4. Membrane introduction into the knee joint. The applicator containing folded membrane is carefully inserted into the knee joint, and the tube is carefully passed with the membrane under all membrane – passing sutures.

time to avoid soft tissue interposition during subsequent matrix passage.

Matrix introduction

The open loop suture retriever "runs" the length of the posterior horn and anterior border matrix – passing sutures, independently, from intra-articular to extra-articular. This is to double check that the sutures are not tangled. Vicryl 1 matrix – passing sutures are passed through both loops to the meniscal posterior horn and to the anterior part of the lesion (Figure 3). The applicator consisting the Chondro-Gide® is inserted into the knee joint. At the same time, the matrix –passing sutures that were previously inserted into the meniscus are carefully pulled out in order to prevent their tangling inside the knee joint (Figure 4). After inserting the matrix, the applicator is removed. The matrix is inserted into the knee in such a manner that its smooth surface is directed to the cartilaginous surfaces and its porous part to the meniscal surface.

Matrix fixation

The matrix is placed over the meniscus by pulling the matrix – passing sutures without marking knots (see Figure 1). The matrix should adhere to the meniscus from the tibial side (Figure 5). Afterwards, the matrix is fixed on the meniscus, with arthroscopic simple knotted sutures sliding on the femoral surface of the meniscus, starting from the meniscal posterior horn (Figure 6A and B). Following this procedure, the meniscus is wrapped in the collagen

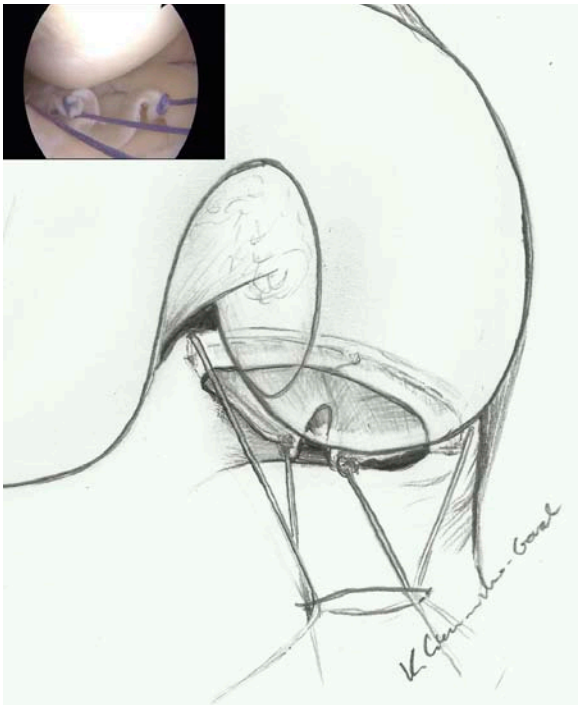


Figure 5. Final membrane placement on the tibial surface of the meniscus.

matrix on both sides, and is fixed into the meniscus in a stable way. At the same time, sutures stabilise the meniscal tear. Additionally, 1 to 4 (3 on average, depending on the extension of the tear) Fast-Fix sutures (Smith & Nephew, Andover, MA, USA) are inserted into the meniscus wrapped with the matrix, for a better stabilisation of the meniscal tear and for an increased tightness of space between the meniscus and the matrix (Figure 6C and D).

Administration of liquid bone marrow collected from the tibial proximal epiphysis

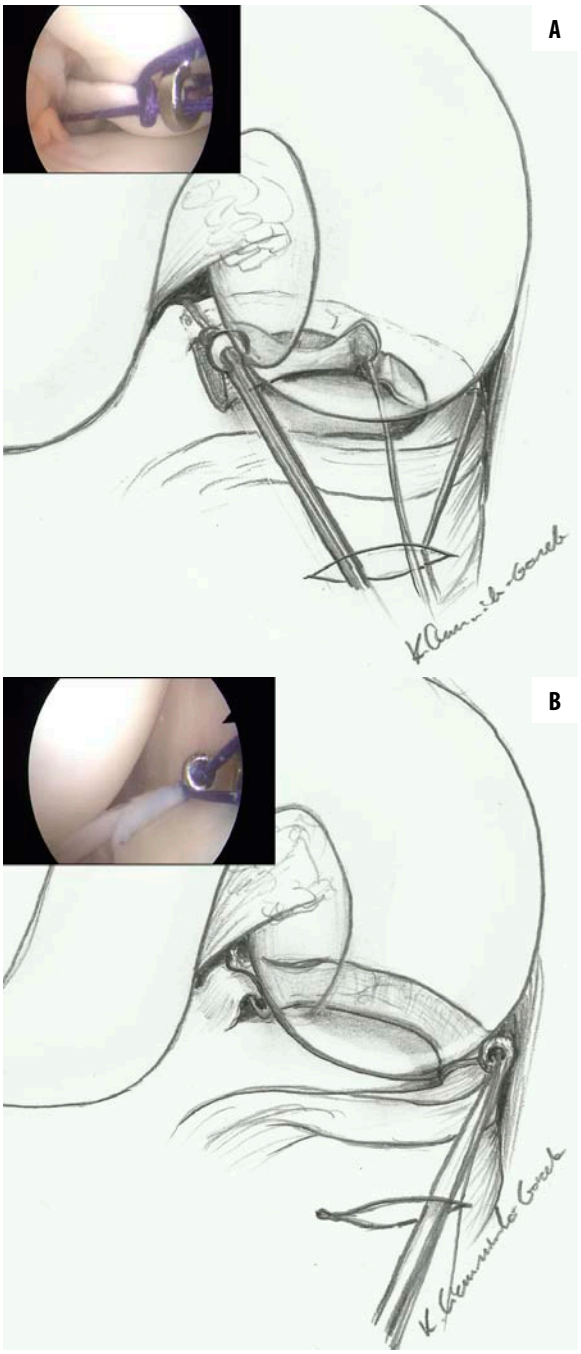
GALL-BM11/10 equipment (Gallini Medical Devices, s.p.a. Italy) is used to collect blood from the bone marrow of the tibial proximal epiphysis. The skin is pierced with the needle at the level of the tendinous attachments of the hamstrings muscles, medially from the patellar ligament. After passing through the cortical layer of the tibial bone with the use of a hammer, the internal mandrin of the cannula is removed, and a 50-mL syringe is attached to the needle. Then, approximately 5 mL of liquid bone marrow is aspirated.

The entire aspirated liquid bone marrow is injected with a long needle (it may be a needle used for epidural anaesthesia) between the Chondro-Gide® matrix and the meniscus, using direct arthroscopic visualisation with a technique of 'dry arthroscopy' (Figure 7).

The surgery is completed by closing the wounds without drainage of the knee. No knee-stabilising orthosis is used.

Discussion

This paper describes a new, fully arthroscopic technique for meniscal tears wrapping.



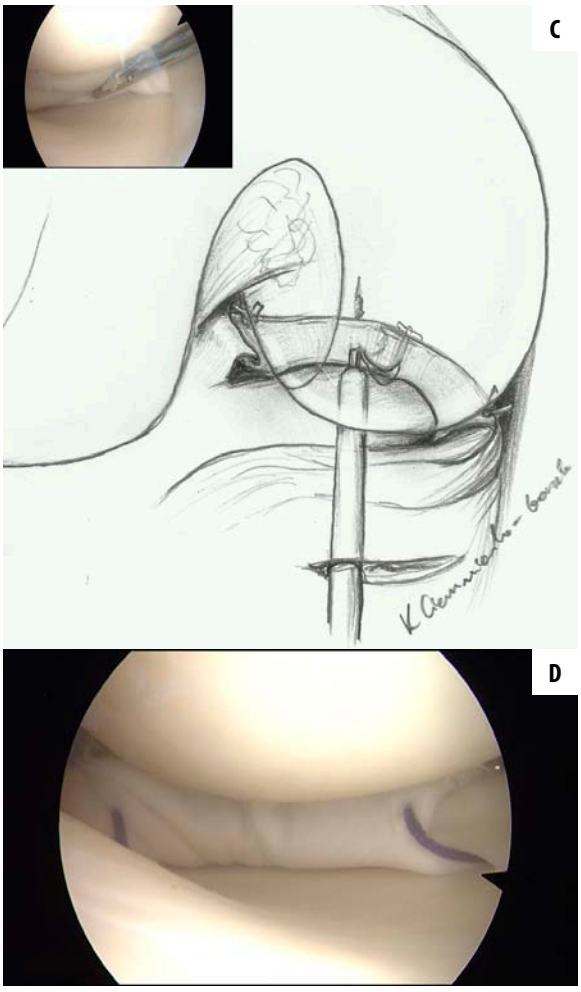


Figure 6. Membrane fixation. Membrane folding over the meniscus: (**A**) – knot sliding on the posterior horn of the meniscus; (**B**) – knot sliding on the meniscus body; (**C**) – stabilisation of membrane and meniscus body with the Fast-Fix suture; (**D**) – final view: meniscus tightly wrapped in Chondro-Gide collagen membrane and stabilized with the suture.

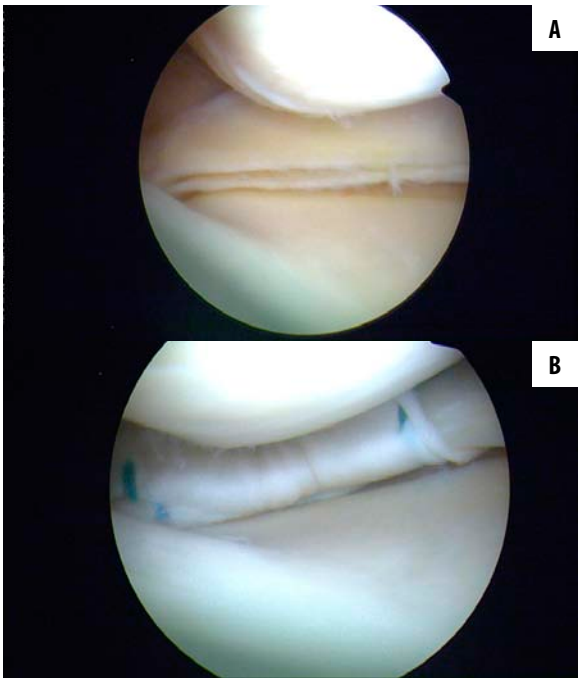
Figure 7. Membrane soaked with liquid bone marrow collected from the proximal epiphysis of the tibial metaphysis.

Author RPJ, based on his own experience and analysis of the data from the literature, indicated 3 fundamental rules worth respecting for meniscal repairs, to increase the chances of successful healing [13]. Firstly, to use sutures to assure a stable reduction of damaged meniscal fragments. Secondly, to achieve knee joint stability by means of ACL or other damaged-ligament reconstruction. And the third important rule is to treat the meniscus as soon as possible after the injury in order to prevent degeneration of the meniscal tissue. The greater the degenerative changes are, the lower the potential for healing will be. (It also concerns patients' ages.) [14]. Those principles are valid for all meniscal repairs. Adding a collagen matrix wrapped around the sutured meniscus allows the creation of an internal "bioreactor" (quote author RPJ) which attracts cells released by synovial fluid, by rasped meniscus and by bleeding inside the joint. These cells are attracted by the matrix that offers hypothetically an ideal bio-environment for them to migrate into the gaps of the tears in the avascular zone. After about 6 weeks the collagen matrix is resorbed.

In the own series presented in 2010 [13] the authors presented an inside-out technique and describe the Chondro-Gide®

Table 1. Important steps of the surgical technique, allowing complete arthroscopic meniscus-wrapping – the senior author TP (main surgeon) recommendations.

Required instruments and devices	The technical pearls of the surgery
Accupass (Smith & Nephew) or any other 'passer' of threads through the meniscus	
Acromial manipulator	Be careful to pass all threads through the soft tissue in one canal out to the surface; they should not cross each other
Knot-pusher', a metal loop handle for sliding intra-articular sutures	
Vicryl 1 absorbable sutures	The membrane should be sutured along two parallel sides so that all pulling forces are transmitted by the threads
Transparent tube (about 10 mm diameter about 10 mm and length about 100 mm) with two holes (how are the holes positioned with respect to each other?) at one end	Transparent tube with two holes at the one end should be used to insert the membrane into the joint space with no risk of tangling
Fast-Fix sutures (Smith & Nephew Fast-Fix)	
Needle for collecting bone marrow and a large 50-mL syringe	



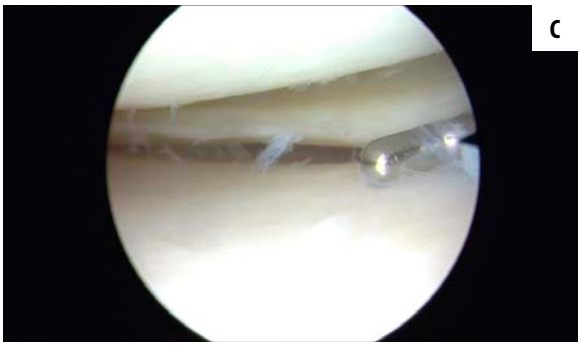


Figure 8. Consecutive stages of meniscal-tear treatment with Chondro-Gide® membrane and early results of the arthroscopic 'second look': (**A**) – meniscus before treatment, 6 months old posttraumatic cleavage tear in association with ACL rupture; (**B**) – after wrapping in the collagen membrane; (**C**) – 3 months after the first arthroscopy: complete healing of the horizontal tear through all layers of medial meniscus vascularisation (arthroscopy being performed because of arthrofibrosis after ACL reconstruction and need of arthrolysis).

collagen matrix insertion and wrapping over the meniscus following anatomical fixation. The study included 30 patients (23 medial and 7 lateral meniscus tears) of which 10 patients had concomitant an ACL reconstruction. In this study 11 patients presented with bucket handle tears, 15 had complex tears and 4 suffered from an horizontal tears.

After a mean follow up of 2,5 years (range 1–5 yrs.), three patients had a symptomatic failure (10%). All other 27 patients (90%) were asymptomatic. Although the surgical technique was challenging the results seemed to justify the effort.

The surgical technique presented in this paper allows reaching a stable synthesis of torn meniscal fragments, applying minimal number of sutures. Unlike Henning and Barrett [11,12], no double-suturing separately for the suturing of free meniscal fragments, for the stabilisation of fascia fragments or for collagen matrix are used in this method. The senior author, TP (main surgeon) uses sutures stabilise the torn meniscal fragments and the collagen matrix simultaneously. Such a technique minimises the number of used implants and, consequently, foreign bodies in the meniscal tissue. In our opinion, described surgical technique of meniscus-wrapping, after some training, does not significantly prolong the duration of surgery, allowing simultaneous reconstruction of all damaged knee structures (ACL reconstruction, cartilage repair) in a acceptable OR time. The procedure needs good arthroscopic skill and we collected the importance technical tricks in Table 1.

Only two serious complications were noted in our group. One patient operated on with medial meniscus-wrapping developed tibial compartment syndrome (most probably resulting from overhydration). Following the surgery, the fascia was decompressed subcutaneously. At present, one year after the incident, following intensive rehabilitation

the motor functioning of both the foot and ankle joints has improved considerably. The knee joint is free from effusion. Full, painless range of motion, as well as negative meniscal tests was achieved. In the other patient, knee arthrofibrosis developed after ACL reconstruction and wrapping of the medial meniscus. Three months after initial surgery the knee arthroscopy was performed in order to remove adhesions in the supra-patellar recess. Complete healing of the meniscus was achieved. Figure 8 demonstrates consecutive arthroscopic images recorded before treatment, after wrapping in collagen matrix, and 3 months after the first arthroscopy. The last image demonstrates complete healing of the horizontal meniscal tear, involving all layers of medial-meniscus vascularisation.

Author RPJ observed complications in 3 patients in his group of patients [12]. One case of arthrofibrosis, another patient developed a damage to the saphenous nerve, and the third case presented a damage to an ACL graft (however, in this case, the treated meniscus was completely healed).

Conclusions

In this paper, we presented arthroscopic technique for wrapping meniscal tears using the Chondro-Gide® collagen matrix sutured with the Fast-Fix sutures. Proposed surgical technique is not straightforward to perform, but can be learned by adhering to strict arthroscopic principles. The use of collagen matrix and bone marrow aspirate from bone-marrow blood, including stem cells, creates favourable biological conditions for meniscus healing, which may increase the rate of healing. We will carry out further studies to evaluate the results achieved in a representative group of patients followed up for a longer period

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