Technical Note

Arthroscopic Minced Cartilage Implantation (MCI): A Technical Note

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Abstract: Articular cartilage lesions are identified with increasing frequency. Several cartilage repair techniques are available to treat symptomatic cartilage defects. The ultimate goal of any cartilage repair procedure is the prevention of premature osteoarthritis. Autologous chondrocyte implantation provides the best tissue quality. However, 2 operations and a resource-intense culturing process with high regulatory demands are disadvantages of this cartilage repair procedure. Furthermore, cellular dedifferentiation and senescence display further cell culture-associated drawbacks that hamper the procedure. Minced cartilage implantation is a relatively simple and cost-effective one-step procedure with promising biologic potential and satisfying clinical results. We present an arthroscopic surgical technique where the surgeon can apply autologous chondrocytes in a one-step procedure to treat articular cartilage defects at the knee joint.

Articular cartilage lesions are being detected with increasing frequency. This increase is related to a society with a high prevalence of obesity and greater consumption of sports activity.[1] In addition, magnetic resonance imaging diagnostics are performed with increasing frequency, paired with greater accuracy and resolution.[2] Symptomatic cartilage defects across the knee joint currently are treated with different cartilage repair techniques to repair the joint surface, re-establish joint homeostasis, and finally prevent progression to osteoarthritis.[3-5]

Minced cartilage implantation (MCI) for treatment of cartilage defects of the knee has evolved as an attractive alternative to other cartilage repair techniques.[6] The biologic potential of activated primary chondrocytes is clearly proven.[7] Chondrocytes establish a de novo extracellular matrix via outgrowth, proliferation, and differentiation. MCI is indicated for all (contained, isolated, and unipolar) lesion sizes and also can be applied in osteochondral defects. Mostly, fragmented cartilage chips are implanted via an open approach.[8] Fixation has been described by the use of fibrin glue, via a membrane, or a combination of both. Autologous chondrocyte implantation (ACI), currently in its fourth generation, can be established via a full arthroscopic approach. The aim of this Technical Note is the introduction of MCI via an all-arthroscopic approach-third generation MCI.

Surgical Technique

The technique has been described before in an open approach.[8] It can be applied arthroscopically at all symptomatic full-thickness cartilage defects of the knee joint including trochlea, both femoral condyles, tibial plateau, and patella surface. In osteochondral defects, a combination of cancellous bone plasty and minced cartilage repair can be performed. Cancellous bone plasty can be achieved via arthroscopic techniques as well. It can then be combined with MCI on top as a sandwich procedure.

The exemplary presented surgical description (Video 1) is for the treatment of a retropatellar cartilage lesion (Fig 1) and can be performed identically for all other locations.

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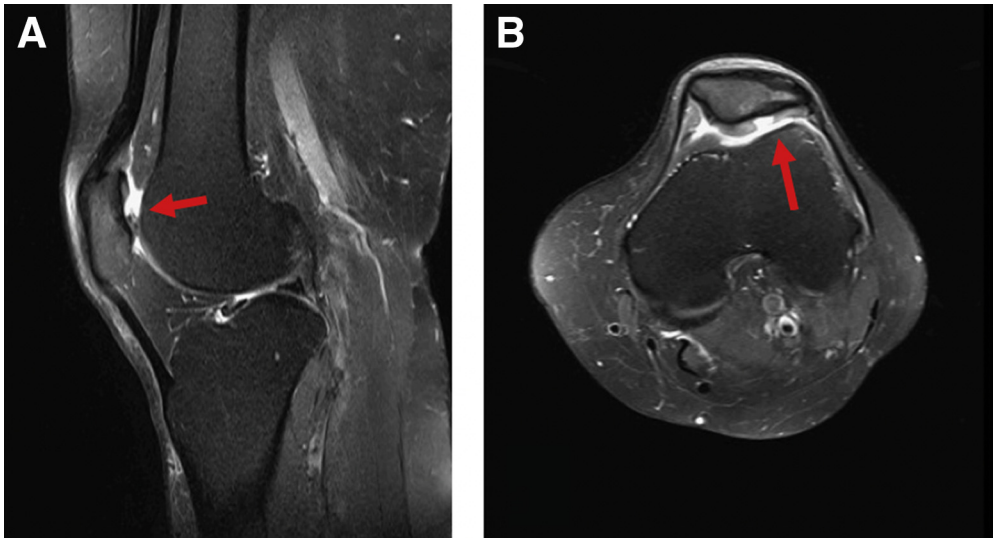

Fig 1. Preoperative magnetic resonance imaging demonstrating a retropatellar full-thickness cartilage lesion in the sagittal (A) and axial (B) planes.

Coexisting pathologies such as ligamentous instability, mechanical axis malalignment, meniscal pathology, or patellar instability are crucial to be identified and treated sufficiently. Such intervention can be performed simultaneously with the particulate cartilage repair procedure. Clinical examination of the index knee joint and examination under anesthesia are mandatory. Perioperative antibiotic prophylaxis is recommended, but not without conflicting evidence. The patient position is supine. For the preparation and filling of the patella defect, the leg is extended, the camera is inserted through the medial portal, and the instruments are inserted through the lateral portal. A tourniquet is recommended to implant the cartilage under dry (bloodless) settings. Since autologous platelet-rich plasma (PRP) will be required for the

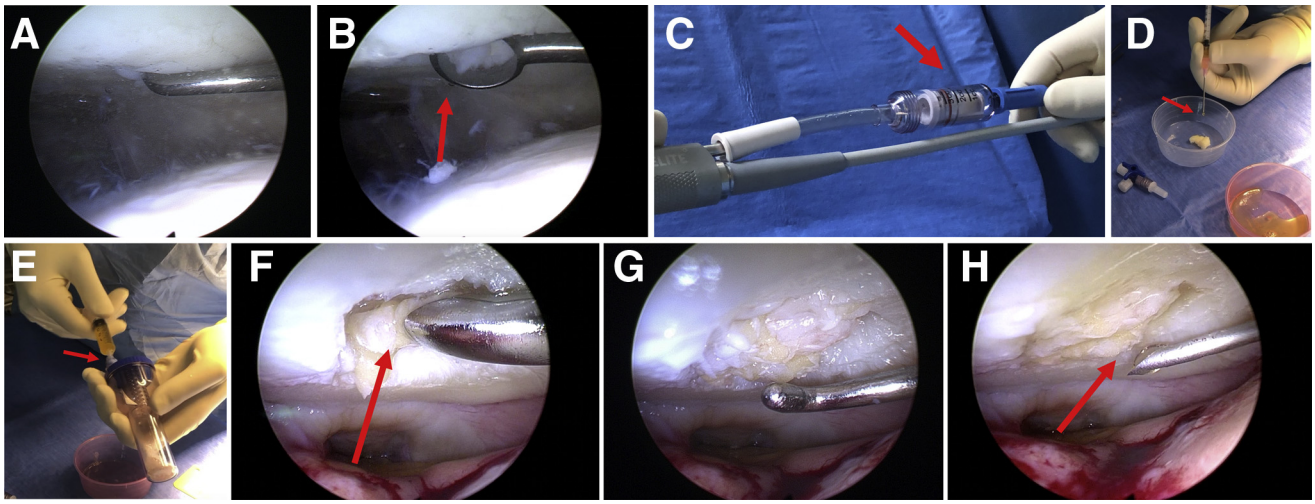

Fig 2. The left knee is extended completely. The camera is inserted through the medial portal, and the instruments through the lateral portal. (A) Cartilage defect at the patella retrosurface. Indication is given under arthroscopic inspection. (B) Debridement of the defect including the calcified layer with a curette. A stable wall should be created. (C) The tissue collector has to be adapted to the shaver for the extraction of the chondral tissue. The filling of the tissue collector can be supervised through the transparent case (red arrow). (D) The paste-like material harvested in the tissue collector should be poured in a cup and mixed with some drops of the PRP to mix the tissue with growth factors before filling it in the applicator. (E) The Thrombinator has to be filled with 3 mL of the PRP before letting it rest for 10-15 minutes. The Thrombinator can be filled and emptied through the locks (red arrow). (F) After draining the arthroscopic fluid with the shaver suction and drying the defect with a swab, the defect is filled with the tissue/PRP mixture with the use of the applicator. The stamp of the applicator can be pushed forward gently to release the mixture. The applicator also can be used for the modelation of the tissue. (G) The defect should be covered approximately up to 80% to 90%; the arthroscopic hook can be used for modelation. (H) The filled defect has to be covered with some drops of the thrombin that was taken out of the thrombinator before the surgery is finished and the leg immobilized. The adherent characteristics of the thrombin fixate the tissue in the defect. (PRP, platelet-rich plasma.)

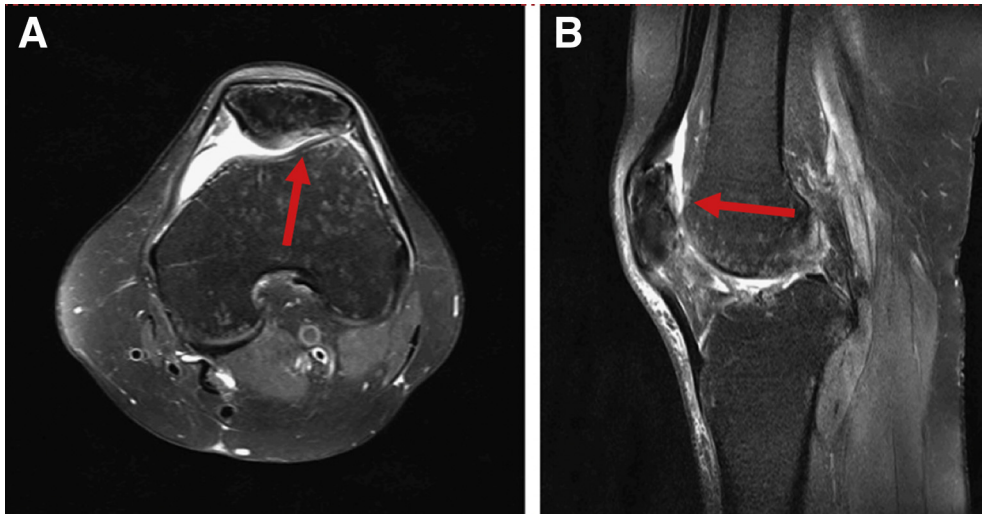

Fig 3. Magnetic resonance imaging 4 months following minced cartilage implantation at the retropatellar surface in axial (A) and sagittal (B) planes, with a satisfactory filling of the defect.

procedure, it is recommended to draw venous blood from the patient (e.g. cubital veins) under absolutely sterile conditions before initiation of anesthesia (to avoid detrimental effects of narcotic substances on the PRP). It is suggested to collect at least 10 to 15 mL of pure PRP. The PRP can then be further processed during arthroscopy. Every indicated minced cartilage procedure is initiated via standard arthroscopy of the index knee joint including possible cointerventions. The intended-to-treat cartilage defect is well inspected, and final indication is given during arthroscopy (Fig 2A).

The size of the defect is measured before and after debridement. The cartilage defect is debrided in standardized fashion by using a small sharp spoon/ringed curette (Fig 2B).

The technique for an optimal debridement of cartilage lesions creating a stable wall and viable rim has been described in detail previously.[9] We suggest removing the calcified layer; however, it remains a matter of debate.[10] Microfracture or microdrilling of the subchondral bone for influx of blood into the defect is not recommended. Contamination of the transplant by the blood clot can negatively affect the chondral fragments and does not provide a significant amount of mesenchymal stem cells.[11] Non-healthy bone lesions are recommended to be removed and can be filled using autologous or allogenic bone plasty. Larger defects possibly need to be treated by autologous bone grafting, e.g. from the iliac crest.[12] It is important to address bone lesions for a successful outcome of any cartilage repair procedure. The cartilage that will be finally applied for the procedure can be gathered from the defective cartilage itself in the setting of acute traumatic chondral lesions where the cartilage appears clearly healthy and has just lately been delaminated. It is not suggested to use degenerative cartilage for further transplantation. The typical and recommended location as a harvest site is the cartilage defect edge. After standard debridement of the lesion, one can subsequently harvest cartilage at this location. The defect itself will be only minimally enlarged after defect preparation.

If not enough cartilage can be collected at the surrounding of the defect itself, one can also gather healthy cartilage at typical ACI harvest locations (condylar notch) that display a safe option without significantly described donor-site morbidity.[13,14] Aurich et al.[15] described a superior redifferentiation of chondrocytes harvested from the edge of the defect compared with non–weight-bearing regions. It is recommended to harvest cartilage by use of a 3.0 shaver device. Beforehand, a collecting device (e.g. GraftNet; Arthrex, GmbH, Munich, Germany) autologous tissue collector is connected to the shaver for harvesting (Fig 2C). By that cartilage is harvested, minced into small fragments (paste-like), and collected at once.[16,17] Subsequently, the minced cartilage is mixed with 2 to 3 drops of PRP, resulting in a malleable substance (Fig 2D).

A chips-applicator (obturator) device is loaded with the chips/PRP mixture. Then, 3 mL of the PRP is inserted into a specific device (Thrombinator; Arthrex, GmbH) and is gently mixed (Fig 2E).

The chips/PRP-paste is distributed over the defect for complete coverage. It is not absolutely necessary to gain an even filling height. A surrounding cartilage edge, approximately 80% to 90% filling, is sufficient (Fig 2F, G).

The consistency of the chips-paste provides initial stability. In the next step, thrombin that was just collected from the Thrombinator is applied drop by drop over the chips-paste (Fig 2H). The thrombin combines with the PRP within the chips and generates fibrin, which coagulates quickly and finally fixes the chips within the cartilage defect. The tissue is sealed with a final layer of fibrin that was mixed together previously at the back table. The procedure is finished. An optional

Table 1. Pearls and Pitfalls of the Arthroscopic Minced Cartilage Technique

Pearls	Pitfalls
Fast procedure	PRP contraindications have to be considered
No substantial change of tissue	Comorbidities have to be treated (e.g. meniscus pathology, malalignment)
One operating room, one surgeon	Dependent on PRP quality
Purely homologous	
Spontaneous application possible	

PRP, platelet-rich plasma.

drain without suction can be applied. The leg is placed into full extension and fixed with a brace. Initially approximately 20 to 24 hours of bedrest are suggested. Hereafter, an ACI-oriented standardized rehabilitation protocol is suggested.[18]

Discussion

Autologous minced cartilage repair was introduced in the early 1980s.[19] Since then, preclinical in vivo and in vitro data have shown promising results in terms of chondrocyte activation via fragmentation.[7,10] Cartilage particulation results in outgrowth, proliferation, and differentiation of articular chondrocytes. Since proliferation and differentiation is being conducted within the joint, the cells are constantly surrounded and influenced by a naive physicobiochemical input. This closed environment may have beneficial effects for the chondrocyte to maintain a differentiated state.[20] Autologous minced cartilage repair is a one-step approach that does not require manipulation of the specimen in the laboratory or the use of allografts. It is therefore economically attractive and should not require significant regulations, as other procedures such as ACI.[21]

Currently, there are several surgical techniques available for minced cartilage implantation. Christensen et al.[22] and Massen et al.[6] described the use of scalpels to particulate the collected cartilage. However, the procedure is time consuming and results in a heterogenous and more block-like appearing particulation.[17] In 2011 Cole et al.[16] reported on the use of a designated mincing device that collected and minced the harvested cartilage at once. However, an open approach was required. Levinson et al.[17] recently reported that mincing devices do not significantly affect chondrocyte viability whereas further outgrowth and proliferation are not influenced.

Here we have described a full arthroscopic approach that provides a minimally invasive cartilage repair method with a small amount of surgical trauma to the knee joint. This method may be a promising alternative for young athletes because of its fast rehabilitation and return to sport.[23] Massen et al.[6] reported in a 2-year follow-up of second-generation MCI significant decrease in pain and improvement of knee function. However, clinical trials in a direct comparison with other cartilage repair methods are still required.

High regulatory processes, a 2-step surgical approach, and resource intense culturing lead to a low cost-effectiveness of ACI as the current gold standard. On-top chondrocyte expansion negatively influences chondrocyte differentiation.[24] In contrast, MCI is a purely autologous technique and can be performed in a single-step approach without a resource-intense culturing process.[21]

This Technical Note presents a transplant fixation combining PRP and thrombin for fixation, resulting in natural fibrin. In addition, PRP might provide a positive milieu for cartilage homeostasis.[25] There are limitations and risks that need to be acknowledged. Large chondral defects or multiple defects with a large area in total can be a limitation for this technique, as chondral donor tissue is limited. Often the defect is covered with vital chondral cells, which can be used for the transplantation; if necessary, tissue from the notch or the trochlear can be added. In this technique, sterile work is very important to avoid any infection. It is necessary to educate the staff, beginning with the processing of the PRP, to avoid any contamination while drawing blood and further handling. Also, the preparation of the chondral tissue for implantation (mixed with PRP and inserted in the applicator) carries the risk of contamination. Elementary limitations for the use of PRP have to be mentioned. Patients with hyperuricemia may not be treated with this technique because this might cause an arthritis. Neoplasia, pathologic liver metabolism, or critical thrombocytopenia can cause insufficient growth factors and bioactive molecules; in these cases, PRP should not be used.[26]

Feasible in vitro and in vivo preclinical data display a strong biologic potential of autologous fragmented chondrocytes. Clinical evidence on autologous minced cartilage repair methods is limited. Further clinical data with long-term follow-up are required to further implement the third-generation full arthroscopic minced cartilage repair technique as an attractive cartilage repair method. Quality outcomes can be analyzed by magnetic resonance imaging 4 months postoperatively (Fig 3). Table 1 summarizes the main

Table 2. Advantages and Disadvantages of the Arthroscopic Minced Cartilage Technique

Advantages	Disadvantages
One-step procedure	Possibly limited by defect size
Transplantation of chondrocytes and extracellular matrix	No long-term follow-up for third-generation minced cartilage
Full arthroscopic approach feasible	
Economically attractive	
Quick procedure	

pearls and pitfalls and Table 2 the advantages and disadvantages of this technique.

References

1. Flanigan DC, Harris JD, Trinh TQ, Siston RA, Brophy RH. Prevalence of chondral defects in athletes' knees: A systematic review. *Med Sci Sports Exerc* 2010;42:1795-1801.
2. Widuchowski W, Widuchowski J, Trzaska T. Articular cartilage defects: Study of 25,124 knee arthroscopies. *Knee* 2007;14:177-182.
3. Chimutengwende-Gordon M, Donaldson J, Bentley G. Current solutions for the treatment of chronic articular cartilage defects in the knee. *EFORT Open Rev* 2020;5:156-163.
4. Gowd AK, Cvetanovich GL, Liu JN, et al. Management of chondral lesions of the knee: Analysis of trends and short-term complications using the National surgical quality improvement Program Database. *Arthroscopy* 2019;35:138-146.
5. Zamborsky R, Danisovic L. Surgical techniques for knee cartilage repair: An Updated large-scale systematic review and network meta-analysis of randomized controlled trials. *Arthroscopy* 2020;36:845-858.
6. Massen FK, Inauen CR, Harder LP, Runer A, Preiss S, Salzmann GM. One-step autologous minced cartilage procedure for the treatment of knee joint chondral and osteochondral lesions: A series of 27 patients with 2-year follow-up. *Orthop J Sports Med* 2019;7:2325967119853773.
7. Domínguez Pérez JM, Fernández-Sarmiento JA, Aguilar García D, et al. Cartilage regeneration using a novel autologous growth factors-based matrix for full-thickness defects in sheep. *Knee Surg Sports Traumatol Arthrosc* 2019;27:950-961.
8. Salzmann GM, Calek A-K, Preiss S. Second-generation autologous minced cartilage repair technique. *Arthrosc Tech* 2017;6:e127-e131.
9. Jones DG, Peterson L. Autologous chondrocyte implantation. *J Bone Joint Surg Am* 2006;88:2502-2520.
10. Lu Y, Dhanaraj S, Wang Z, et al. Minced cartilage without cell culture serves as an effective intraoperative cell source for cartilage repair. *J Orthop Res* 2006;24:1261-1270.
11. De Girolamo L, Bertolini G, Cervellin M, Sozzi G, Volpi P. Treatment of chondral defects of the knee with one step matrix-assisted technique enhanced by autologous concentrated bone marrow: In vitro characterisation of mesenchymal stem cells from iliac crest and subchondral bone. *Injury* 2010;41:1172-1177.
12. Grechenig S, Worlicek M, Penzkofer R, et al. Bone block augmentation from the iliac crest for treatment of deep osteochondral defects of the knee resembles biomechanical properties of the subchondral bone. *Knee Surg Sports Traumatol Arthrosc* 2019;27:2488-2493.
13. McCarthy HS, Richardson JB, Parker JCE, Roberts S. Evaluating joint morbidity after chondral harvest for autologous chondrocyte implantation (ACI): A study of ACI-treated ankles and hips with a knee chondral harvest. *Cartilage* 2016;7:7-15.
14. Niemeyer P, Pestka JM, Kreuz PC, et al. Standardized cartilage biopsies from the intercondylar notch for autologous chondrocyte implantation (ACI). *Knee Surg Sports Traumatol Arthrosc* 2010;18:1122-1127.
15. Aurich M, Hofmann GO, Best N, Rolauffs B. Induced redifferentiation of human chondrocytes from articular cartilage lesion in alginate bead culture after monolayer dedifferentiation: An alternative cell source for cell-based therapies? *Tissue Eng Part A* 2018;24:275-286.
16. Cole BJ, Farr J, Winalski CS, et al. Outcomes after a single-stage procedure for cell-based cartilage repair: A prospective clinical safety trial with 2-year follow-up. *Am J Sports Med* 2011;39:1170-1179.
17. Levinson C, Cavalli E, Sindi DM, et al. Chondrocytes from device-minced articular cartilage show potent outgrowth into fibrin and collagen hydrogels. *Orthop J Sports Med* 2019;7. 2325967119867618.
18. Hurley ET, Davey MS, Jamal MS, Manjunath AK, Alaia MJ, Strauss EJ. Return-to-play and rehabilitation protocols following cartilage restoration procedures of the knee: A systematic review. *Cartilage* 2019;Dec 19:1947603519894733.
19. Albrecht FH. Closure of joint cartilage defects using cartilage fragments and fibrin glue. *Fortschr Med* 1983;101:1650-1652 [in German].
20. Wang N, Grad S, Stoddart MJ, et al. Particulate cartilage under bioreactor-induced compression and shear. *Int Orthop* 2014;38:1105-1111.
21. Everhart JS, Campbell AB, Abouljoud MM, Kirven JC, Flanigan DC. Cost-efficacy of knee cartilage defect treatments in the United States. *Am J Sports Med* 2020;48:242-251.
22. Christensen BB, Foldager CB, Olesen ML, Hede KC, Lind M. Implantation of autologous cartilage chips improves cartilage repair tissue quality in osteochondral defects: A study in Göttingen minipigs. *Am J Sports Med* 2016;44:1597-1604.
23. Krych AJ, Pareek A, King AH, Johnson NR, Stuart MJ, Williams RJ. Return to sport after the surgical management of articular cartilage lesions in the knee: A meta-analysis. *Knee Surg Sports Traumatol Arthrosc* 2017;25:3186-3196.
24. Darling EM, Athanasiou KA. Rapid phenotypic changes in passaged articular chondrocyte subpopulations. *J Orthop Res* 2005;23:425-432.
25. Irwin RM, Bonassar LJ, Cohen I, et al. The clot thickens: Autologous and allogeneic fibrin sealants are mechanically equivalent in an ex vivo model of cartilage repair. *PLoS One* 2019;14:e0224756.
26. Smith PA. Intra-articular autologous conditioned plasma injections provide safe and efficacious treatment for knee osteoarthritis: An FDA-sanctioned, randomized, double-blind, placebo-controlled clinical trial. *Am J Sports Med* 2016;44:884-891.