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Arthroscopic implantation of a three dimensional scaffold for autologous chondrocyte transplantation

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Abstract The arthroscopic M-ACT technique is applicable for defects at the femoral condyle up to 5 cm². The size of the defect has to be assessed with a specific scaled, percutaneously inserted needle. Then an 8 mm water-stop-cannula is positioned in a suprameniscal portal. The chondrocyte seeded matrix is trimmed to size the defect. The scaffold is introduced in the joint through the cannula and placed into the defect with a blunt arthroscopic grasp instrument to prevent damage of the scaffold. Then a specific drill guide is inserted through an additional anteromedial portal to place it on the scaffold in a perpendicular angle. The position of the drill guide should not be changed during the next two steps. It may be helpful to hold the matrix in place with a probe inserted through the cannula. A 1.5 mm K-wire is drilled at least 16 mm into the subchondral bone. Then the biodegradable pin (length 16 mm) is placed in the drill guide and carefully hammered into the subchondral bone. The joint is flexed so that the drill guide can be placed on the posterior end of the scaffold. Another hole is drilled with the K-wire and a second pin is inserted. Finally the stability of the matrix is tested with a probe and the joint is mobilized.

Keywords Arthroscopic M-ACT technique · Femoral condyle defect · Chondrocyte seeded matrix · Biodegradeable pin

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Introduction

Autologous chondrocyte transplantation (ALT) was introduced by Brittberg et al. [2] as a method for the treatment of chondral defects. In a first arthroscopy a small sample of cartilage has to be harvested. The biopsies were digested and the chondrocytes were cultured in vitro to increase the number of cells. After app. 4 weeks the cells were implanted back into the chondral defect. During this surgical procedure an arthrotomy was performed to inject the cells below a periosteal flap that was sutured to the surrounding cartilage. In this study 14 of 16 patients with a femoral defect are presented with good to excellent results [2]. These results could be confirmed later by prospective clinical studies with a larger number of patients and a longer follow up. However, these studies released some disadvantages of this technique which were associated with the use of periosteum. First, for harvesting the periosteum a large incision was needed. Secondly, for the fixation of the periosteum with sutures an arthrotomy was performed. Thirdly, Peterson et al. [6] observed hypertrophy of the periosteum in 26 of 101 patients.

During the recent years new techniques were developed to eliminate these disadvantages [3, 4]. All these techniques use a biodegradable matrix with seeded chondrocytes instead of the periosteum to cover the defect (Bioseed C™, MACI™, Novocard™, Hyalograft™). With these scaffolds the size of the skin incision was reduced. Another advantage of the use of the matrices is that the chondrocytes have fewer tendencies to differentiate due to the three dimensional culture conditions. Most authors still use an arthrotomy for the implantation of the cell seeded matrix [2]. There are only few reports about arthroscopic techniques for the implantation of a matrix seeded with chondrocytes [3, 4]. One of these techniques is technically demanding

[3]; the other technique uses only adhesion forces for the fixation of the graft [4]. A disadvantage of this technique could be the low stability of the grafts.

This article describes a new arthroscopic technique for the implantation of a cell seeded biodegradable matrix. The matrix is composed of a fibrin gel and a mesh of vicryl fibers (Bioseed C™). For the fixation of the matrix a biodegradable pin was used that was originally developed for the fixation of osteochondral defects (SmartNail®, Linvatec, Conmed™). With this technique an easy and stable fixation of the chondrocyte seeded matrix is possible.

Surgical technique

The arthroscopic M-ACI is a two staged surgery. In a first arthroscopy, the defect is assessed carefully to find out if there is an indication for an M-ACI. We perform M-ACI in patients with localized chondral defects with a minimum size of 2 cm² after failed microfracture. For the arthroscopic technique the size of the defect should not be greater than 5 cm². Osteoarthritis or malalignment is a contraindication. If there is an indication for M-ACI, a small biopsy of healthy cartilage is obtained from the non weight bearing cartilage adjacent to the femoral notch. Harvesting of the cartilage can be performed with a spoon or a curette. Then the cartilage biopsy is send to the laboratory, cells are isolated and cultured on a monolayer, transferred to a fibrin gel (human Tissucol, Baxter) and then incorporated into a three dimensional polymer scaffold (Bioseed C™). The scaffold contains 3–4 million vital cells/cm² and the fibrin gel is absorbed in appr. 14 days. The three dimensional scaffold is built of vicryl and PDS reinforcements that are degraded after 3 and 6 months, respectively.

After cultivation of the scaffold, a second surgery is needed. A high anterolateral portal is created and a standard arthroscopy is performed in supine position. The arthroscopic M-ACT technique is applicable for defects at the medial and lateral femoral condyle. After a complete inspection of the joint and assessment of the defect, the chondral lesion is carefully debrided down to the subchondral bone with a curette, spoon and a shaver. A stable shoulder of the cartilage should surround the defect. A round or oval form of the defect is advantageous. The size of the defect has to be assessed with a specific scaled needle as described by Erggelet et al. [3] (Fig. 1a). This needle can

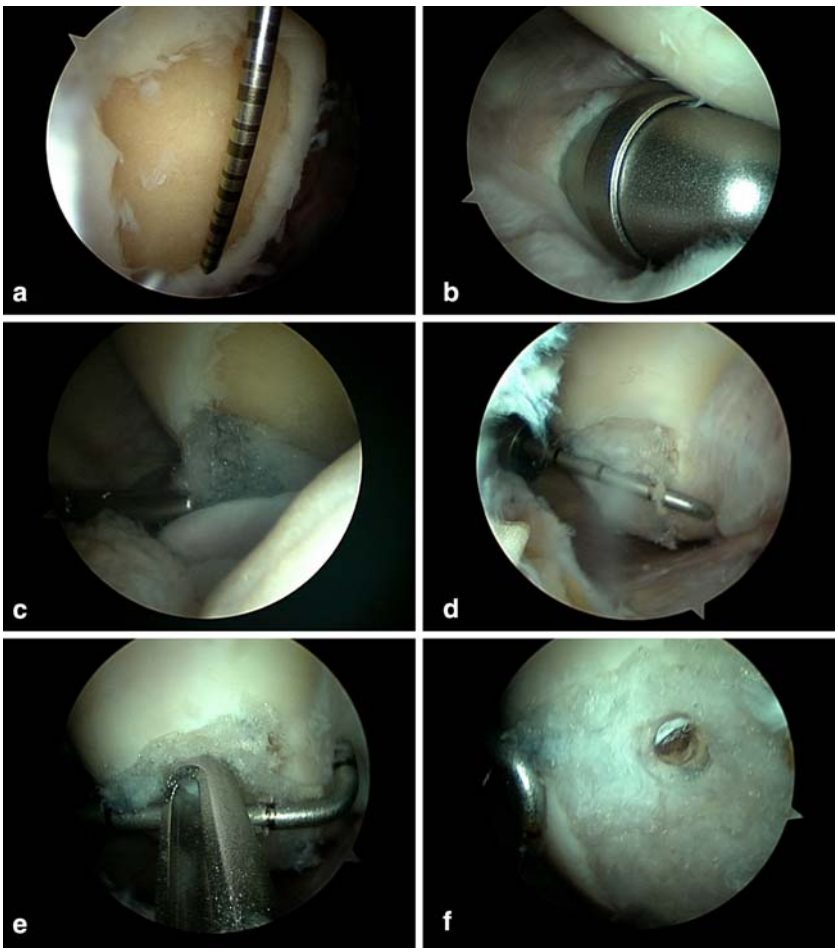

Fig. 1 **a** Measurement of the defect size with a specific needle which can be inserted percutaneously in all necessary angles. **b** Insertion of a water stop cannula in the medial suprameniscal portal. **c** The scaffold is introduced through the water-stop-cannula with a grasper. **d** The matrix can be held in the defect with a probe which can be inserted through the medial suprameniscal portal. **e** Insertion of the drill guide (Linvatech, Conmed™) through an additional anteromedial portal. The drill guide must be perpendicular to the surface of the scaffold. **f** The scaffold is fixated with a SmartNail® (Linvatech, Conmed™)

be inserted percutaneously in all necessary angles. The needle enables precise measurement of the defect size without the need of an additional portal.

For a defect at the medial femoral condyle a medial suprameniscal portal is created (Fig. 1b). This portal is needed to introduce the matrix into the joint and it is equipped with an 8 mm water-stop-cannula (Karl Storz, Tuttlingen, Germany). This cannula is needed to introduce the scaffold into the joint.

The chondrocyte seeded matrix is then cut with scissor or scalpel to the size of the defect. The scaffold is introduced in the joint through the cannula and placed into the defect with an arthroscopic grasp instrument (Fig. 1c, d). This instrument should not be sharp to prevent damage of the scaffold. Then a specific drill guide (Linvatec, Conmed™) is inserted through an additional anteromedial portal (Fig. 1e, 2a). This portal has to be created so that the drill guide can be placed on the scaffold in a perpendicular angle. Care should be taken not to change the position of the drill guide during the next two steps. It may be helpful to hold the matrix in place with a probe which is inserted through the water-stop-cannula (Fig. 1d). A 1.5 mm K-wire is drilled into the subchondral bone. The drill-hole should have a minimum length of 16 mm. Then the biodegradable pin (length 16 mm, SmartPin, Conmed Livatec Biomaterials) is placed in the guide and carefully tapped into the subchondral bone (Fig. 1e, 2b). The pin consists out of a self-reinforced 96L/4D PLA copolymer material that biodegrades in bone tissue during 2–3 years in vivo. Then the joint is flexed so that the drill guide can be placed on the posterior end of the scaffold. Another hole is drilled with the K-wire and a second pin is inserted. In the end the stability of the matrix is tested with a probe and the joint is mobilized.

The patients start early with continuous passive motion and are mobilized with partial weight bearing on crutches between 6 and 8 weeks depending on the size of the defect.

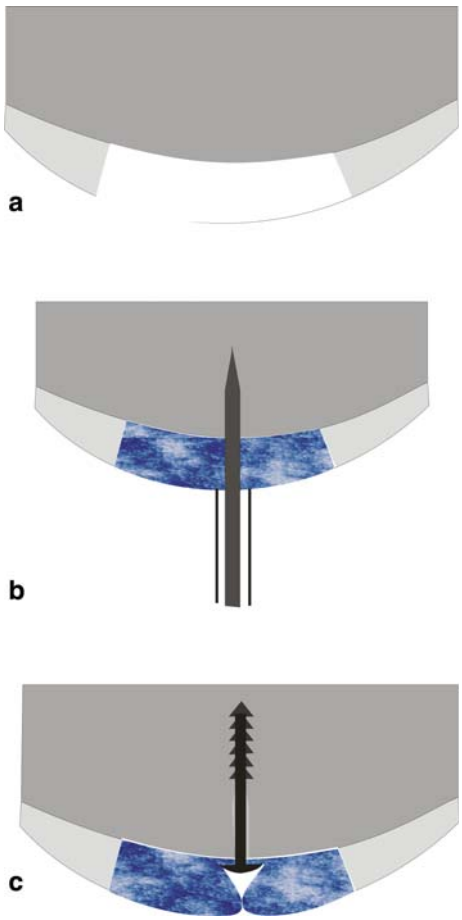

Fig. 2 **a** Schematic drawing of the drill guide, **b** SmartNail® in place

Discussion

This article presents a technique for arthroscopic implantation scaffolds that can be used for autologous chondrocyte implantation. It is well known from other procedure such as ACL reconstruction or meniscus surgery that the arthroscopic technique reduces postoperative side effects such as scar formation, adhesions and arthrofibrosis. Therefore the postoperative rehabilitation may be faster due to reduced pain and less muscular deficit [3]. However, the period of partial weight bearing should be as long as for an open technique.

In our hands the current fixation of the matrix was not as technically demanding as the transosseous anchoring technique stated by Erggelet et al. [3]. Another technique for arthroscopic M-ACI has been stated by Marcacci et al. [4]. These authors believe that only the adhesion forces are strong enough to hold the scaffold in place. Biomechanical data about fixation techniques of Marcacci et al. [4] have not been published yet.

In our clinical practise we use a biodegradable polymer fleece on which the chondrocytes are cultured and expanded for a period of 3–4 weeks. Animal studies have shown degradation of the scaffold and regeneration of the cartilage [5, 7]. However, the clinical experience with these scaffolds is limited and only short time results about the open M-ACI have been published. These results were encouraging [1]. Recently, a follow up of 3 years after ACI in chondral defects of the knee with a type I/III collagen membrane have been reported [8]. In this study the authors reported that ICRS and modified Cincinnati score showed significant improvement after 6, 18 and 36 months and concluded that ACI is an effective method in the treatment of isolated cartilage defects in the knee [8]. Gooding et al. confirmed flap hypertrophy as a possible downside of periosteum flap covered ACI as stated by Peterson et al. [6] and

showed superior results for a matrix associated ACI technique at a follow up of 24 months [9].

Hunziker [10] commented on the importance of fixation for scaffolds used for matrix associated ACI and reported a high failure rate after suturing the scaffolds to the hyaline articular cartilage borders of defects. In a recent biomechanical study we could show that the pin fixation technique provides significantly higher yield load, maximum load and stiffness than the conventional suture technique [11]. The initial fixation may be an important factor for the early postoperative period since the matrix is not integrated into bone. Sufficient structural properties of the matrix/bone construct may limit early failure of the ACI. However, the integration of the scaffolds may be reduced at the border to the intact cartilage. Here, the avascular cartilage layer may be a reason for prolonged integration of the scaffolds at the border to the intact cartilage.

A possible downside of arthroscopic fixation methods could be the opening of the subchondral bone due to the implantation of a fixation device. Theoretically, this could cause bleeding and may interfere with the regeneration of the in vitro grown cartilage. Cystic deformation within the bone has been reported in ACL reconstruction with interference screw in contact with the syniovial fluid [12]. Weiler et al. [13] stated that an osteolytic reaction is predictable for polyglycolide (PGA) implants, however, copolymer implants are associated with a lower incidence and intensity.

In conclusion, we believe that the arthroscopic technique may further improve the outcome after M-ACI.

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