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Treatment of articular cartilage lesions of the knee joint using a modified AMIC technique

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Abstract This study describes a modified AMIC technique consisting of perforations according to Pridie, rather than microfractures, and the covering of the focus of the lesion with a biological collagen patch enriched with bone marrow blood drawn through the knee itself. This technique allows advantages of both the Pridie technique and the in situ proliferation of mesenchymal cells beneath a biological collagen membrane, 'augmented', with bone marrow blood. The collagen membrane forms the roof of a 'biological chamber', and serves to protect and contains the stem cells as they differentiate into chondrocytes, which will form a healthy regenerative cartilage.

Keywords Cartilage · Perforations · Mesenchymal cell · Knee · Collagen patch · AMIC

Introduction

Articular cartilage defects of the knee are found frequently in patients who undergo a knee arthroscopy as reported by Curl et al. [8] who found an incidence of 63% of chondral lesions among 31,516 patients of all ages. However, their incidence is often underestimated because many lesions are clinically silent [1, 2]. Due to their poor spontaneous repair potential, these lesions have always presented a challenge for the orthopaedic surgeon. Several surgical techniques for the treatment of chondral defects have been proposed, but the correct indications and clinical results are still being debated in current literature [7, 15].

Wash-out and debridement is an easy and less invasive technique but benefits are often short-term [5, 16]. Marrow stimulating techniques have been suggested to expose the subchondral bone and to allow the colonisation of the defect area by pluripotential bone marrow cells [13]. Abrasion artroplasty and drilling [19] have been substituted by the more reproducible and atraumatic method of microfractures [18] according to Steadman et al. [21], and by the more recent AMIC technique [6, 12, 23], both aiming for a biological result. Osteochondral grafts are another surgical option: autografts are indicated for small chondral defects due to the morbidity at the donor site [14]; allografts provide larger constructs from cadaveric donors, and, as described previously, are contraindicated in lesions caused by diffuse degenerative processes such as osteoarthritis or inflammatory arthropathies and avascular necrosis. Autologous chondrocyte implantation, due to technological advancement and studies in cartilage repair, has allowed a significant leap in surgical methods, with good results in treating full-thickness lesions in the distal femur in patients who have had a bad outcome after other kinds of treatment [10].

The purpose of this paper is to describe a modified AMIC technique that accumulates a great number of mesenchymal stem cells into the focus of the chondral lesion by both increasing the bleeding from cancellous bone and enriching the membrane with marrow blood drawn through the lesion itself. The expectation is that the greater number of mesenchymal stem cells, protected by the collagenic membrane, will differentiate into a greater number of chondrocytes, resulting in a healthy regenerative cartilage.

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Fig. 1 Aetiology, localisation and size of defects

AETIOLOGY		
POST-TRAUMATIC	DEGENERATIVE	OSTEOCHONDRITIS DISSECANS
57%	34%	9%

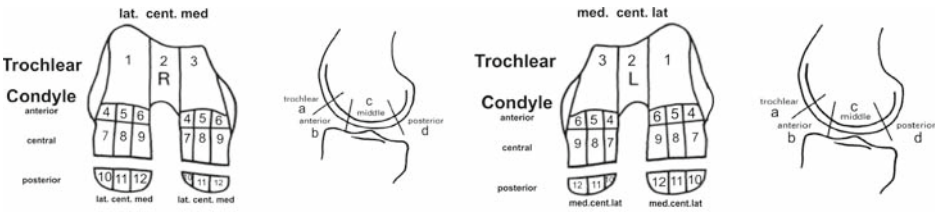
LOCALIZATION			
RIGHT KNEE		LEFT KNEE	
57%		43%	
FEMORAL CONDYLE	PATELLA	FEMORAL CONDYLE	PATELLA
48%	9%	43%	-

LESIONS DIMENSIONS	
Mean Ø minimum	1.8 cm (min 1.5 – max 2.2)
Mean Ø maximum	2.5 cm (min 2.2 – max 2.8)
Mean area (cm^2)	3.6 cm^2 (min 2.8 – max 3.9)

CHONDRAL LESION GRADE	
I	-
II	-
III	62%
IV	38%

RIGHT KNEE	
FEMORAL CONDYLE 48%	
MEDIAL	LATERAL
34%	14%

LEFT KNEE	
FEMORAL CONDYLE 43%	
MEDIAL	LATERAL
29%	14%



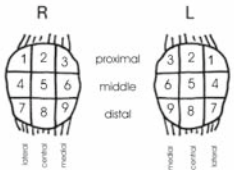
Zone 8 med	14%
Zone 6 med	10 %
Zone 5 med	5%
Zone 11 med	5%
Zone 8 lat	10%
Zone 5 lat	5%

Zone a	-
Zone b	19 %
Zone c	24%
Zone d	5%

Zone 8 med	10 %
Zone 5 med	10 %
Zone 7 med	5%
Zone 9 med	5%
Zone 5 lat	10%
Zone 8 lat	5%

Zone a	-
Zone b	19 %
Zone c	24 %
Zone d	-

PATELLA	
9%	
Zone 5R	9 %



Materials and methods

Patients

Between 2006 and 2008, a total of 19 patients treated with this technique were enroled in the present study. The inclusion criteria were the age of the patients, between 18 and 50, and the presence of a single symptomatic grade III-IV cartilage lesion, according to the ICRS classification system. The exclusion criteria were the presence of osteoarthritis, axial deviations, ligamentous injuries, complete meniscal resection and an allergy to collagen membrane components (verified with a patch test previous to surgery).

The median age of the patients enroled was 26 (18–50) years, 7 female and 12 male. The patients were checked every 15 days for the first 4 months and then every 6 months. The median follow-up period was 24 months (range 12–36).

Pre-operative and post-operative evaluation was made according to IKDC score, Lysholm Knee Scale revised version for chondral injuries [20], Ikeuchi score [11] which was modified by adding the ability to jump using the operated leg and duck-walking, and high-resolution fast spin echo cartilage-sensitive MRI measured according to Mithoefer et al. [17].

Lesions were localised in the medial or lateral femoral condyle or in the patellar articular surface. Aetiology, localisation and size of the defects are shown in Fig. 1.

Surgical technique

The modified technique consists of a one-session surgical operation. First an arthroscopic examination is performed to analyse and record the lesion according to ICRS, and to identify any additional intra-articular lesions which could not fit the inclusion criteria. As described by Steadman et al. [21], once the cartilage defect is identified, all unstable cartilage at the edge of the lesion is removed with a shaver, obtaining a firm and "well-shouldered" lesion.

A second mini-open surgery stage is then performed. Once exposed, the lesion is re-evaluated and debrided. All the calcified cartilage at the base of the lesion is carefully

removed according to Frisbie et al. [9]. A template of the lesion is then made, on which the animal-derived collagen patch (Chondro-Gide®; Geistlich) is cut to obtain optimal coverage. Perforation holes are then created using a 2-mm Kirschner wire placed perpendicular to the surface of the lesion. A homogeneous distribution of the perforations is made, with the required amount of bone bridges 3–5 mm apart, avoiding a reduction of the biomechanical integrity of the bone. When the lesion is localised on a femoral condyle, the depth of the perforations is 15 mm. This results in a greater release of mesenchymal cell-rich bone marrow blood. If the lesion is localised in the patellar articular surface, the Kirschner wire must penetrate the bone by two-thirds of its thickness. Perforations are made by hand. When treating a femoral lesion, a needle for bone marrow aspiration is inserted through one or two of the perforations [3, 4]. The needle must be inserted into the bone through the perforations to avoid a weakening of the mechanical resistance of the bone which could result from oblique samples [18]. When treating a patellar lesion, oblique insertions should be made into a low-load-bearing area on the proximal part of a femoral condyle of the affected knee in order to draw blood from shallower bone marrow. A volume of 1–2 cc of bone marrow blood is obtained into which the previously cut membrane is immersed. The quantity of blood depends on the size of the defect. During the immersion, the membrane enriches with bone marrow blood and all its components and this can be considered an "augmentation" to the bleeding of marrow blood through the perforations. Fibrin glue (Tissucol; Baxter) is then put on the defect site to attach the enriched membrane acting both as a scaffold and as a shield for the stem cells flowing from the marrow blood. This takes 3–4 min to adhere, the knee is then flexed and extended to check adherence, and the surgical wound is closed.

Results

The median pre-operative subjective IKDC score of 30 (24–40) significantly increased to an average of 83 (74–94) at 24 months post-operatively. The mean pre-operative Lysholm Knee Scale revised for chondral injuries was 54 (38–83). This score significantly increased to a median of 98 (96–100) at 24 months post-operatively. Results according to the modified Ikeuchi score were 78% excellent and good but 22% fair and poor at 24 months post-operatively, whereas the pre-operative values were 42% fair and 58% poor.

Ten post-operative MRI (53%) showed a significant reduction of the defect area, both in shape, filling, interface and subchondral oedema (Fig. 2).

Discussion

The most important finding of the present study was the method by which a maximum amount of mesenchymal cells can be accumulated into the cartilage defect area by both increasing the bleeding from cancellous bone and by enriching the membrane with marrow blood drawn through the knee itself.

The use of a collagenic membrane or a periosteal patch and fibrin glue to avoid the loss of mesenchymal cells into the joint is a well-known and well-described technique for sealing the site of an autologous chondrocyte implantation [6, 12, 22]. However, in this technique, a collagenic membrane, already enriched with bone marrow blood, is used to prevent mesenchymal cells from being lost into the joint space. The bone marrow blood with which the membrane is enriched is drawn from the surgical area itself and in the correct quantity according to the dimensions of the defect. This avoids further discomfort to the patient than would the drawing of marrow blood from, for example, the iliac crest.

Tallheden et al. [24] described that mesenchymal stem cells have the same phenotypic plasticity of one subpopulation of chondrogenic cells in the basal zone of the hyaline articular cartilage. In 1 cc of bone marrow blood drawn from femoral condyle of two 26-year-old male patients, 8,000 CD34 + stem cells were counted. The number of cells distributed on the rough part of the membrane and their potential capacity to differentiate into chondrocytes under the membrane itself is a significant consequence. The membrane acts as the roof of a 'biological chamber', and serves to protect and contain the stem cells as they differentiate into chondrocytes, which will form a healthy regenerative cartilage.

The adhesion of the collagenic matrix enriched with mesenchymal cells to the focus of the lesion is secured by the fibrin glue which could stimulate further the viability and differentiation of the stem cells [25].

Conclusion

In conclusion, this technique can be considered as simple, reproducible and without the need of a second surgery. Results according to IKDC, Lysholm Knee Scale revised for chondral injuries, Ikeuchi score and MRI evidence, suggest a good to excellent outcome for the majority of the patients with the previously described follow-up terms. These clinical results, corroborated by histological exams showing a healthy regenerative cartilage, could be compared to those of autologous chondrocyte implantation from a biological point of view. They are, however, achieved without the need of future surgery, hence

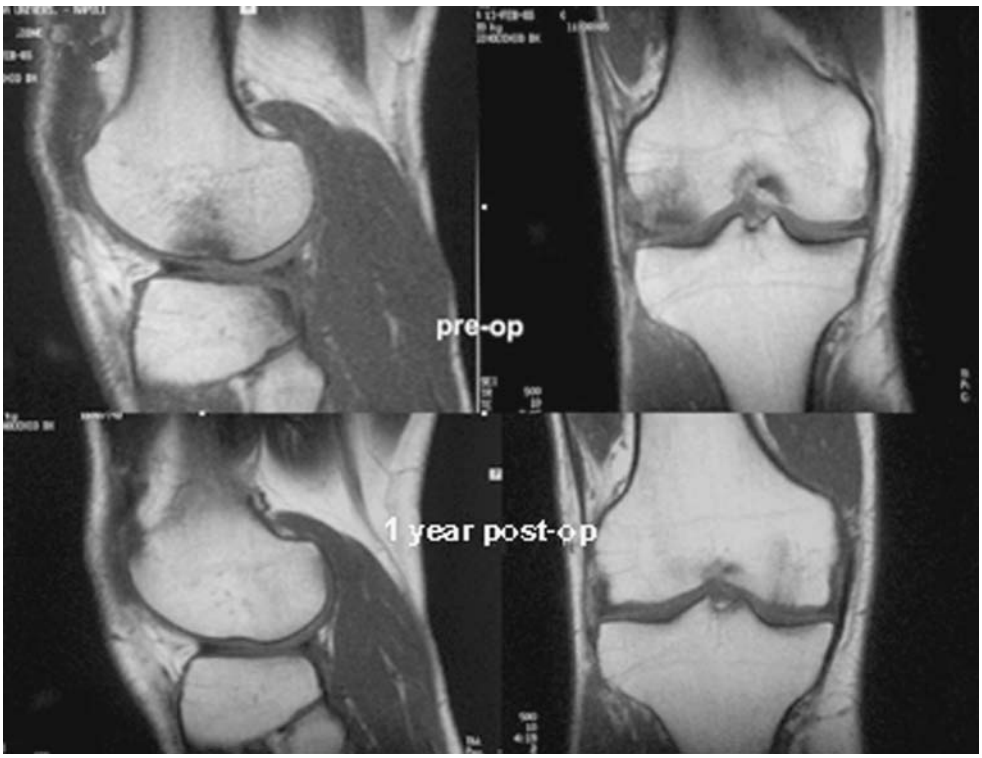


Fig. 2 Pre-operative and post-operative MRI images

avoiding further anesthesiologic procedure, hospital admission and rehabilitation programs. All this, in our experience, improves compliance of patients.

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