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Operative Techniques in
Orthopaedics

Enhanced Marrow Stimulation Techniques for Cartilage Repair

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Representing the most popular marrow stimulation technique, microfracture surgery has been established as a gold standard for the treatment of articular cartilage defects. Enhanced marrow stimulation techniques for the treatment of cartilage defects promise faster rehabilitation owing to increased initial stability of the regenerating tissue; better tissue quality, allowing for early compression, and shear stress, promoting chondrogenesis; the benefits of a single-stage procedure compared with a chondrocyte transplantation; and multiple future options to increase outcome quality, for example, with growth factor augmentation or drug release. A variety of different techniques and materials are available for arthroscopic and open surgery. To date, power and follow-up of published studies indicate stable fixation techniques but show no significant benefit over microfracture alone, which might change after 5 years when the results of microfracture seem to show degradation. The evidence for the effectiveness of the microfracture procedure alone is largely derived from case series and few randomized trials. Clinical outcomes improve with microfracture for the most part, but according to some studies, these effects are not sustained. The quality of cartilage repair following microfracture is variable and inconsistent for unknown reasons. Younger patients have better clinical outcomes and quality of cartilage repair than older patients do. The necessity of long postoperative continuous passive motion and restricted weight bearing is widely accepted but not completely supported by the evidence in the literature. Maybe a new approach to clinical evidence might be necessary. International registries should be able to create comprehensive data sets at significant lower costs and administrative hurdles, thereby promoting safe and quick implementation of new developments in the field of cartilage repair.
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Introduction

As the most popular marrow stimulation technique, microfracture surgery has been established as a gold standard for the treatment of articular cartilage defects. Multiple clinical trials show good results for microfracture, whereas other studies present a variable outcome.

The technique and initial results were published in 1994.[1] It was originally performed in patients with posttraumatic lesions of the knee that progressed to full-thickness chondral defects. Unstable articular cartilage and degenerative changes were also the indications for microfracture in the presence of normal leg alignment.

Microfracture follows the principle of bone marrow stimulation. The intrinsic repair mechanisms are activated by perforating the subchondral bone plate. As a result, the medullary bleeding carries proteins and pluripotent cells into the cartilage defect, starting a cascade of physiological cell differentiation. In vitro, the chondrogenic differentiation of subchondral progenitor cells has be proven.[2] In many cases, with the predominant existence of fibroblasts in those conglomerates, the development of fibrous cartilage is described.[3] Other studies did not support this theory.[4] Various techniques based on the simple perforation of the subchondral bone plate with a drill or a K-wire were reported in 1959 by Pridie.[5] With an intact cartilage surface, a retrograde technique should be preferred. Motorized shaver systems enable the resection of the

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superficial sclerosized layer of the subchondral bone plate to expose the healthy spongious tissue—the so-called "abrasion chondroplasty."[6] The microfracture technique was developed by Steadman using specially designed instruments to open the subchondral bone space without harming the subchondral bone plate.[7]

Although the microfracture technique is performed by many orthopaedic surgeons, clinical experience has shown that some patient populations may benefit more from it than others.

Additionally, long rehabilitation protocols and high treatment costs are no longer tolerated in today's professional environment.

To maintain the idea of using autologous cells for cartilage repair and to develop further the idea of an autologous one-step procedure to repair cartilage lesions, the use of resorbable scaffolds was developed, with an increase of primary stability owing to an initial protection of the blood clot.

Early loading of the defect area seems to be crucial for the differentiation of pluripotent cells and the chondrogenesis.[8,9]

Comparing the outcome of microfracture and scaffold-augmented microfracture with a polyglycolic acid (PGA) fleece in a sheep model showed a significant higher degree of defect filling and collagen II content in the augmented defects, with immediate full and unrestricted weight bearing postoperatively.[10]

Specially designed biomaterial scaffolds are one of the key components in tissue engineering. Current research is focused on developing bioresorbable scaffolds that exhibit optimal physical properties coupled with excellent biocompatibility. Scaffolds act as shape and guidance templates for in vitro and in vivo tissue development. For cartilage and bone tissues, a suitable scaffold provides initial mechanical stability and supports even cell distribution.

Various materials have been tested for chondral defects—collagen and polymer blends are most widely used.

Surgical Techniques

For the arthroscopic procedure, 2-3 portals are recommended: 1 for the inflow cannula and 1 each for the arthroscope and the working instruments. After assessing the full-thickness articular cartilage lesion, the exposed bone is debrided of all remaining unstable cartilage. A full-radius resector or a handheld curved curette or both are used to debride loose or marginally attached cartilage to form a stable perpendicular edge of healthy cartilage around the defect (Fig. 1). The crater surrounded by normal cartilage forms a pool that helps to hold the bone marrow clot. Thorough and complete removal of the calcified cartilage layer is extremely important according to Frisbie et al[11] (Fig. 2). To avoid excessive damage to the subchondral bone, an arthroscopic awl is then used to make multiple perforations, or microfractures, into the exposed subchondral bone plate[12] (Fig. 3). The holes should be placed 3- to 4-mm apart without breaking the subchondral bone plate between them. Fat emerging from the marrow cavity indicates the appropriate depth (2-4 mm of penetration). Thermal damage to the bone does not occur with this technique. When the blood flow from the bone marrow seems to be adequate in all areas of the defect after reducing the irrigation fluid pressure, the procedure is terminated (Fig. 4). Intra-articular drains are not recommended.

New research indicates a better quality of the repaired tissue after subchondral drilling down to 1 cm using a 2-mm drill or smaller.[13]

Once the suchondral bone is opened by fracturing or drilling, the scaffold is cut and prepared according to the size of the defect and implanted. Arthroscopic and open techniques are available.

These matrices may be fixed by autoadhesion, with fibrin glue, sutured or anchored transosseously. Biomechanical and preclinical studies showed that the stability of fixation varies tremendously with obvious clinical implications.

Various techniques are currently used for the implantation of matrices (availability may vary from country to country):

1. After debriding the defect, a size-matching scaffold is sutured or glued into the defect. Different materials may simply be attached by adhesion forces.
2. After the exact determination of the defect size, a matching implant is prepared. The implant will then be prearmed with resorbable threads (eg, Vicryl), which are to be knotted using a special technique. Anchoring holes will be placed anterogradely or tibially using a guide instrument. After the insertion of pulling threads, the prearmed matrix is anchored within the defect by pulling the knots into the holes for a press-fit fixation[14] (Figs. 5 and 6).
3. Stable matrices enable a fast and stable but more costly fixation with intraosseous pins (Smart Nail, Lead Pin) (Figs 7-10).

One of the first studies to examine the stability of implants for cartilage repair was done by Driesang in 2000.[15] He applied autologous chondrocyte transplantation with a periosteal flap in goats and discovered that all sutured flaps ($n = 6$ animals) became detached from nonimmobilized joints during the recovery period. The purpose of this study further was to ascertain whether postoperative restriction of joint movement could prevent the delamination of flaps. Partial-thickness defects were created in the knee joint cartilage of 27 goats. These defects were then filled with a fibrin matrix and covered with periosteal ($n = 6$) or fascial ($n = 21$) flaps, which were sutured with simple, interrupted stitches to the surrounding tissue. The joints were immobilized by means of a modified Robert Jones bandage for periods of 2-6 weeks, after which time, they were inspected for the absence or presence of flaps. In 4 animals, joint immobilization for 3 weeks was followed by free movement for a similar period. Overall, 4 of the 6 periosteal flaps and 2 of the 21 fascial ones became delaminated after the period of immobilization. In the 4 goats permitted 3 weeks of free joint movement following a similar period of joint immobilization, all flaps (which had been retained up to the end of the immobilization period) became detached. These findings indicated that joint immobilization hinders the delamination of flaps but that this restriction of movement