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Arthroscopic Technique for Matrix-Induced Autologous Chondrocyte Implantation for the Treatment of Large Chondral Defects in the Knee and Ankle

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Matrix/membrane-induced autologous chondrocyte implantation (MACI) is a new biotechnology allowing the impregnation of autologous cultured chondrocytes onto a purified collagen membrane. The MACI implant is fixed with fibrin glue, and little or no suturing is necessary. The procedure can be performed arthroscopically or by miniarthrotomy. The use of magnetic resonance imaging shows progressive signal change with progressive loss of subchondral edema. Histologically a "hyaline-like" cartilage similar to autologous chondrocyte implantation was produced. Specialized instrumentation has been developed to allow for easy arthroscopic implantation of the MACI membrane.

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KEYWORDS ●●●

Large, full-thickness articular cartilage defects greater than 2.5 to 3.0 cm² can pose a special problem in the young and middle-aged population. These lesions often are too large for marrow stimulation or osteochondral autologous transplantation procedures to be predictably successful. Untreated, these lesions often progress to posttraumatic arthritis¹ and disability.

Autologous chondrocyte implantation (ACI), first reported by Brittberg and coworkers in 1994,² has yielded good-to-excellent results in greater than 77% of the cases of deep chondral lesions (92% in isolated femoral condyle lesions) with more than 9 years' follow-up.^{3,4} ACI is a 2-stage process. It requires arthroscopic harvesting of articular chondrocytes. The chondrocytes are cultured, expanded, and reimplanted by arthrotomy. A periosteal graft must be harvested and sutured in place over the chondral defect in a "water-tight" manner (2-3 mm apart). The cultured autologous chondrocytes are then injected into the defect and the arthrotomy incision is closed. This action often requires a wide arthrotomy incision to allow for proper suturing of the periosteal patch. Complications such as intraarticular adhesions, periosteal hypertrophy and delamination of the defect have been reported.³

Matrix/membrane-induced autologous chondrocyte implantation (MACI) is a new biotechnology allowing the impregnation of autologous cultured chondrocytes onto a highly purified porcine collagen I/III membrane. (Verigen AG, a wholly owned subsidiary of Genzyme Corporation, Cambridge, MA.) The MACI implant is fixed with fibrin glue (no or little suture is necessary) and can be performed arthroscopically or by mini-arthrotomy. No periosteal graft is needed. MACI offers access to certain areas where suturing of a periosteal flap is difficult or even impossible.

Open Technique

Chondrocytes are harvested arthroscopically from a nonweight-bearing area of the ipsilateral knee (200-300 mg of healthy cartilage). The chondrocytes are then cultured and expanded and then impregnated on an absorbable bilayer-purified porcine collagen I/III membrane. The bilayer structure has a smooth side acting as a natural barrier and faces the joint, and a porous side, which faces the bone. Chondrocytes are seeded in the porous side of the membrane in a 3-dimensional type of matrix. The membrane is tear resistant and can be cut to shape. The membrane is nonantigenic (telopeptides are split off during the manufacturing process) and is bioabsorbable.

The membrane can be fixed to the cartilage with fibrin glue, pins, or suture. Using an open arthrotomy or miniarthrotomy, the cartilage defect is curetted to remove the calcified

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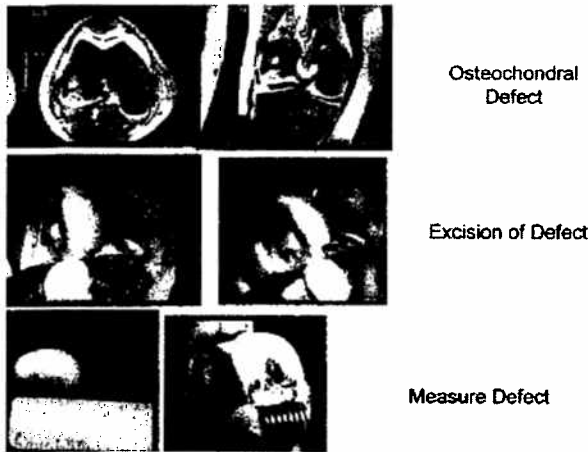


Figure 1 Identification of the defect.

cartilage layer. A stable cartilage rim with sharp, vertical walls of healthy cartilage is created, and the chondral defect is templated and the MACI membrane is cut to the proper shape with a scissors (Figs. 1-4).

The membrane is then fixed in place with fibrin glue (Tisucol, Baxter, Spain). Suture and/or bioabsorbable pins may also be used, but fibrin glue by itself is all that is usually needed. (Figs. 5 and 6). Postoperatively the patient is placed on continuous passive motion (when available) and is kept to nonweight-bearing activity for 12 weeks.



Figure 2 Templating and cutting of the MACI implant.



Figure 3 Cartilage defect of femoral condyle.



Figure 4 Curette the defect. Create a stable cartilage rim with sharp vertical walls.

Arthroscopic Technique

After previous biopsy and culturing of chondrocytes, a standard arthroscopy is performed using a specially designed arthroscopic canula, the cartilage defect is curetted, using ring curettes, to remove the calcified cartilage layer. A stable cartilage rim with sharp vertical walls of healthy cartilage is created. Using a specially designed caliper (Fig. 7) and flexible ruler, the size of the lesion is calculated. A template is created (using the packaging from a suture pack) and placed in the cartilage defect to test for size. The membrane is then cut to size to match the template.

Using a "dry scope," the area of the cartilage defect is visualized (ambient air, no insufflation). Two small "mini anchors" with 5-0 Dexon suture are placed at the opposite sides of the periphery of the cartilage lesion (3 and 9 o'clock or 12 and 6 o'clock). The sutures are then passed through the MACI membrane at corresponding points to the cartilage lesion. Using the specially designed articulated passer, the membrane is guided down the suture to the cartilage defect. The membrane is then smoothed out using an articulated "T"



Figure 5 Fibrin glue applied.

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Figure 6 MACI membrane implanted in femoral condyle.

smoother/tamper. Fibrin glue (Tisucol, Baxter, Spain) is then placed under the membrane. The membrane over the area grafted is smoothed out to the contours of the cartilage defect.

The articulated inserter is used to hold the grafted MACI membrane in place, and the "T" smoother is used to remove the excess glue and assure that the periphery of the graft is well fitted and securely glued in place. The 2 sutures are then tied over the MACI graft using arthroscopic knot tying technique. Pressure is applied for 6 or 7 minutes to allow the fibrin glue to fully set. The joint is taken through several ranges of motion to assure the graft is stable (Figs 8–11). For easily accessible lesions, the membrane can be pushed down the canula and held in place by fibrin glue and bioabsorbable pins.

Recently, we have developed new instrumentation that allows the MACI membrane to be pierced in its center and then place it in the center of the cartilage defect. The membrane is then pushed down the canula with a slotted articulated inserter and held in place by the arthroscopic "skewer" (Figs. 12–14). Fibrin glue is then placed under the MACI membrane, and the membrane is smoothed out. The excess glue is removed, and the membranes contour to the cartilage defect while the fibrin glue is setting.

Conclusions

To date, 92 MACIs have been performed at the Clinica CEMTRO, Madrid, Spain (82 knees, 10 ankles). The first 50



Figure 7 Arthroscopic caliper.

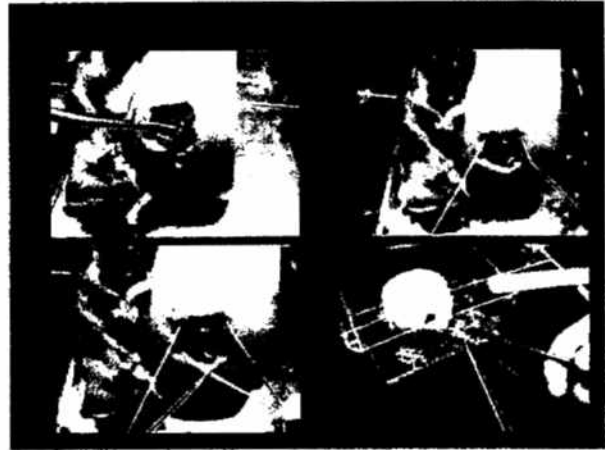


Figure 8 Lesion curretted and suture anchors placed. Lower right, membrane being placed.

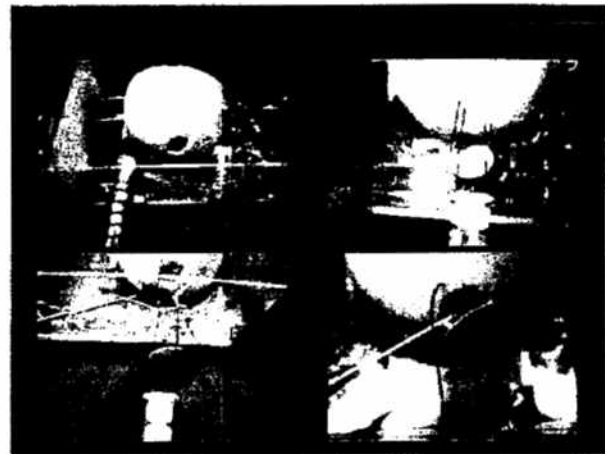


Figure 9 Placement of membrane and fibrin glue.



Figure 10 Securing the membrane.

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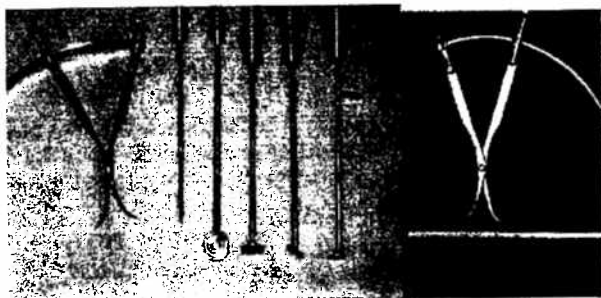


Figure 11 Arthroscopic MACI instrumentation.

cases have been evaluated and reported (42 knees, 8 ankles). Defects were large grade 3 (severely abnormal, 50% cartilage depth) or grade 4 (severely abnormal extending to the subchondral bone) chondral defects (International Cartilage Repair So-



Figure 12 MACI graft inserted into femoral condyle.



Figure 13 MACI graft held in place while glue is setting.



Figure 14 MACI autologous chondrocyte implant.

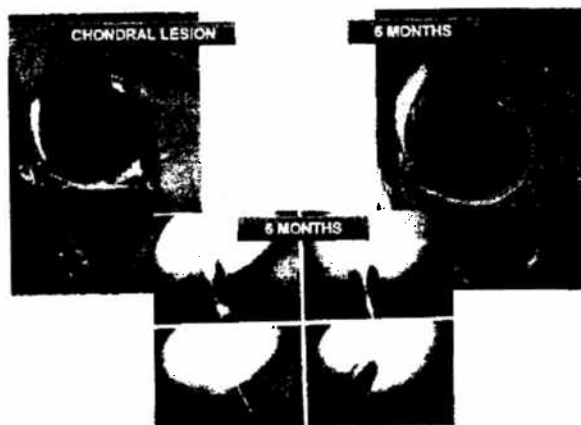


Figure 15 MRI and 6-month "second-look" arthroscopic appearance of MACI implant.

ciety). The size of the knee lesions varied from 2.5 cm² to 20 cm². The ankle lesions varied from 3 cm² to 6 cm².

Pain levels before surgery (Visual Analog Scale) had 32 patients (64%) at pain levels greater than 6. At follow-up, only 2 of the patients (4%) related pain at a level greater than 6. A total of 70% of all patients reported a pain level 0 to 3. Most of the patients had previous surgeries but, of the patients without a previous chondral procedure, 89% had no or minimal pain. There were no cases of infection, delamination, or phlebitis. Progressive signal change was shown on magnetic resonance imaging, with progressive loss of the subchondral edema (Fig. 15). Biopsies showed immature chondrocytes and immature cartilage that was "hyaline-like" in appearance. The results of the current MACI procedure seem to parallel the results of our previous 152 ACI procedures performed at the Clinica CEMTRO (and other published results of various cartilage treatments).

MACI appears to be a viable treatment for large deep full-thickness chondral and osteochondral defects of the knee and ankle in the young and middle-aged population. It appears to be a viable alternative to ACI and does not require periosteal harvest or suturing. The MACI procedure is a simple procedure that can be performed by arthroscopy or mini-arthrotomy and can be implanted in sites that suturing of a periosteal patch would be difficult or impossible. New arthroscopic instrumentation makes implantation of autologous chondrocytes a relatively easy arthroscopic procedure.

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