

Repair of articular defects by perichondrial grafts: Experiments in the rabbit

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A defect was created in the articular cartilage of the rabbit knee leaving the subchondral bone intact. The lesion was repaired by an autologous graft of costal perichondrium and fixed with fibrin glue. The result was compared with a nontreated defect in the contralateral knee.

In 26 out of 30 knees, graft fixation proved to be adequate. In the grafted group the perichondrium developed macroscopically and histologically into normal hyaline cartilage. The nongrafted defects showed only limited repair.

Most clinical investigators have found that injuries of hyaline cartilage will heal with fibrous tissue or fibrocartilage (Campbell 1969, Salter et al. 1980). Perichondrium has been used, in conjunction with various kinds of graft fixation, to restore cartilage defects in animals and man (Ritsilä and Alhopuro 1975, Skoog and Johansson 1976, Tajima et al. 1978, Pastacaldi and Engkvist 1979, Wilbrand and Engkvist 1979, Engkvist and Johansson 1980, Johansson and Engkvist 1981, Sully et al. 1980, Kon 1981, Hvid et al. 1981, Jackson 1981, Seradge et al. 1984). Only a few experiments have been carried out to compare the results of perichondrial arthroplasty with spontaneous healing (Engkvist 1979, Engkvist and Wilander 1979). In these studies the defect was made in the subchondral bone, whereas in the clinical situation the subchondral bone is mostly intact.

We compared the results of perichondrial arthroplasty with spontaneous healing of defects in intact subchondral bone.

Materials and methods

Thirty rabbits, crossbred Flemish giants, weighing 3.5–5 kg, were used. All but 1 were male, 16–20 weeks old, with the epiphyses still open. Anesthesia was given by intravenous injection of ketamine hydrochloride (100 mg/kg) and diazepam (8 mg/kg). Before the oper-

ation, 200 mg/kg ampicillin was given prophylactically. Arthrotomy of both knees was performed by a medial parapatellar incision, and the patella was dislocated laterally. A cartilage defect measuring 10 x 5 mm was created in the intercondylar groove down to the subchondral bone.

Subsequently, a strip of perichondrium was dissected from the cartilaginous part of one of the lower ribs and kept in a normal saline solution. Tissucol[®], a human fibrin glue, was prepared by mixing fibrinogen (70–110 mg/mL) and aprotinin (3,000 KIE/mL) and thrombin (4 IU) with calcium chloride (40 mmol/L). After heating to 37 °C, the mixture was applied to the defects. The perichondrial graft was placed in the defect with the chondral side facing the knee joint and firmly pressed against the subchondral bone for 1 min (Figure 1). The defect in the left knee was left untreated. The right knee was immobilized by external fixation by

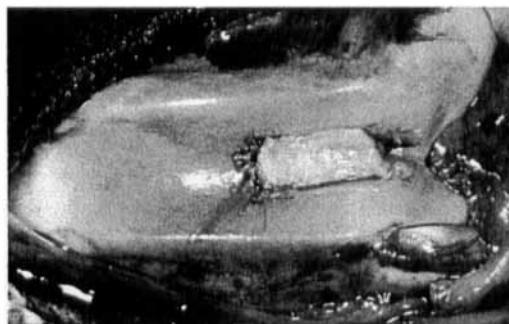


Figure 1. A piece of perichondrium has been placed in a cartilage defect of the intercondylar groove of a rabbit knee. The chondral side is facing the knee joint.

Kirschner wires through the distal femur and proximal tibia connected by medial and lateral bars. Two weeks later, the device was removed and the rabbits were left to move freely about in their cages.

The animals were killed after 1, 2, and 4 months, giving three groups of 10 rabbits. The graft was examined macroscopically and compared with the appearance of the control defect. One biopsy was taken from the grafted site, one from the femoral condyle of the same knee, and one from the nongrafted defect of the control knee. The specimens were fixed in neutral formalin, embedded in paraffin, sectioned at 10 μm , and stained with hematoxylin-eosin, safranin O-fast green, and Alcian blue-PAS (Burck 1981). Microscopic examination focused on the tissue, orientation of the cells, formation of palisades, number of cells in the deep and superficial layers, and cytologic features. Matrix production in the different layers was judged according to safranin-O staining (Rosenberg 1971). Acid mucopolysaccharide production, indicating the formation of cartilaginous tissue, was assessed by Alcian-blue staining (Erronen 1978).

Results

Four of the 30 grafts had dislocated to form hyaline-like loose bodies in the knee. One rabbit developed a septic arthritis, and in 1 rabbit the right leg was paralytic after the operation. (This complication was probably caused by a misrouted Kirschner wire of the external fixation device perforating the sciatic nerve).

One month (n = 7). An elevated, white, soft tissue had developed at the graft site. Microscopically, a thick layer, average 1210 μm , was seen with mainly fibrocyte-like cells with oval-shaped cells at the base (Figure 2). No specific organization, such as in hyaline cartilage, could be observed. Intense matrix staining was present in all the layers. The specimens taken from the medial femoral condyle showed normal hyaline cartilage with an average thickness of 340 μm . In the control defect, only a very thin veil of fibrous tissue was found at the bottom. Histologically, spindle-like cells were seen without any signs of matrix production.

Two months (n = 9). Upon gross examination the grafted area was at the same level as the surrounding cartilage. Microscopically, the average graft thickness had decreased to 710 μm . Most of the cells resembled chondrocytes (Figure 3). In the basal layer, palisade formation had started. The average thickness of the cartilage biopsy of the medial femoral condyle of the right knee was 380 μm . The control defect of the left knee remained clearly visible owing to its depressed level and irregular surface. In 7 of the control specimens the cells were oval shaped and the matrix was

stained only slightly. In the remaining 3, spindle-like cells, resembling fibrocytes, were arranged in parallel in a nonstaining matrix.

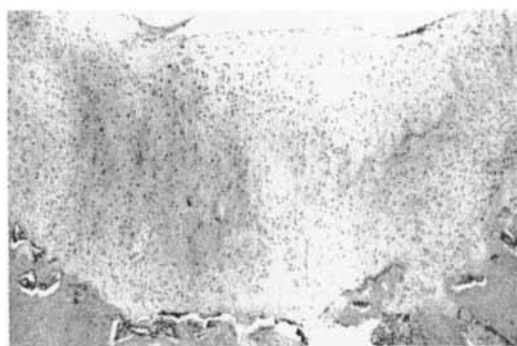
Four months (n = 10). Normal-appearing cartilage had formed out of the perichondrium. This was microscopically confirmed (Figure 4). This neocartilage (average thickness 410 μm) resembled closely the specimens taken from the medial femoral condyle (average thickness 440 μm). The control defects showed only partial repair (average thickness 190 μm). In the latter, only incompletely differentiated mesenchymal cells were seen without any sign of matrix production (Figure 5). In 4 specimens, a thin layer of chondrocytes were randomly distributed in a sparsely stained matrix (Figure 6).

Discussion

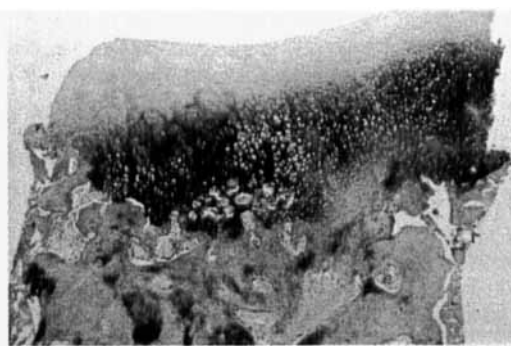
This study confirms that perichondrium can be used to repair articular cartilage defects. The histologic development of perichondrium to cartilage is similar to that described by Ohlsén (1983). In our experiments, we found great variation in graft thickness, cell number, and morphology at the same stage of repair. This reflects that there is a great variation between knees, although ultimately resulting in hyaline cartilage. We did not expose the cancellous bone by removing the subchondral bone. This did not impair the ingrowth of the graft as supposed by Engkvist et al. (1979). Chondral lesions of the human knee do not usually affect the subchondral bone. In repairing these defects, it might be important to leave the subchondral bone intact, because it may play an important role in preventing cartilage degeneration (Radin 1986).

Graft fixation is a problem in perichondrial arthroplasty of major joints like the knee. Fibrin glue gives a firm fixation of the graft when combined with an external fixation device for 2 weeks, as demonstrated by Widenfalk et al. (1986).

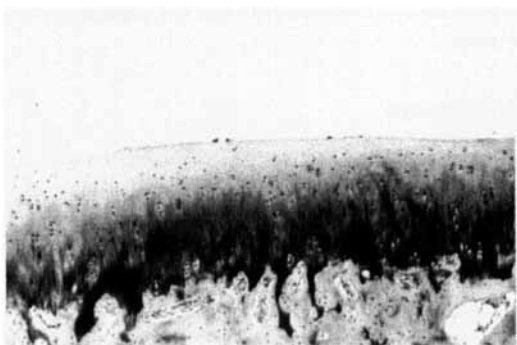
This study dealt with the macroscopic and histologic results during periods up to 4 months. A comparison with the results of spontaneous healing of a chondral lesion proved the superiority of the grafting. The findings in the nontreated defect were similar to those described by Salter et al. (1980), who perforated the subchondral bone. The viscoelastic properties of tissues derived from perichondrium have been shown to approach the properties of normal articular cartilage (Woo et al. 1987). More recently, Amiel et al. (1988) demonstrated that after 1 year the neocartilage formed from perichondrium is morphologically and biochemically similar to normal hyaline cartilage. Whether perichondrial grafting of defects, e.g., in arthrosis, can give the same results remains to be demonstrated.



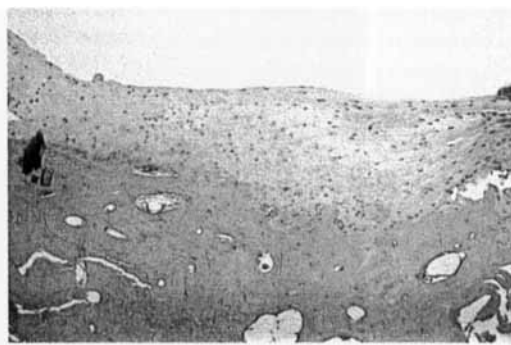
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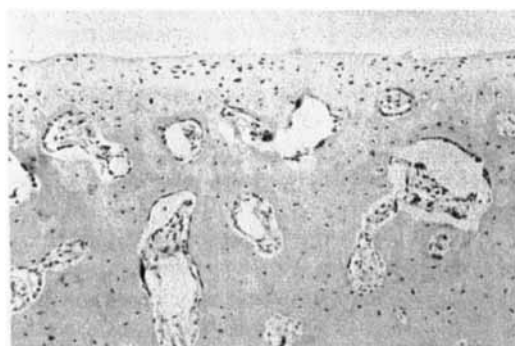
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Figure 2. Condylar specimen 1 month after perichondrial grafting. Note the very thick tissue with fibrocyte-like cells. HE, x144.

Figure 3. Biopsy specimen 2 months postoperatively. All the layers are densely filled with chondrocytes. Safranin O, x144.

Figure 4. Four months after grafting. A normal hyaline cartilage structure has been formed. HE, x144.

Figure 5. Nontreated control defect after 4 months. A fibrous tissue layer has been formed. HE, x144.

Figure 6. Nontreated control defect after 4 months. A thin layer with atypically arranged chondrocytes. HE, x144.

Table 1. Quantitative data of histologic specimens of the tissue formed after perichondrial grafting—a cartilage biopsy of the right knee and spontaneous healing of a nontreated cartilage defect of the left knee. Thickness was measured in the middle of the graft or defect. Cells were counted over an area of 0.5 x 0.05 mm. Values are mean and *SD*

	Graft thickness		Number of cells per mm ²				Percentage chondrocytes	
	Mean	SD	Deep		Superficiality		Mean	SD
Perichondrium	230	20	1040	140	710	64		
4-week graft	1210	360	1812	808	1226	396	32	27.1
Cartilage	340	60	1560	266	1240	560	100	
8-week graft	710	440	335	84	1890	11	83	28.4
Cartilage	380	180	1446	434	1160	386	94	14.0
16-week graft	410	240	1028	290	834	252	100	
Cartilage	440	260	1088	328	952	128	100	
Defect, left knee	190	140	1458	516	1342	542	37	30.6

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