Articular cartilage changes following meniscal lesions

Repair and meniscectomy studied in the rabbit knee

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A well-defined, longitudinal lesion in the avascular part of the medial meniscus of the right knee was made in 30 rabbits. After 3 months, the lesion was repaired surgically in 12 rabbits, was untreated in 12 rabbits, and a meniscectomy was performed in 6 rabbits. The articular cartilage was studied macroscopically and microscopically at 3-month intervals. Cartilage changes 3 months after meniscectomy were more pronounced than after meniscal repair or than in untreated lesions. However, meniscal repair did not reverse the cartilage changes.

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Submitted 90-10-20. Accepted 91-02-25

Repair of lesions in the peripheral vascular part of the meniscus has become routine (Hamberg et al. 1983), and it reduces the risk of long-term cartilage degeneration (DeHaven et al. 1989). Lesions in the avascular part of the meniscus do not heal spontaneously (King 1936, Arnoczky and Warren 1983), and their healing is uncertain after being sutured (Veth et al. 1983). Animal models of both immediate (Kawai et al. 1989) and delayed repair (Hede 1991) have been developed. Whether or not repair of old lesions in the avascular area will prevent cartilage degeneration has not been clarified.

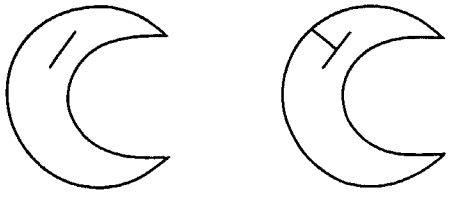
We have assessed the reaction of the knee joint cartilage to a well-defined experimental meniscal lesion and have compared the outcome after varying periods of time following nontreatment, meniscectomy, and meniscal repair.

Materials and methods

Thirty full-grown 9–12-month-old New Zealand white rabbits that weighed between 3.5 and 5.5 kg were used for the experiments.

Under Hypnorm™ (Janssen Pharmaceutica N.V., Beerse, Belgium) anesthesia, an anteromedial arthrotomy of the right knee was performed. After retracting the tissues, including the extensor mechanism, a smooth-edged stainless-steel spatula was carefully placed under the medial meniscus, protecting the underlying cartilage. Using a scalpel with a No. BB 511 blade (Aesculap-Werke), a 3–4-mm-long, full-thickness incision was made in the central avascular part of the medial meniscus at the junction of the anterior and middle third (Figure 1). The capsule, aponeurosis, and skin incisions were closed in layers with absorbable Dexon 3–0 continuous sutures. The left knee joints underwent a sham procedure, i.e., arthrotomy without incision in the meniscus. The joints were not immobilized, and the animals were allowed to move without restriction in their cages.

Three months after the arthrotomy, 3 of the animals (Group U3) were killed with sodium pentobarbital, and both knee joints were removed for examination (Table 1). Eighteen rabbits had another arthrotomy on both knee joints. To allow vascular access from the periphery of the meniscus to the lesion, a repair was performed through a full-thickness radial cut with the spatula inserted in the right knees of 12 of the rabbits. The cut extended from the lesion to the capsular insertion (Figure 1), cutting through the synovia (Groups



Primary lesion Lesion and repair cut

Figure 1. Meniscal lesions.

Table 1. Cartilage scores in 30 experimental knees and 15 control knees (in parentheses) from 30 rabbits treated for a lesion in the right medial meniscus

Treatment groups	U 3	R 6	E 6	U 6	R 9	U 9	Total
Examined knees	3 (3)	6 (2)	6 (1)	6 (2)	6 (4)	3 (3)	30 (15)
Macroscopic scores							
Medial tibial cartilage	1 (0)	1 (0)	2 (0)	1 (0)	1.5 (0)	2 (0)	
Medial femoral cartilage	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	1 (0)	
Microscopic scores		*	*/**	**	***	***	
Aggregate score of each knee	6 (2)	8	19	8	12 (0)	18 (2)	
	6 (2)	8 (1)	15	9	10 (2)	14 (1)	
	8 (2)	5	20	7 (1)	8 (1)	18 (3)	
		8	30	7 (1)	8		
		9 (1)	37 (1)	6	10		
		6	21	10	6 (0)		
Percentage contribution to aggregate score							
Medial tibial cartilage	80	68	44	73	67	40	
Lateral tibial cartilage	10	21	12	21	20	20	
Medial femoral cartilage	10	11	34	6	11	26	
Lateral femoral cartilage	0	0	10	0	2	14	
Total number of knees	6	8	7	8	10	6	45

* and ** $P < 0.001$, *** $P = 0.001$

U 3 3 months after the lesion

R 6 6 months after the lesion, repaired at 3 months

E 6 6 months after the lesion, treated with total meniscectomy at 3 months

U 6 6 months after a meniscal lesion

R 9 9 months after a meniscal lesion, repaired after 3 months

U 9 9 months after a meniscal lesion

For further details, see the running text.

R6 and R9). In 6 of the rabbits the right medial meniscus was excised (Group E6). These 18 rabbits had a sham operation on the left side.

Six months after the lesion, 18 of the remaining 27 rabbits were killed, i.e., 6 in each of groups E6, U6, and R6. The knees were removed for further examination (Table 1).

Nine months after the lesion, the remaining 9 rabbits were killed (Groups R9 and U9). All the knees were removed for further examination.

At random, 15 of the 30 left-sided knees were selected and served as controls (Table 1).

Methods of tissue preparation and evaluation

The femoral and tibial condyles were examined under a stereomicroscope. From each tibial condyle, the medial meniscus (except in Group E6) was excised for microscopy. The cartilage of each medial femoral and tibial condyles was classified from 0 to 2 according to Shapiro and Glimcher (1980) as either normal, with loss of glistening appearance, or as irregular.

The 45 knees undergoing examination were placed in 10 percent neutral buffered formaldehyde, decalcified in 22 percent formic acid with 10 percent sodium citrate, and double embedded in celloidin-paraffin. Ten 6-μ-thick transverse sections were taken from each of the femoral and tibial condyles cutting through that area of joint cartilage where maximal stereomicroscopic abnormality was seen. In knees with normal macroscopic appearance, specimens were obtained by incising through the center of the cartilage at each condyle. Five specimens were stained with hematoxylin and eosin, whereas the other five were stained with safranin O, fast green, and iron hematoxylin for semiquantitative histologic-histochemical grading according to Mankin et al. (1971). The most pronounced changes as assessed microscopically in each joint cartilage will be reported. The four cartilage surfaces covering the medial and lateral femoral and tibial condyles in all the knees were scored blindly.

The Mann-Whitney rank sum test applied to these scores was used for a comparison between the treatment groups.

Results

None of the 12 untreated meniscal lesions (Groups U3, U6, and U9) had healed. After 3 and 6 months (Groups U3 and U6), the lesions were unchanged; but in all three menisci that were inspected 9 months after the lesion was made (Group U9), a longitudinal approximately twofold lengthening of the lesion was seen decreasing the stability of the central part.

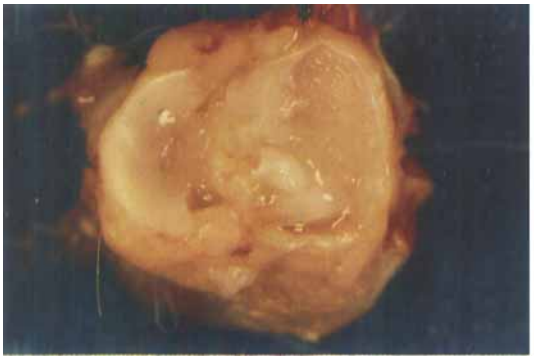


Figure 2. Tibial condyles from a rabbit inspected 3 months after a medial meniscectomy (Group E6). Irregularities are seen on the articular surface of the medial condyle.

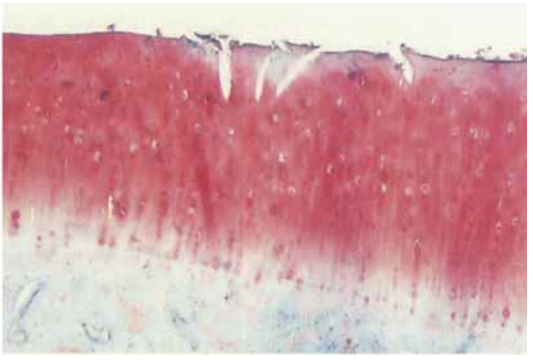


Figure 3. Surface irregularities, cleft formation, and hypocellularity in cartilage from the medial tibial condyle in a knee with an untreated 6-month-old meniscal lesion (Group U6). (Stains: safranin O, fast green, and iron hematoxylin; ×100).

In the 12 repaired menisci (Groups R6 and R9), lesions had healed. In five of the six knees that had undergone total meniscectomy (Group E6), a fibrous meniscal regenerate measuring between 2 and 4 mm was found.

Changes in the medial tibial cartilage were seen in all right-sided knees. Surface irregularities (score 2) were seen in at least 50 percent of the animals in Groups E6, R9, and U9 (Figure 2). A pathologic score in the medial femoral condyles was only found in groups E6 and U9. No changes were observed in the cartilage of the 15 control knees.

Microscopic findings

All three knees examined 3 months after the meniscal lesion (Group U3) had clefts to the transitional zone of the cartilage at the medial tibial condyle.

Six months after the meniscal lesion, meniscectomized knees (Group E6) had higher scores than the repaired knees (Group R6) or the untreated knees (Group U6, Figure 3). There was no difference between the scores of the repaired and the untreated knees.

Nine months after the meniscal lesion, knees with repaired lesions (Group R9) had lower scores than untreated lesions (Group U9), and there was no difference between the findings in knees with repaired lesions inspected 6 and 9 months after the lesion.

Eighty percent of the aggregate Mankin score 3 months after the lesion (Group U3) was derived from the tibial surface, with no contribution from the lateral femoral cartilage (Table 1). A similar pattern was seen in knees with untreated, 6-month-old lesions (Group U6). Knees in which a meniscectomy had been performed (Group E6) had degenerative changes in all four cartilage surfaces, similar to knees at 9 months after the lesion (Group U9). The only knee in Group E6 in which no meniscal regenerate was found after meniscectomy had the overall highest score.

In the knees with repaired lesions that were inspected 6 (Group R6) and 9 (Group R9) months after the lesion, the four condyles contributed equally to the Mankin score (Table 1).

Discussion

The articular cartilage is known to degenerate after experimental meniscectomy (King 1936, Lufti 1975, Cox and Cordell 1977, Korkala et al. 1984). Our findings after meniscectomy—the necessity to treat 3-month-old lesions—confirmed this degeneration. Elmer et al. (1977) demonstrated that the degenerative changes developed more frequently in animals in which the menisci failed to regenerate, which was possibly related to the extent of postoperative joint mobilization (Ghosh et al. 1983).

In experimental models, a partial meniscectomy has been shown to limit cartilage destruction when compared with a total meniscectomy (Dann et al. 1969, Cox et al. 1975). These alterations depend on the size and location of the meniscal tissue removed (Bruce and Walmsley 1937, Moskowitz et al. 1973).

The cartilage degeneration in our animals with 3-month-old meniscal lesions included changes with cleft formation that reached the transitional zone; but the degeneration appeared to be moderate, and it did

not extend to the subchondral bone (Mankin et al. 1971). These alterations may be considered irreversible (Reimann et al. 1982), and they influence the hemodynamics of the joint (Hede et al. 1989).

Accordingly, repaired 3-month old lesions in the avascular part of the meniscus that were evaluated 3 months later (Hede et al. 1991) did not show evidence that the cartilage changes observed at the time of repair had become attenuated. However, these cartilage changes did not differ from those observed after leaving the lesions untreated, except that the medial femoral condyle was relatively more affected after repair, which may have been due to the resulting abnormal mechanical contact between the condyle and the edge of the surrounding meniscal tissue or due to interference with cartilage nutrition owing to pressure changes on the cartilage at the site of repair (Moskowitz et al. 1973).

The findings 9 months after the lesion (Groups R9 and U9) demonstrate that meniscal repair in our model does not prevent a cartilage reaction. In a clinical study, Sommerlath and Gillquist (1987) found that repair of peripheral meniscal lesions did not result in a better functional outcome than did a total meniscectomy. In our experiment, there was not a significant difference when the repaired knees were studied 6 and 9 months after the lesion.

Further longitudinal splitting of the unrepaired meniscal lesion in the avascular area occurs approximately parallel to the course of the collagen bundles in the meniscus (Shakespeare and Rigby 1983, Wirth et al. 1988). The interference of an unstable meniscal lesion with the normal biomechanics of the joint explains the high Mankin scores in untreated knees examined 9 months after the lesion.

Acknowledgements

Grants were obtained from the Danish Sports Research Council. The help of Ms. K. E. Sønderlev, Calcified Tissue Research Laboratory, Department of Orthopedics, Rigshospitalet, Copenhagen, in preparing the microscopic slides is gratefully acknowledged.

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