

# Knee cartilage injury after tibial lengthening

## Radiographic and histological studies in rabbits after 3–6 months

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We investigated the effects of tibial lengthening by callotasis on the knee articular cartilage in 10 rabbits at 3 and 6 months after distraction. The distraction rate was 1 mm per day, until a 30 percent gain in length. On the right tibia, the daily distraction frequency was in 2 steps by hand, while on the left it was in 120 steps by an autodistractor. 5 animals were killed at 3 months and 5 at 6 months following distraction, and their knee joints were radiographi-

cally and histologically examined. On the 2-step side, arthrotic changes at 3 and 6 months after distraction were found in 3 of 5 and 4 of 5 knees, respectively. The severity of change increased with time. On the 120-step side, however, no arthrotic changes were found, except in one knee at 6 months. Our findings suggest that by increasing the frequency of distraction for limb lengthening one can prevent the onset of arthrosis in adjacent joints.

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Gradual distraction for limb lengthening may damage the articular cartilage in adjacent joints due to increased mechanical stress, leading to arthrosis (de Pablos and Cañadell 1989). Previously we have shown that the frequency of distraction was important for the incidence and magnitude of fibrillation in the rabbit knee cartilage (Nakamura et al. 1993). It is still unknown, however, whether or not this degenerative change at the end of distraction will develop into arthrosis.

In this study, we investigated the effect of tibial lengthening on the rabbit knee articular cartilage for up to 6 months, based on 2 frequencies of distraction.

### Animals and methods

10 skeletally mature New Zealand white rabbits were used. Under Nembutal® anesthesia, a longitudinal incision was made on the medial aspect of the tibia, and 4 fixation pins were inserted transversely into the diaphysis. After a transverse osteotomy just below the tibiofibular junction, unilateral external fixators were applied. Both tibiae were operated on in the same manner.

Distraction at a rate of 1 mm per day was started on the day after the operation and was continued until a 30 percent increase in length was achieved. On the right tibia, the frequency of distraction was 2 steps

per day (0.5 mm every 12 hours) by hand, while on the left it was 120 steps per day (0.0083 mm every 12 minutes) by an autodistractor, as described in our previous study (Nakamura et al. 1993).

5 animals were followed for 3 months from the end of distraction, and the other 5 for 6 months. At the end of each group's follow-up period, the animals were killed with Nembutal®.

### Radiologic evaluation

Both knees of all animals were radiographed in posteroanterior projections from the prone position, with the hips and knees extended and from the lateral position, preoperatively and immediately before they were killed. The radiographs were evaluated according to the grading scale of Christiane and Giles (1986): grade 3 normal, grade 2 < 50% joint space narrowing, grade 1 > 50% joint space narrowing, mild subchondral sclerosis and cysts, and grade 0 complete joint space loss, severe subchondral sclerosis, cysts and osteophytes.

### Gross pathology and histologic evaluation

The articular surfaces of both tibial condyles were evaluated grossly, using the point system of Shapiro and Glimcher (1980). For light microscopy examinations, osteochondral samples were cut sagittally to a thickness of about 2 mm during cooling irrigation from the area of the tibial condyle not covered by the meniscus.



Figure 1. The knee on the 2-step side at the start of distraction (left), at 3 months (middle), and 6 months (right) after distraction. After 3 months, the medial joint space is narrow, grade 2. At 6 months, it is even narrower.

After fixation in 10% formalin and decalcification, the samples were embedded in paraffin, sectioned, and stained with hematoxylin and eosin (HE) and safranin-O and fast green. Each section was evaluated using Mankin's histological and histochemical grading system (Mankin et al. 1971).

### Statistics

The Mann-Whitney U-test was used to evaluate differences between the follow-up periods for the same step. As for Mankin's score, ANOVA was used to evaluate the influence of the follow-up period and the frequency of distraction, while the Kruskal-Wallis test and the Mann-Whitney U-test were used to assess the differences.  $P < 0.05$  was considered significant.

## Results

### Radiographic findings

Preoperatively, all radiographs were normal. On the 2-step side, the radiographs at 3 months after distraction showed 2 at grade 3, 3 at grade 2 and none at grade 1. Those at 6 months showed none at grade 3, 1 at grade 2 and 4 at grade 1 (Figure 1). In contrast, on the 120-step side, all radiographs at 3 months were grade 3 (normal). Those at 6 months showed 4 at grade 3 and 1 at grade 2. All radiographic changes with narrowed joint spaces and osteophyte formations were present in the medial knee compartments.

### Gross pathology and histologic observations

All the changes were seen on cartilage not covered by the meniscus on the medial tibial condyle; knees with radiographic changes showed slight osteophyte formations from the central to the posterior ridge of the medial tibial condyles. On the 2-step side, all cartilage surfaces lacked the normal glistening smooth-

ness. At 3 months, 2 of the 5 knees had a fibrillation and the remaining 3 had an erosion. At 6 months, all cartilages were more severely eroded than at 3 months. On the 120-step side, however, no knees showed any visible surface irregularities, except one with erosion on the medial tibial cartilage.

Microscopically, on the 2-step side, 3 of the 5 knees at 3 months showed typical arthrotic changes in the medial tibial cartilage including numerous vertical clefts to the radial zone, various fragmentations, and loss of safranin-O staining. All cartilages were thinner at 6 months and showed more severe arthrotic changes than those seen at 3 months. In contrast, on the 120-step side, there were no changes except hypercellularity (Figure 2).

## Discussion

Hiroshima (1992) reported narrowing of the joint space in the hip in 3 of 26 patients after femoral lengthening and Murashima et al. (1990) described it in 4 of 8 patients. The cause of these radiographic changes is unknown.

Our previous experiment (Nakamura et al. 1993) showed that, at the end of distraction on the 2-step side, at 30 percent length gain, most rabbits had fibrillations which did not extend into the calcified zone of the tibial medial cartilage, while on the 120-step side, mainly hypercellularities were found. It has not been determined whether the fibrillations will develop into arthrosis. Several authors, however, have reported that such a fibrillation caused by increased mechanical loading progresses to an arthrotic lesion if the trauma continues, while prompt termination of the trauma when the damage is not extreme may allow the lesion to improve (Mankin 1982, Buckwalter et al. 1987, Williams et al. 1992). Hede et

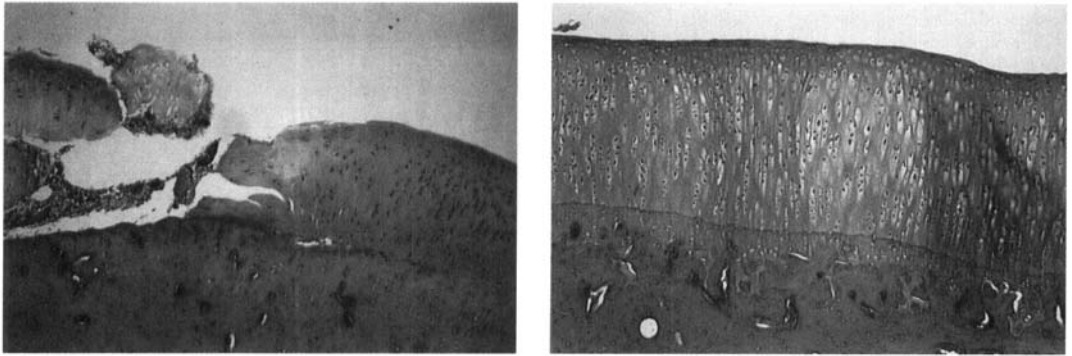


Figure 2. Articular cartilage from medial tibial condyles on the 2-step (left) and the 120-step (right) side at 6 months after distraction. HE stain,  $\times 350$ . The cartilage on the 2-step side thinned and showed destruction of the matrix. On the 120-step side, no changes were seen, except hypercellularity.

Table 1. The radiographic changes in the knees and the histological changes in the tibial medial articular cartilages by step. Median (range)

Months after distraction	Radiography <sup>a</sup>		Macroscopy <sup>b</sup>		Mankin's score	
	2 steps	120 steps	2 steps	120 steps	2 steps	120 steps
0 <sup>c</sup>					8 (6-9)	2 (1-6)
3	2 (2-3)	3 (3-3)	3 (2-4)	1 (0-2)	9 <sup>d</sup> (9-10)	2 (1-2)
6	1 <sup>f</sup> (1-2)	3 (2-3)	4 (2-8)	2 (0-2)	12 <sup>ef</sup> (10-14)	2 (1-4)

<sup>a</sup>Christiane and Giles' score. <sup>b</sup>Shapiro and Glimcher's score. <sup>c</sup>Values at the end of distraction. Differs <sup>d</sup> ( $p < 0.05$ ), <sup>e</sup> ( $p < 0.01$ ) from value at the end of distraction. Differs <sup>f</sup> ( $p < 0.05$ ) from value at 3 months.

al. (1991) investigated cartilage degeneration following meniscal injury in rabbit knees. The clefts, which did not extend to the tide mark and hypocellularities in articular cartilage with a 3-month-old meniscal injury, progressed if the meniscal lesion was left untreated, while degeneration did not increase if the lesion was repaired.

In the present study, the cartilages on the 2-step side at 3 and 6 months had Mankin's scores of 9 and 12, respectively. Compared to the score of 8 at the end of distraction, described by Nakamura et al. (1993), the degenerative changes seen at 3 and 6 months had increased with the length of the follow-up period. In contrast, Mankin's scores on the 120-step side at 3 and 6 months were 2 and 2. Compared to the score of 2 at the end of distraction reported by Nakamura et al. (1993), there was no increase in the degenerative changes (Table 1). In view of these observations, the fact that the degenerative change at the end of the 2-step distraction developed into an arthrosis change suggests that the trauma caused by increased mechanical loading may have persisted after the end of distraction.

Radin et al. (1984) found that the hypercellularity that occurred in rabbit knee cartilage after repetitive impulsive loading remained even at one month after its removal. In our experiment too, the hypercellularity seen on the 120-step side at the end of distraction remained, even at 6 months after distraction.

Our findings cannot be directly applied to humans because of basic differences in the mechanical properties of the articular cartilage (Athanasios et al. 1991) and in the distraction rate against original bone length. Our data showed, however, that the frequency of distraction is one of the factors affecting the onset of arthrosis in adjacent joints. From the results of this and our previous study (Nakamura et al. 1993), we conclude that by increasing the frequency of distraction in gradual distraction techniques one may be able to prevent arthrosis in adjacent joints.

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