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Significance of laser treatment in arthroscopic therapy of degenerative gonarthritis

A prospective, randomised clinical study and experimental research

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Abstract. To ascertain the efficiency of different techniques of arthroscopic therapy for gonarthritis and establish the relevance of the extent of chondromalacia, clinical and experimental studies were performed. In principle, the process of chondromalacia determines the course of the disease. Treatment of additional meniscus lesions temporarily leads to better clinical results, but after only a few months the symptoms caused by the arthritic process reappear. Compared with the temporary relief of complaints after debridement and lavage, smoothing with a xenon chloride excimer laser in grade II chondromalacia leads to statistically significantly better clinical results. Scanning electron microscopic studies confirm the extremely good smoothing. These studies permit clear statements as to the various methods of treatment and their application in the different grades of chondromalacia, thus leading to differentiated arthroscopic treatment of degenerative gonarthritis.

Key words: Chondromalacia – Debridement – Degenerative gonarthritis – Laser surgery

Introduction

The development of arthroscopic therapy led to transfers of current standard operation procedures for arthritic degeneration to arthroscopical application. As in the treatment of other articular diseases, the advantages of arthroscopy in the therapy of degenerative gonarthritis are a better diagnostic differentiation of chondromalacia grading and a minimally invasive proceeding. Uncertain even today is the gradation of therapeutical procedures corresponding to the diagnostic classification. This carries the danger of judging arthroscopic therapy as the advantageous, minimally invasive standard procedure with less operation trauma and therefore of extending the indication for arthroscopy without graduated differentiation. We have to be aware that debridement had been developed half a century earlier [15] for open surgery and was just transferred to arthroscopic application, while no qualified treatment has been established since for smoothing the cartilage surface in degenerative gonarthritis. Considering the common use of debridement in patients 30 years old as well as in those 80 years old – with only the therapeutic aim of achieving a short-lasting relief of complaints – Casscells [3] wonders how the effectivity of debridement for osteoarthritis should be judged and a proper selection of patients carried out. In the world's first prospective, randomised study for laser application in degenerative arthritis, we used the xenon chloride excimer laser, which was one of the first lasers available for arthroscopy and the very first which could be used in irrigation fluid for cartilage smoothing routinely. Furthermore, scanning electron microscopy was employed to examine the surface changes of cartilage after treatment in experimental studies. Based on these examinations, a recommended usage of debridement and excimer laser in degenerative gonarthritis is made.

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Usual arthroscopical procedures

Debridement and lavage

Modern arthroscopic arthritis therapy is essentially based on house cleaning, also called debridement, which was initiated by Magnuson [19] 50 years ago. Even in the original description Magnuson summarised all measures leading to improved mobility. Besides cartilage smoothing, cutting of oestophytes, removing of floating cartilage and loose parts, he mentioned the resection of damaged meniscus parts.

In addition, the cleaning effect of lavage is used in the arthroscopic procedure, as Burmann et al. [2] described after the exclusive use of knee joint lavage. The positive effect seen by Jungmichel et al. [15] after repeated joint lavage in patients with activated gonarthritis, namely the diminution of detritus-induced synovialitis, was classified by Jackson et al. [13] as a temporary improvement over a period of 1–50 (average 18.8) months. However, Jackson et al. [13] also mentioned critically that 20% of their patients with degenerative cartilage lesions showed no improvement after lavage and additional debridement. The effect of lavage is caused by removing detritus and reducing the enzymatic activity of the synovia, leading to temporary pain relief [23, 24]. Therefore, the resulting reduction of secondary synovialitis – based on the transient elimination of mediators – could be understood as the treatment of chondromalacia only in a transferred sense [5, 6].

Use of shavers

At an early stage of arthrosis, chondromalacia grade I according to Outerbridge [25], there is a general consensus that at the smooth but softened surface no procedures of surface treatment are indicated. At lesions of the joint surface, as in grade II, usually motorised shavers are used, which were first developed by Johnson [21]. Problems result on the one hand in the practical use, and on the other in effects typically caused by damaged cartilage tissue. The shaver coupling often does not respond with its cutting window to the joint surface, and it is not always possible to create a smooth cartilage surface with shavers. The process of cartilage tissue damage depends on histological changes of fuzzing and softening, and light microscopy verifies shaver-caused waves and grooves [9, 37] as typical problems of resulting surface irregularities.

Postoperative follow-up

In patients with severe chondromalacia and simultaneous meniscus lesions – which mean an additional mechanical reduction of the load capacity of the knee – after treatment of the meniscus lesion, a progressing diminution of good or very good results can be seen with increasing duration of the postoperative period [10, 12, 28]. McBride et al. [20] found satisfying results after meniscectomies without degenerative changes at a 3-year follow-up study in 96%, but with stimultaneous degenerative changes in only 65%. Lotke et al. [18] reported good or very good results after a follow-up period of 10.8 years in only 21% of patients with additional degenerative changes. Odenbring et al. [22] found at a control after 14 years a worsening in all cases. So over all, as compared with the usual meniscus operations [16], with stimultaneous degenerative changes a severe increase of pain and a decrease of mobility are reported.

The general experience is that the higher the stage of chondromalacia, the worse is the postoperative course [26]. An exact differentiation of the postoperative course was done in the retrospective study of Rosenthal [29]. In this follow-up study of 1125 patients (average of 23 months postoperatively) being treated between 1984 and 1987 with an arthroscopic debridement, a significant difference in their Lysholm score as modified by Klein [17] was found. Patients with chondromalacia grades II/III gained 83.5 points, and those with chondromalacia IV, 74 points. With advanced age a higher prevalence of severe chondromalacia and therefore lower points on the Lysholm score were found. For patients with only cartilage smoothing and those with smoothing and partial meniscectomy, the results were an average of 75 and 76 points, respectively, while for those treated exclusively with partial meniscectomy, a significant higher rate of 86 points was noted. This corresponds to the retrospective preoperative Lysholm score, with a gain of 16 points for exclusive cartilage smoothing, 20 points for smoothing with partial meniscectomy and 38 points for exclusive partial meniscectomy. This emphasises that the grade of chondromalacia is important in the further course after debridement. The removal of mechanical impediments leads to only a temporary improvement. In the long run the chondromalacia progresses, so that the stage of chondromalacia is most important for the prognosis.

Laser use for smoothing in chondromalacia grades II/III

Due to problems of treating chondromalacia, especially the progress of the arthritic process after the usual mechanical therapy, improved laser techniques have been developed. After poor experiences with a CO_2 laser in arthroscopic knee surgery, particularly because of the tissue damage by carbonisation, namely necrotic marginal areas [36], the excimer laser with its principle of photoablation [33] was developed for the use of cartilage smoothing. The xenon chloride laser with a short wavelength of 308 nm is oligotherm [32]. In addition, it offers the advantage of being transmissible by flexible fibres. In experimental studies different cutting qualities were examined [34]. By using this type of laser (40 Hz, 40–50 mJ/pulse) for smoothing of experimentally roughened cartilage surfaces in pig knees, Gerber et al. [7, 8] showed a better surface smoothing under electron microscopic analysis than with other treatments. Jahn et al. [14] described an effect of "sealing" at this energy level. The necrosis zone was minimal (40 μm). Considering these experimental data a controlled comparative study of laser treatment in clinical use was required [1, 27].

Prospective, randomised study

After clinical experience with the excimer laser for arthroscopic therapy in gonarthrosis, we performed a prospective, randomised study to compare the usual mechanical cartilage smoothing to treatment with the xenon chloride excimer laser in chondromalacia II/III. Laser therapy was done at 60 ns pulse duration, 50 Hz and energy of 40–50 mJ at the exit of a 0.6-mm quartz monofibre, with a distance of 3–5 mm to the cartilage (Fig. 1). Over a randomised operation distribution from October 1989 to July 1990, the data collecting was done prospectively before arthroscopy, and follow-up controls took place twice postoperatively, after at least 6 months (mean 7.2) and 2 years (mean 2.4). Parameters for age, sex and side distribution and therapeutical methods used were comparable for the laser and mechanically treated groups. The duration of operation was 49 min for the laser group, which was 10 min longer than for the mechanically treated group. The distribution of chondromalacic areas within different knee parts and the duration of stationary therapy showed no difference between groups.

Fig. 1. Excimer laser fibre *(right side)* with blue aim beam in arthroscopic use

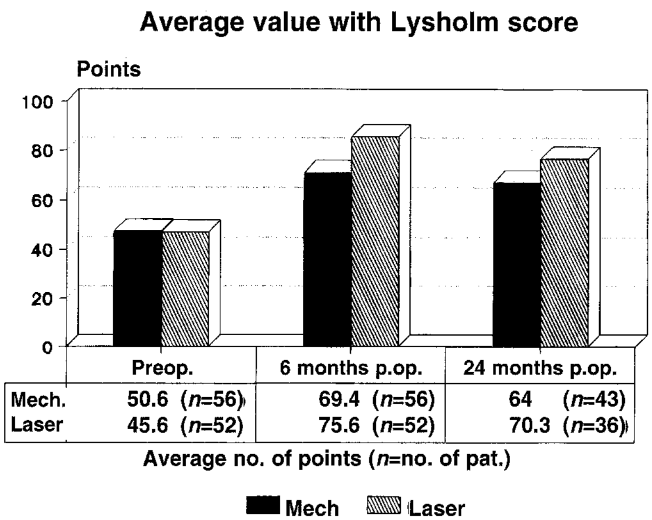

Fig. 2. Comparison of average values in Lysholm score as modified by Klein [17] pre-and postoperatively for laser and mechanical treatment

At the first follow-up all 108 patients (56 mechanical, 52 laser) were examined. At the second follow-up 79 patients (43 mechanic, 36 laser) were examined. Two patients had died, two of both groups had received a knee prosthesis meanwhile, three patients refused a repeat examination, and the others were not contactable. The group characteristics were distributed as in the beginning of the study and showed no significant differences in the collective parameters.

As evident in Fig. 2 there are a higher increase and a better result in the Lysholm score as modified by Klein [17] for the laser-treated group. The rise in the score for both groups was significant at $P < 0.03$ in Student's t-test for two variables (stat-graphics, Version 5.0 [4]), which was used for the following calculations also. The highest improvement in the Lysholm score was seen for the criterion "pain". In the laser-treated group the increase of the score for this criterion at the half-year follow-up is highly significant at $P < 0.003$ in the t-test.

Considering the results in the Lysholm score for different chondromalacia grades separately, there is a significant difference between II and III. At follow-up grade II patients in the laser-treated group showed a statistically significantly better result (Fig. 3; 6 months, $P < 0.007$; 24 months, $P < 0.05$). For grade III patients no significant differences are evident (Fig. 4).

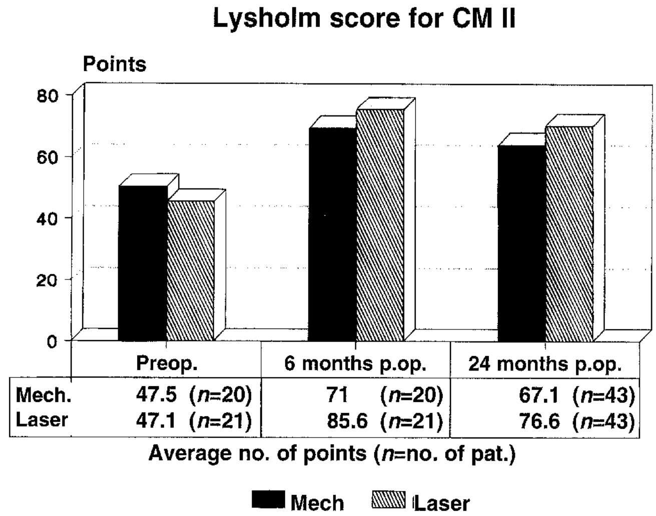

Fig. 3. Significantly better results in Lysholm score in laser-treated group of chondromalacia grade II patients

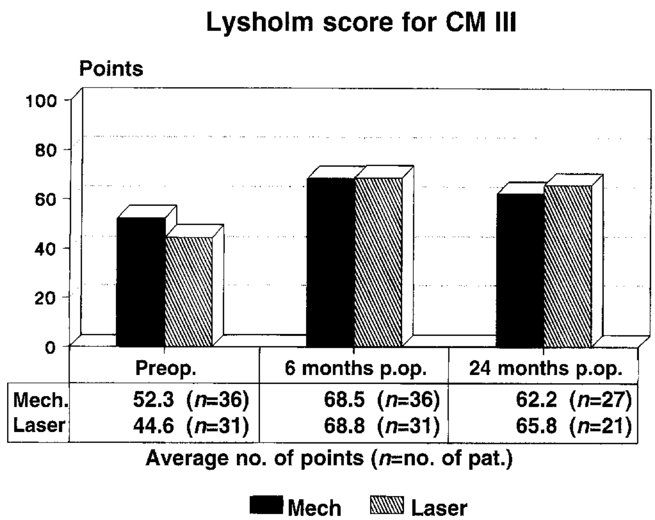

Fig. 4. No significant difference in Lysholm score between both groups in the follow-up control for chondromalacia grade III patients

There is also a difference between patients with and without additional meniscus lesions in both groups of grade II. The laser-treated group shows a significantly higher increase of score compared with the mechanically treated group. Between the subcollectives with and without meniscus lesions in grade III there is no significant difference.

These results show that the excimer laser therapy compared with the usual mechanical therapy in chondromalacia II patients yields significantly better results over a 2-year follow-up period. For grade III patients no important improvement was found, probably because the cartilage changes (advanced destruction) cannot be treated successfully by either method, and only extensive lavage results in a minor improvement. In grade II an improvement of cartilage loading is seen as measured by the modified Lysholm score. Therefore, it seems reasonable to interpret these results as indicating that laser therapy in grade II brings about not only an initial improvement but also a delay of further development of the arthritic process. The question of whether there is an influence on the treatment of chondromalacia with simultanous meniscus lesions due to a mechanic moment [30] has to be answered similarly; the meniscus lesion is to be regarded as an attending phaenomenon, which does not influence the postoperative course over a 2-year period. Thus, the postoperative course is only influenced by the chondromalacia grade and the treatment.

Experimental study of surface smoothing

In order to test the condition of the cartilage surface and cartilage photoablation by excimer laser as described in the literature [10, 12], an experimental study was set up to examine the different methods of treatment of the cartilage surface by scanning electron microscopy. Using ten cadaver knees (from subjects 41–83 years old) surface treatment was done by scalpel, shaver, file and excimer laser in Puirsole analogous to the arthroscopic procedure. From treated and untreated parts of the femur and the tibia plateau, cartilage rectangles of 0.5 × 0.7 mm were taken (Fig. 5), altogether 136 samples.

Fig. 5. After different surface treatment methods cartilage parts were taken for scanning electron microscopy

After the usual work-up for scanning electron microscopic examination, a descriptive judgement was possible. Scalpel smoothing showed clod-like areas with smoothing and thin channel-like clefts between them. However, scalpel-treated cartilage seems smoother than the initial state (Fig. 6a, b). The file-treated cartilage shows further fuzzing of the fibres. At some sites parts of the cartilage even seem to be torn out (Fig. 6c). Thus, the surface appears rough. After shaver treatment the image of the scanning electron microscopic picture (Fig. 6d) is comparable to the histological findings described in the literature [37]. This supports not only the macroscopic finding of a rough surface but also of the damaged fibre texture [31]. The use of the excimer laser, which seems to melt the cartilage surface in arthroscopic therapy, results in a smooth surface, without torn-out fibres. The surface even seems to be condensed, so that the fibre texture is no longer seen (Fig. 6e, f). The picture of the surface after excimer use is comparable to the results of the experimental studies of Stahl et al. [34], when using this type of laser for cutting. Furthermore, these results correlate with the data of cut testings by Tönshoff and Bütje [35]. They also support the findings of Gerber et al. [7, 8] and Jahn et al. [14] that at the new surface no free cartilage fibres could be found, and the treated area looks condensed. The best smoothing therefore was seen after using the excimer laser, and thus the best reduction of mechanical resistance at the joint surfaces can be expected.

Discussion

The above-described studies show that the arthrotic changes themselves determine further progress. Our results support data from the literature that lavage and debridement bring about temporary relief only. Also, the follow-up results of patients who have meniscus lesions besides chondromalacia show that this has to be regarded as additional damage, but that the progression of the arthrotic process cannot be influenced by treating the meniscus lesion. As demonstrated in the prospective, randomised study, the xenon chloride excimer laser is the best treatment for chondromalacia II compared with the usual mechanical methods. Although the effect of the laser on the tissue is unclear in the histological field even under scanning electron microscopy examination, it yields the best surface smoothing. The postoperative course shows – as demonstrated in the 2-year follow-up studies – a reduction of progression of the arthrotic cartilage destruction after laser therapy for grade II patients. In grade III there is no significant influence of debridement or laser. Therefore, excessive laser use is of no advantage, and expectations that even in advanced chondromalacia a remarkable improvement could be gained by arthroscopic laser treatment have to be disappointed. There is distinct advantage, however, in delaying progression of the arthrotic process by using an excimer laser in grade II. Considering the results of the clinical and structure analytical study, a treatment concept with graduated proceedings has been established (Table 1), which is helpful for arthroscopic therapy of the otherwise quickly progress-

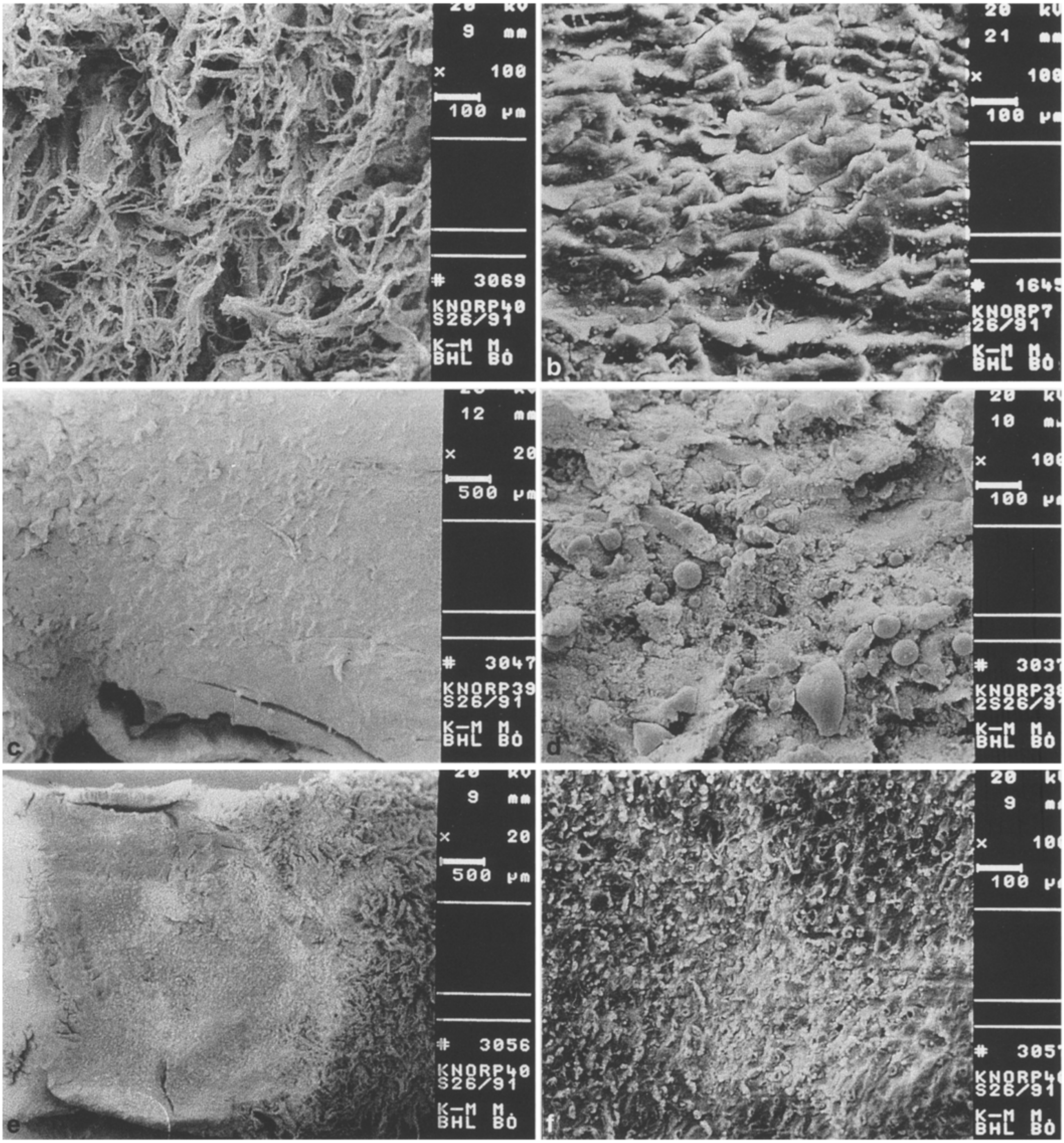

Fig. 6. **a** Scanning electron microscopy imaging of the surface of the knee joint cartilage of a sample of a 71-year-old female patient in an area of chondromalacia II. Typical fuzzing of collagen tissue due to deficit of hyaline material; magnification × 100. **b–e** Samples of the same knee after different surface treatment methods in chondromalacia II. **b** After scalpel treatment the surface looks clod-like, smooth with channel-like clefts; magnification × 100. **c** After file treatment even at low magnification a fuzzy-like, destroyed surface appears; magnification × 20. **d** After mechanical shaver smoothing an even further destroyed surface texture results; magnification × 100. **e** Comparison of untreated surface alterations in chondromalacia grade II *(right)* and the completed smoothing after xenon chloride excimer treatment *(middle)*; magnification × 20. **f** Detail of **e**. After laser treatment a condensed-looking tissue is left, and the fuzzy fibre texture no longer exists, magnification × 100

Table 1. Basis scheme for arthroscopic therapy of tibio-femoral gonarthrosis, depending on chondromalacia grade. X: usual indication; (X): in severe cases; [X]: refinishing treatment

Grading of chondromalacia similar to Outerbridge [25]		Arthroscopic treatment		
		Lavage	Debridement	Laser
0	Macroscopic intact cartilage			
I	Cartilage oedema with smooth surface	X		
	Fine surface fibrillation	X		(X)
II	Cartilage fissuring/fuzzing	X		X
	Cartilage fragmentation (crabmeat)	X	(X)	X
	Fragment loosening	X	X	[X]
III	Cartilage ulcers	X	X	
IV	Cartilage bladness	X	X	

ing, self-supporting process of cartilage destruction in degenerative gonarthritis.

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