Knee Surg Sports Traumatol Arthrosc (2016) 24:1560–1568
DOI 10.1007/s00167-015-3810-6

KNEE

Mechanical debridement versus radiofrequency in knee chondroplasty with concomitant medial meniscectomy: 10-year results from a randomized controlled study

Gunter Spahn[1] · Gunther O. Hofmann[2] · Lars Victor von Engelhardt[3]

Received: 16 June 2015 / Accepted: 22 September 2015 / Published online: 1 October 2015

Abstract

Purpose We compared the effectiveness of mechanical debridement (MD) and bipolar radiofrequency chondroplasty (RF) with regard to clinical outcome, rate of revision, and progression of knee osteoarthritis.

Methods Sixty patients with MRI-detected grade III cartilage lesions on the medial femoral condyle were considered for the study. For MD (group 1; $n = 30$), each lesion was debrided using a mechanical shaver. For RF (group 2; $n = 30$), each lesion was smoothed using a temperature-controlled RF probe set at 50 °C.

Results The 10-year follow-up was available for 47 patients (78.3 %). Sixty per cent of group 1 ($n = 18$) underwent revision during the follow-up period. In contrast, the revision rate in group 2 was 23.3 % ($n = 7$; $p = 0.061$). The mean survival was 94.1 months (95 % CI 77.1–111.3) and 62.5 months (95 % CI 45.9–79.2) for group 2 and group 1, respectively. Patients who did not require revision (group 1, $n = 9$; group 2, $n = 13$) were assessed before surgery and 1, 4, and 10 years after surgery using the knee injury and osteoarthritis outcome score (KOOS). At follow-up, the KOOS was higher for group 2 than group 1. At the time of surgery, no patient showed any radiological signs of osteoarthritis. The width of the medial joint was 5.4 mm (95 % CI 4.3–6.5) and 5.6 mm (95 % CI 4.9–6.3) in the MD and RF groups, respectively (n.s.). During the follow-up period, the joint space width narrowed continuously in both groups ($p < 0.001$), but more rapidly in the group 1 (n.s).

Conclusion Compared to conventional MD, 50° RF treatment appears to be a superior method based on short- and medium-term clinical outcomes and the progression of knee osteoarthritis. Clear predictors for the indications of different cartilage treatments and more randomized clinical trials are needed.

Level of evidence I.

Keywords Knee · Cartilage · Arthroscopy · Radiofrequency · Debridement · RCT

✉ Gunter Spahn
spahn@pk-eisenach.de

1 Center of Trauma and Orthopaedic Surgery and Jena University Hospital, Sophienstr. 16, 99817 Eisenach, Germany

2 Trauma Department and Trauma Center Bergmannstrost Halle/S., Jena University Hospital, Erlanger Allee 101, 07740 Jena, Germany

3 Department of Orthopedics, Trauma Surgery and Sports Medicine, University of Witten/Herdecke and Johanna-Etienne-Hospital, Am Hasenberg 46, 41462 Neuss, Germany

Introduction

Cartilage lesions are detected in approximately 60 % of all knee arthroscopies [8, 35]. Recently, the International Cartilage Repair Society (ICRS) grading system has become the norm [4]. Low-grade lesions (ICRS grade I and II) are characterized by softening and superficial fissures without subchondral bone contact. Deep cartilage lesions (ICRS grade III) are fissures and flakes reaching the subchondral bone. A complete defect (ICRS grade IV) is defined by complete loss of the cartilage layer with widely opened subchondral bone. The different stages of the disease are approximate orientations for different treatment options. Low-grade lesions are usually not addressed surgically. Complete defects with a small diameter (<1.5–2.0 cm) can be treated with bone marrow stimulation, such as drilling, abrasion, or microfracturing (Steadman et al. 2003). Lesions with a diameter of 1.5–2.0 cm should undergo osteochondral transplantation or chondrocyte transplantation [10, 16, 21]. However, no clear consensus has been met regarding the best treatment of deep grade III cartilage lesions, though they are a significant risk factor for the progression of osteoarthritis [6]. For many years, mechanical debridement (MD), or shaving, was considered the method of choice [28].

MD aims to produce stable and nearly smooth articular cartilage surfaces, remove loose flakes, and potentially stimulate the regeneration of articular cartilage. The most important disadvantages of MD are the inability to control ablation within the deep layer and the removal of intact tissue surrounding the lesion [9, 23]. The application of thermal energy is sufficient to smooth the articular cartilage surface within deep lesions [2].

Thermal application is possible through the use of laser devices or the application of monopolar or bipolar radiofrequency (RF). Laser or monopolar RF energy produces high temperatures within the cartilage layer (≥100 °C), smelting the matrix and causing cell death among chondrocytes [9]. Earlier investigations demonstrated that the temperature should not be >52 °C [1, 12, 14]. Though several clinical studies have reported that RF treatment can be effective in the short or middle term, no clinical data have been published regarding long-term results [3, 5, 11, 18, 19, 25, 27, 30, 32].

The present randomized study compared the effectiveness of MD and 50 °C controlled bipolar RF chondroplasty at 50 °C in patients with grade III cartilage lesions and a concomitant medial meniscus tear. Clinical outcomes, the rate of surgical revision, and the progression of knee osteoarthritis were compared between the two procedures. We hypothesized that RF treatment produces better long-term clinical outcomes than MD.

Materials and methods

Patients

Patients who presented with a medial meniscus tear and idiopathic grade III cartilage defect(s) of the medial femoral condyle were considered for participation in the study. Exclusion criteria were previous injuries (ligaments, fractures, or patellar dislocation) or previous operations. Sixty patients with knee pain (<3 months) and grade III cartilage lesions detected on MRI were enrolled. After the approval of the regional ethics committee, patients who provided informed consent were randomly assigned to undergo MD (group 1) or RF (group 2) on the morning of the day of the procedure using blind, sealed envelopes constructed using a random numbers table technique. The patients remained blinded to the chondral treatment procedure. No patient demonstrated any radiological signs of osteoarthritis in the pre-operative radiographs (varus or valgus dysalignment, osteophytes >1 mm, or subchondral sclerosis). The pre-operative data for all patients are provided in Table 1.

Operative procedure

All patients underwent partial or subtotal medial meniscectomy to treat a symptomatic medial meniscopathy. In group 1, the meniscectomy was performed using a full-radius resector (Arthrex, Naples, FL, USA). The instrument was moved over the lesions three times by permanent suction for approximately 5 s. The top of the instrument had only mild contact with the surface. No significant manual pressure was applied to avoid a deep abrasion.

In group 2, we used the Paragon T2 device (AC5531-01, Arthrocare, Austin, TX, USA). This instrument contains a temperature indicator to signal heating over 50 °C, the critical temperature for articular cartilage damage. A temperature violation was not observed in any patient. This probe also had only mild contact with the surface, and the surgeon did not apply significant manual pressure (setting 40 W).

A Redon drain was positioned for 24 h in all knees. All patients took varying doses of ibuprofen depending on the level of pain and the amount of swelling experienced. All patients completed a physical exercise programme for 6 weeks.

Table 1 Baseline data for all patients

	Group 1	Group 2	*p* value
n	30	30	–
Male/female	15/15	13/17	n.s.
Age (years)	53.8 (40.4–47.2)	42.9 (39.0–46.7)	n.s.
BMI (kg/m^2)	27.7 (26.1–29.4)	26.6 (24.7–28.5)	n.s.
History of disease (months)	9.0 (7.5–10.5)	7.4 (5.6–9.2)	n.s.
Medial joint space width (mm)	4.2 (3.4–5.0)	4.7 (4.1–5.4)	n.s.
Diameter of the MFC defect (mm^2)	21.0 (19.7–22.9)	20.3 (18.8–21.8)	n.s.
Extent of meniscectomy, partial/subtotal	19/11	55/8	n.s.

Data are given as mean (95 % CI) unless otherwise noted

n.s. not significant

During the observational interval, no patient underwent additional treatments, such as slow-acting drugs in osteoarthritis (SADOA) or disease-modifying osteoarthritis drugs (DMOAD).

Self-reported assessment and radiography

The patients were evaluated using the knee injury and osteoarthritis outcome score (KOOS) before surgery (baseline) and at 1-, 4-, and 10-year follow-ups [20]. The KOSS profiles were evaluated according to the KOOS guidelines (www.koos.nu).

We used the Tegner score to assess each patient's activity level before the onset of symptoms and at the time of follow-up [29]. To assess the score before the onset of symptoms, patients had to estimate their activity level retrospectively.

The medial joint space width and varus angle (anatomical axis) were radiologically evaluation by an independent and blinded observer using standard weight-bearing radiographs in a 30° flexion position. No patient had a pathological varus. Articular cartilage lesions were classified according to the ICRS score at the start of the study [4].

All patients meeting the inclusion criteria who agreed to participate in the study provided informed consent. This study was approved by the regional ethics committee (Medical Cabinet of Thuringia, Germany. 1026/05/111). A control group in which no chondral treatment was performed for a grade III defect was not allowed.

Statistical analysis

For validation of the study, sample size calculations were performed a priori (G Power version 3.1, Heinrich Heine University, Düsseldorf, Germany) based on a significance level of 0.05 and power of 0.80 for the measurement of clinical scores. This calculation estimated that 25 patients were needed for each group.

All statistical analyses were performed using SPSS version 20.0 (Chicago, IL, USA).

The time interval between operation and revision was calculated using the Kaplan–Meier analysis, and we tested for differences using the Mantel–Cox log-rank test.

The KOOS and joint space measurements are presented as mean (95 % CI). The Tegner score was calculated as median (range). For a comparison of dichotomous parameters between the groups, Chi-square test was used. Continuous parameters were compared between the groups using the Mann–Whitney *U* test. The Wilcoxon signed-rank test was used for comparisons between the pre-operative data and results obtained during follow-up. A p value ≤ 0.050 was considered significant.

Table 2 Baseline data for patients lost to follow-up

n	10
Male/female	4/6
Age (years)	40.3 (31.8–48.8)
BMI (kg/m^2)	25.9 (21.4–29.7)
History of disease (months)	6.8 (3.1–10.4)
Medial joint space width (mm)	4.9 (3.4–6.4)
Diameter of the MFC defect (mm^2)	20.2 (17.3–23.0)
Extent of meniscectomy, partial/subtotal	6/4

Data are given as mean (95 % CI) unless otherwise noted

Results

Follow-up, survival to revision, and loss to follow-up

Ten patients (one from group 1 and nine from group 2) were lost to follow-up (16.6 %, Table 2). The clinical course of these patients is unknown. The loss of these patients decreased the study power to 0.69. In addition, three patients (two from group 1 and one from group 2) died during the follow-up period. Therefore, it was only possible to evaluate the 10-year post-operative time course in 47 (78.3 %) patients. Eighteen patients (60.0 %) in group 1 underwent revision surgery: 11 were unicondylar or total replacements, 5 were osteotomies, and 2 were revision arthroscopies. The rate of revision in group 2 was 23.3 % ($n = 7$). The difference between the groups was not significant. The baseline data for these patients are provided in Table 3.

The time to a required revision in group 1 was 62.5 months (95 % CI 45.9–79.2). In group 2, the mean survival was 94.1 months (95 % CI 77.1–111.3). This difference was significant ($p = 0.022$, log Mantel–Cox). The Kaplan–Meier curve is shown in Fig. 1.

Self-reported assessment

Patients who did not require revision (baseline data in Table 4) were assessed pre-operatively and at 1-, 4-, and 10-year follow-ups. The subjective outcome assessed by KOOS was better in group 2 ($n = 13$) than in group 1 ($n = 9$; Table 5). The KOOS profiles are presented in Figs. 2 and 3.

Pre-operatively, patients in both groups had a moderate activity level without any significant difference between the two groups. The Tegner activity scores are presented in Table 6. The onset of disease caused a significant reduction in activity level, and patients from both groups benefitted from the operation. However, RF-treated patients achieved a higher activity level 1 and 4 years after surgery

Table 3 Baseline data for patients undergoing revision surgery

n	Group 1 18[a]	Group 2 7	*p* value
Male/female	9/9	4/3	n.s.
Age (years)	41.6 (36.8–46.4)	43.3 (31.8–54.4)	n.s.
BMI (kg/m^2)	28.1 (25.9–30.4)	27.4 (21.0–33.8)	n.s.
History of disease (months)	7.8 (6.1–9.6)	8.1 (3.3–12.2)	n.s.
Medial joint space width (mm)	3.7 (2.6–4.7)	4.7 (3.1–6.3)	n.s.
Diameter of the MFC defect (mm^2)	21.9 (19.9–23.8)	19.6 (14.9–24.2)	n.s.
Extent of meniscectomy, partial/subtotal	8/10	5/2	n.s.

Data are given as mean (95 % CI) unless otherwise noted

n.s. not significant

[a] One patient from the MD group died during the 10-year follow-up period. He did undergo arthroplasty 15 months after the arthroscopy

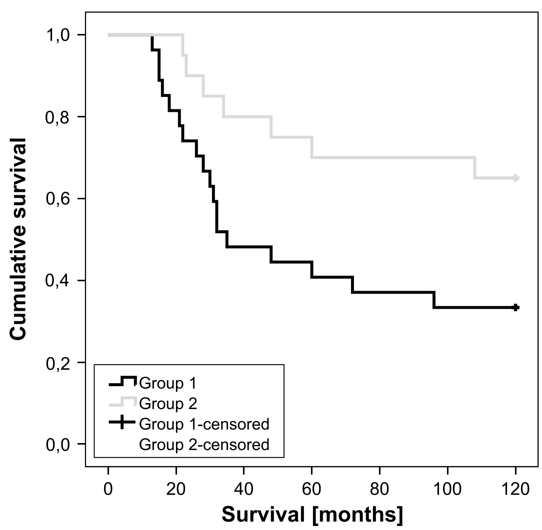

Fig. 1 Survival to revision (Kaplan–Meier). The mean survival in group 2 was 94.1 (95 % CI 77.1–111.3) months. The time to a required revision in group 1 was 62.5 (95 % CI 45.9–79.2) months, $p < 0.001$

compared to MD-treated patients. The patients' activity levels decreased in both groups over time, and activity levels were similar at the 10-year follow-up.

Factors (e.g. age, gender, history, diameter of the defect, and extent of meniscus surgery) that predict the outcome regarding self-reported assessment, progression of radiological osteoarthritis (JSN), or need for revision were not found in the long-term follow-up.

Radiological investigation

At the time of surgery, no patient had any radiological signs of osteoarthritis (i.e. osteophytes or subchondral sclerosis). The medial joint width was similar in both groups (group 1: 5.4 mm, 95 % CI 4.3–6.5; group 2: 5.6 mm, 95 % CI 4.9–6.3). During the follow-up period, the joint space width narrowed continuously in both groups (Table 7). The joint space narrowing tended to increase more rapidly in group 1, but the difference from group 2 was not significant.

Table 4 Baseline data for patients undergoing 10-year follow-up

n	Group 1 9	Group 2 13[a]	*p* value
Male/female	6/3	5/8	n.s.
Age (years)	47.2 (41.3–54.0)	44.0 (37.9–50.0)	n.s.
BMI (kg/m^2)	720.4 (24.1–30.7)	27.1 (24.1–29.6)	n.s.
History of disease (months)	10.1 (7.9–13.6)	6.8 (4.4–10.8)	n.s.
Medial joint space width (mm)	5.4 (2.8–5.6)	5.6 (3.6–5.8)	n.s.
Diameter of the MFC defect (mm^2)	21.3 (16.3–24.9)	20.3 (18.1–22.9	n.s.
Extent of meniscectomy, partial/subtotal	8/1	11/2	n.s.

Data are given as mean (95 % CI) unless otherwise noted

n.s. not significant

[a] Two patients from the RF group died 5 and 7 years after the arthroscopy. A revision was not required

Table 5 Knee injury and osteoarthritis outcome score (KOOS)

	Group 1		Group 2		*p* value
	Mean *n* = 9	95 % CI	Mean *n* = 13	95 % CI	
Baseline					
Symptoms	6.3	0.1–12.6	21.1	12.1–30.1	0.012
Pain	11.7	4.3–19.1	16.4	5.0–27.8	n.s.
Function in activities of daily life	10.1	3.7–16.5	17.2	6.8–27.4	n.s.
Function in sports/recreation	7.3	2.4–11. 9	18.3	9.6–27.0	0.036
Knee-related quality of life	6.9	3.1–10.7	17.8	9.2–25.1	0.032
KOOS	9.1	4.1–14.3	17.8	8.9–26.6	n.s.
1-year follow-up					
Symptoms	53.9	49.9–57.9	81.5	77.9–85.1	0.001
Pain	54.6	47.9–61.3	81.5	78.3–84.7	0.001
Function in activities of daily life	59.6	55.8–63.2	81.7	78.9–84.5	0.001
Function in sports/recreation	47.3	43.4–62.1	68.2	58.2–85.1	0.001
Knee-related quality of life	54.8	46.3–63.4	81.7	77.4–86.1	0.001
KOOS	56.9	53.2–60.4	81.6	78.8–84.4	0.001
4-year follow-up					
Symptoms	57.9	44.1–71.7	70.8	63.9–77.7	0.050
Pain	59.3	42.1–76.4	76.4	70.6–82.1	0.026
Function in activities of daily life	53.2	39.7–66.7	70.9	64.0–77.9	0.010
Function in sports/recreation	47.1	42.5–71.9	67.5	62.5–82.8	0.004
Knee-related quality of life	59.7	43.8–75.6	70.3	63.3–77.3	0.147
KOOS	56.4	42.6–70.3	72.8	66.9–78.7	0.013
10-year follow-up					
Symptoms	33.7	26.2–41.1	50.4	47.1–53.9	<0.001
Pain	40.7	29.1–52.3	45.2	39.0–51.3	n.s.
Function in activities of daily life	27.2	16.6–37.7	56.9	49.1–64.7	<0.001
Function in sports/recreation	21.6	18.1–45.8	40.7	33.4–47.8	n.s.
Knee-related quality of life	41.6	27.9–55.4	50.4	44.4–56.4	n.s.
KOOS	33.1	25.3–40.9	50.8	46.9–54.8	<0.001

n.s. not significant

Discussion

The most important finding in the present randomized study was that RF treatment produced better clinical outcomes and lower revision rates than a simple MD over short- and middle-term follow-up. The rate of needed revisions was significantly lower after RF treatment. After the long-term follow-up, the treatments did not differ meaningfully.

Different methods are available for the treatment of grade III lesions. First, it is possible to treat conservatively by SADOA or DMOAD. Patients who suffer from a concomitant degenerative meniscus tear mostly undergo arthroscopy. In this situation, the surgeon must decide on a treatment for the cartilage lesion. Partial resection of the loose meniscus fragments often produces good short-term results because of the reduction in meniscus-related symptoms, but deep cartilage lesions (grade III) or

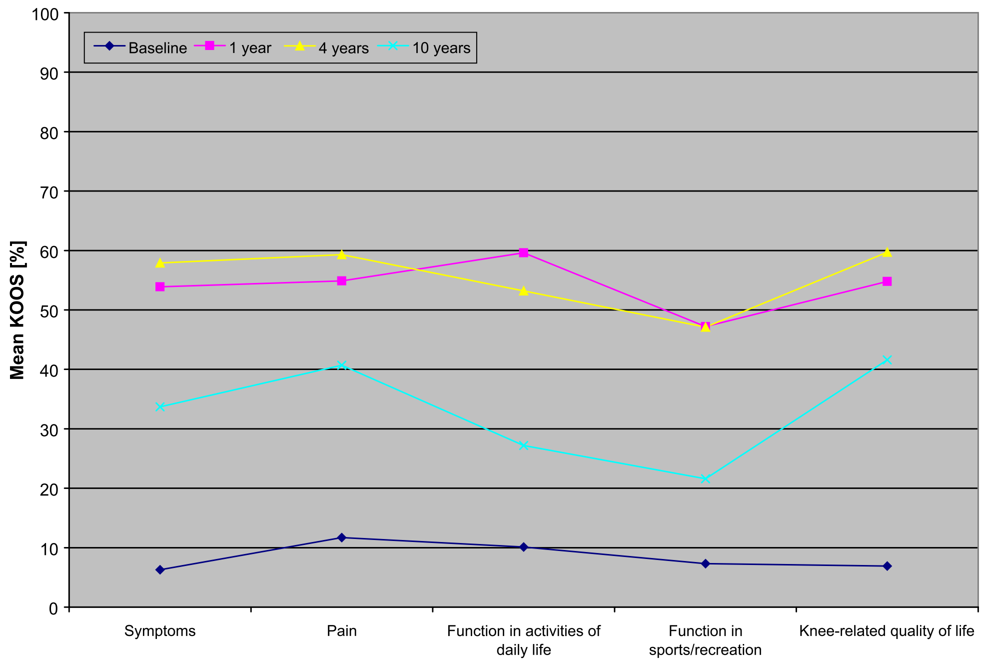

Fig. 2 KOOS profiles of group 1

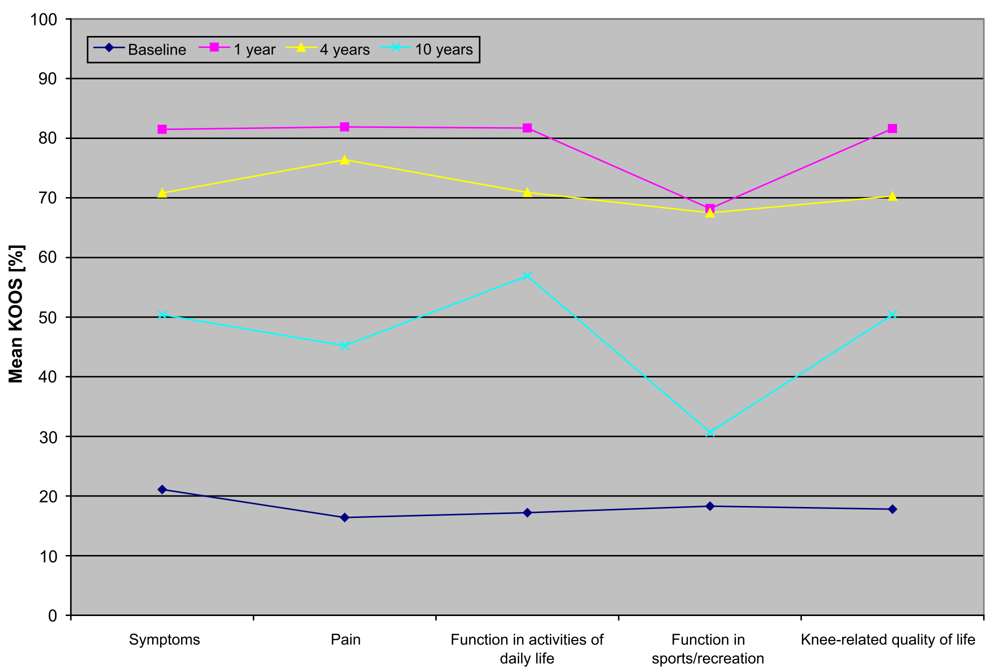

Fig. 3 KOOS profiles of group 2

complete defects (grade IV) must be considered as the initial phase in the development of osteoarthritis. Without treatment of the cartilage lesions, more than 50 % of these patients develop osteoarthritis within 10 years [24]. For the treatment of complete defects (grade IIIb or grade VI), the guidelines give relatively clear directions [16]. Small full-thickness cartilage defects (diameter < 1 cm) should be treated by bone marrow techniques (e.g. microfracture), whereas defects with a diameter > 1 cm should undergo autologous chondrocyte transplantation (ACT), osteochondral transplantation (OATS), or cell-free autologous matrix-induced chondrogenesis (AMIC). However, the best treatment for deep grade III cartilage lesions is controversial. Simple MD aims to smooth the joint surface and remove loose flakes or osteophytes. This procedure became very popular

Table 6 Tegner activity score

	Group 1		Group 2		*p* value
	Median $n = 9$	Range	Median $n = 13$	Range	
Before history	5	3–8	5	3–8	n.s
Baseline	3	1–3	3	1–4	n.s
1-year control	4	2–4	5	2–6	0.049
4-year follow-up	3	2–5	5	2–6	0.030
10-year follow-up	1	1–3	1	1–3	n.s.

n.s. not significant

Table 7 Joint space narrowing

	Group 1		Group 2		*p* value
	Mean (mm) $n = 9$	95 % CI	Mean (mm) $n = 13$	95 % CI	n.s.
Baseline	5.4	4.3–6.5	5.6	4.9–6.3	n.s.
1-year control	4.2	3.0–5.3	5.4	4.6–6.2	<0.049
4-year follow-up	3.6	2.4–4.6	5.1	4.3–5.9	<0.013
10-year follow-up	2.1	0.9–3.2	3.4	2.4–4.4	n.s.

n.s. not significant

during the era of arthroscopy and is one of the most commonly performed arthroscopic operations [17]. Experimental studies regarding the effect of shavers have demonstrated that shaving leads to uncontrollable effects within the chondral matrix and structure [7, 31]. Spahn et al. [23] investigated the cartilage layer after shaving and monopolar RF treatment using scanning electron microscopy. Mechanical shaving produces a rough surface with grooves and open-laying collagen fibres. This causes nearly uncontrolled destruction within the ultrastructure of the chondral matrix. During a 15-month observational study in rabbits, Mitchell and Shepard observed a significant progression of the knee osteoarthritis after shaving. The grade of osteoarthritis varied in accordance with the depth of the shaving and the types of instruments used [15]. In previous randomized clinical investigations, shaving did not produce any positive effect compared to control groups. No scientific evidence supports the use of mechanical shavers to treat cartilage lesions [13]. In a study of patients who did undergo control arthroscopy after osteotomy, we observed complete defects after MD in approximately 30 % and no effects in the remaining patients [26]. In contrast, among patients who underwent RF treatment, 81.6 % demonstrated regeneration (grade III to grade I). In the current study, patients who underwent this treatment had significantly worse short- and middle-term outcomes, which may be the reason for the significantly higher revision rate in this group. Thus, MD of grade III lesions is not indicated.

RF treatment (monopolar or bipolar) produces thermal energy, which has a smelting effect within the cartilage layers. Thus, this method causes smoothing of the degenerated articular cartilage surface. After the procedure, the cartilage appears to regenerate. However, uncontrolled heating of the cartilage is associated with irreversible cell necrosis and destruction of the tissue ultrastructure. RF energy can cause the temperature within the cartilage to rise by 100° or more [34]. This effect is not controlled during surgery. After this procedure, the restoration of normal tissue is improbable [12, 22, 31]. Furthermore, thermoablation has another severe side effect; it alters the subchondral bone. Osteonecrosis occurs in a number of cases, possibly due to ischaemia of the blood vessels within the bone [5]. Clinical trials contain reports of the contradictory effects of RF treatment in regard to clinical outcome, cartilage restoration, and the progression of knee osteoarthritis. Osti et al. [18] observed a better 5-year outcome after microfracturing compared to RF treatment in a case series of ACL-deficient patients. Kang et al. [11] also reported worse results after monopolar RF treatment of cartilage lesions compared to simple debridement.

Regarding monopolar RF treatment, Barber and Iwasko [2] found that its use as an adjuvant to mechanical chondroplasty with a shaver for the treatment of grade III chondral lesions does not affect MRI findings or pain and functional outcomes compared with mechanical chondroplasty using a shaver only. Voloshin et al. reported a significant positive effect in 88 % of patients after treatment with bipolar RF energy. They performed five control arthroscopies, and more than 50 % exhibited partial or complete filling of the defect. The authors concluded that bipolar radiofrequency chondroplasty is an effective method for treating partial-thickness cartilage lesions [33].

Our study is the first long-term study in this field of investigation. Patients undergoing RF treatment benefitted more from surgery than those undergoing MD, as the clinical knee score was higher in RF-treated patients at 1 year [25].

Patients in both groups had to accept a decrease in their physical activity level (Tegner score). The better outcome regarding activity level during short- and middle-term follow-up after RF may be caused by the better clinical outcome (KOOS). After 10 years, the activity level in both groups was less than the pre-operative level. There are two possible reasons for this result. First, the progression of osteoarthritis can reduce the activity level. Second, as patients age there is a “natural” reduction in physical activity. However, the results in both groups worsened over time, and neither treatment option completely avoided the progression of osteoarthritis over the long term.

The pace of osteoarthritis progression in patients who underwent MD did not differ from the natural progression of the disease. Taking grave study-related limitations into account, we conclude that careful RF treatment is sufficient to decelerate osteoarthritis progression in a small number of patients. Among patients who underwent RF, better outcomes were observed at the short- and mid-term follow-ups, as well as at the 10-year assessment. Furthermore, the incidence of osteoarthritis, as indicated by joint space narrowing, was lower in this group. Thus, patients who underwent bipolar RF treatment benefitted during the study period.

Although this study was randomized, the relatively small number of patients in both treatment groups resulted in only moderate statistical power. Significantly more RF-treated patients than MD-treated patients were lost to the 10-year follow-up. We speculate that these patients declined a control because they were unsatisfied with the results. These patients possibly suffered from a post-arthroscopy osteonecrosis. This complication occurs more frequently after RF treatment than other procedures [30]. However, these patients were lost after the fourth post-operative year. Therefore, the RF-related osteonecrosis is more improbable, attenuating the beneficial effect of RF treatment considerably.

Another limitation is the absence of a real control group with an untreated cartilage lesion. Though we decided against this for ethical reasons, the lack of such a control group makes it difficult to appraise the effect of RF in both groups. Furthermore, all patients had a symptomatic medial meniscus tear, which often produces grave clinical symptoms. The short-term and 1-year clinical results were likely influenced by the extent of meniscus resection.

Taken together, our results indicate that the positive effect of MD is doubtful. RF treatment at 50 °C produced better clinical outcomes in the short- and middle-term follow-up, but this method is also not sufficient to stop the progression of osteoarthritis.

Conclusion

Compared to conventional MD, bipolar temperature-controlled RF treatment at 50 °C appears to be a superior method regarding short- and medium-term clinical outcomes and the progression of knee osteoarthritis. Clear predictors of the indications of different cartilage treatments are needed. Moreover, because the power of this study is limited, more randomized controlled trials in this scientific field are needed in the future.

References

1. Amiel D, Ball ST, Tasto JP (2004) Chondrocyte viability and metabolic activity after treatment of bovine articular cartilage with bipolar radiofrequency: an in vitro study. Arthroscopy 20:503–510
2. Barber FA, Iwasko NG (2006) Treatment of grade III femoral chondral lesions: mechanical chondroplasty versus monopolar radiofrequency probe. Arthroscopy 22:1312–1317
3. Barber FA, Uribe JW, Weber SC (2002) Current applications for arthroscopic thermal surgery. Arthroscopy 18:40–50
4. Brittberg M, Winalski CS (2003) Evaluation of cartilage injuries and repair. J Bone Joint Surg Am 85-A(Suppl. 2):58–69
5. Cetik O, Cift H, Comert B, Cirpar M (2009) Risk of osteonecrosis of the femoral condyle after arthroscopic chondroplasty using radiofrequency: a prospective clinical series. Knee Surg Sports Traumatol Arthrosc 17:24–29
6. Cicuttini FM, Jones G, Forbes A, Wluka AE (2004) Rate of cartilage loss at two years predicts subsequent total knee arthroplasty: a prospective study. Ann Rheum Dis 63:1124–1127
7. Edwards RB, Lu Y, Cole BJ, Muir P, Markel MD (2008) Comparison of radiofrequency treatment and mechanical debridement of fibrillated cartilage in an equine model. Vet Comp Orthop Traumatol 21:41–48
8. Hjelle K, Solheim E, Strand T, Muri R, Brittberg M (2002) Articular cartilage defects in 1000 knee arthroscopies. Arthroscopy 18:730–734
9. Horton D, Anderson S, Hope NG (2014) A review of current concepts in radiofrequency chondroplasty. ANZ J Surg 84:412–416
10. Howell SM (2010) The role of arthroscopy in treating osteoarthritis of the knee in the older patient. Orthopedics 33:652
11. Kang RW, Gomoll AH, Nho SJ, Pylawka TK, Cole BJ (2008) Outcomes of mechanical debridement and radiofrequency ablation in the treatment of chondral defects: a prospective randomized study. J Knee Surg 21:116–121
12. Kaplan L, Uribe JW (2000) The acute effects of radiofrequency energy in articular cartilage: an in vitro study. Arthroscopy 16:2–5
13. Laupattarakasem W, Laopaiboon M, Laupattarakasem P, Sumananont C (2008) Arthroscopic debridement for knee osteoarthritis. Cochrane Database Syst Rev CD005118
14. Lu Y, Hayashi K, Hecht P, Fanton GS, Thabit G III, Cooley AJ, Edwards RB, Markel MD (2000) The effect of monopolar radiofrequency energy on partial-thickness defects of articular cartilage. Arthroscopy 16:527–536
15. Mitchell N, Shepard N (1987) Effect of patellar shaving in the rabbit. J Orthop Res 5:388–392
16. Niemeyer P, Andereya S, Angele P, Ateschrang A, Aurich M, Baumann M, Behrens P, Bosch U, Erggelet C, Fickert S, Fritz J, Gebhard H, Gelse K, Gunther D, Hoburg A, Kasten P, Kolombe T, Madry H, Marlovits S, Meenen NM, Muller PE, Noth U, Petersen JP, Pietschmann M, Richter W, Rolauffs B, Rhunau K, Schewe B, Steinert A, Steinwachs MR, Welsch GH, Zinser W, Albrecht D (2013) Autologous chondrocyte implantation (ACI) for cartilage defects of the knee: a guideline by the working group “Tissue Regeneration” of the German Society of Orthopaedic Surgery and Traumatology (DGOU). Z Orthop Unfall 151:38–47
17. Ogilvie-Harris DJ, Jackson RW (1984) The arthroscopic treatment of chondromalacia patellae. J Bone Joint Surg Br 66:660–665
18. Osti L, Papalia R, Del BA, Amato C, Denaro V, Maffulli N (2010) Good results five years after surgical management of anterior cruciate ligament tears, and meniscal and cartilage injuries. Knee Surg Sports Traumatol Arthrosc 18:1385–1390
19. Owens BD, Stickles BJ, Balikian P, Busconi BD (2002) Prospective analysis of radiofrequency versus mechanical debridement of isolated patellar chondral lesions. Arthroscopy 18:151–155

20. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD (1998) Knee injury and osteoarthritis outcome score (KOOS)—development of a self-administered outcome measure. J Orthop Sports Phys Ther 28:88–96
21. Sgaglione NA, Miniaci A, Gillogly SD, Carter TR (2002) Update on advanced surgical techniques in the treatment of traumatic focal articular cartilage lesions in the knee. Arthroscopy 18:9–32
22. Shellock FG, Shields CL Jr (2000) Radiofrequency energy-induced heating of bovine articular cartilage using a bipolar radiofrequency electrode. Am J Sports Med 28:720–724
23. Spahn G, Frober R, Linss W (2006) Treatment of chondral defects by hydro jet. Results of a preliminary scanning electron microscopic evaluation. Arch Orthop Trauma Surg 126:223–227
24. Spahn G, Hofmann GO (2014) Focal cartilage defects within the medial knee compartment. predictors for osteoarthritis progression. Z Orthop Unfall 152:480–488
25. Spahn G, Kahl E, Muckley T, Hofmann GO, Klinger HM (2008) Arthroscopic knee chondroplasty using a bipolar radiofrequency-based device compared to mechanical shaver: results of a prospective, randomized, controlled study. Knee Surg Sports Traumatol Arthrosc 16:565–573
26. Spahn G, Klinger HM, Harth P, Hofmann GO (2012) Cartilage regeneration after high tibial osteotomy. Results of an arthroscopic study. Z Orthop Unfall 150:272–279
27. Stein DT, Ricciardi CA, Viehe T (2002) The effectiveness of the use of electrocautery with chondroplasty in treating chondromalacic lesions: a randomized prospective study. Arthroscopy 18:190–193
28. Strobel M (1998) Manual of arthroscopic surgery. Springer, Berlin, Heidelberg
29. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 198:43–49
30. Turker M, Cetik O, Cirpar M, Durusoy S, Comert B (2015) Post-arthroscopy osteonecrosis of the knee. Knee Surg Sports Traumatol Arthrosc 23:246–250
31. Turner AS, Tippett JW, Powers BE, Dewell RD, Mallinckrodt CH (1998) Radiofrequency (electrosurgical) ablation of articular cartilage: a study in sheep. Arthroscopy 14:585–591
32. Voloshin I, DeHaven KE, Steadman JR (2005) Second-look arthroscopic observations after radiofrequency treatment of partial thickness articular cartilage defects in human knees: report of four cases. J Knee Surg 18:116–122
33. Voloshin I, Morse KR, Allred CD, Bissell SA, Maloney MD, DeHaven KE (2007) Arthroscopic evaluation of radiofrequency chondroplasty of the knee. Am J Sports Med 35:1702–1707
34. Wang N, Liu YJ, Xue J, Li HF, He W, Wang JL (2012) Effects of radiofrequency energy on porcine articular cartilage: higher-power settings in ablation mode show lower thermal radiation injury. Knee Surg Sports Traumatol Arthrosc 20:1901–1906
35. Widuchowski W, Widuchowski J, Trzaska T (2007) Articular cartilage defects: study of 25,124 knee arthroscopies. Knee 14:177–182