Outcomes of Mechanical Debridement and Radiofrequency Ablation in the Treatment of Chondral Defects

A Prospective Randomized Study

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ABSTRACT: This study compared the clinical and biomechanical outcomes of mechanical debridement with and without monopolar radiofrequency energy in treating chondral defects. Patients who were scheduled for arthroscopic procedures (diagnostic, debridement and lavage, and meniscectomy) and consented to biomechanical cartilage stiffness testing comprised the study population. Patients were randomized into 2 groups. In group 1, 14 patients underwent mechanical debridement only, and in group 2, 15 patients underwent mechanical debridement followed by monopolar radiofrequency. Clinical status was evaluated using the International Knee Documentation Committee (IKDC) subjective knee form. In group 2, the biomechanical properties of the defective cartilage before and after treatment also were evaluated. Findings showed a trend toward improvement in mechanical stiffness of energy-treated chondral lesions. Moreover, no significant differences were found between IKDC scores at average follow-up of 16 to 19 months. The addition of radiofrequency energy, at least in the investigated form, does not add clinically significant benefits over mechanical debridement alone of chondral defects.

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INTRODUCTION

Articular cartilage provides a smooth, low-friction surface that distributes contact pressures to protect the underlying subchondral bone in synovial joints.[5] Chondral damage from acute or repetitive impact, or torsional joint loading, occurs in more than 900,000 Americans each year.[5,10] These injuries may include chondral fragmentation, tearing, fibrillation, delamination, or segmental loss of articular cartilage, which ultimately leads to alterations and decreases in the biomechanical properties of articular cartilage.[1,6,10] Partial-thickness defects are associated with subjective complaints such as activity-related pain and swelling, loss of function, and eventually, chronic pain mediated by inflammatory or mechanical processes.[8] Moreover, these defects have limited potential to heal.[27]

The standard treatment for partial-thickness lesions is mechanical debridement (chondral shaving) and lavage of the affected area with sparing of the unaffected articular cartilage. Debridement procedures have shown good short-term results, but long-term follow-up studies have demonstrated deterioration with time.[3,4,11] The procedure yields a macroscopically smoother surface; however, a roughly contoured rim and fine surface fibrillation frequently remain. Over time, the rough surface eventually leads to further degeneration of the treated cartilage.[9,17]

Thermal chondroplasty with monopolar radiofrequency energy (mRFE) is a treatment modality that can smooth irregular chondral surfaces.[19-21] By reducing the amount of fibrillation, radiofrequency energy also may in-

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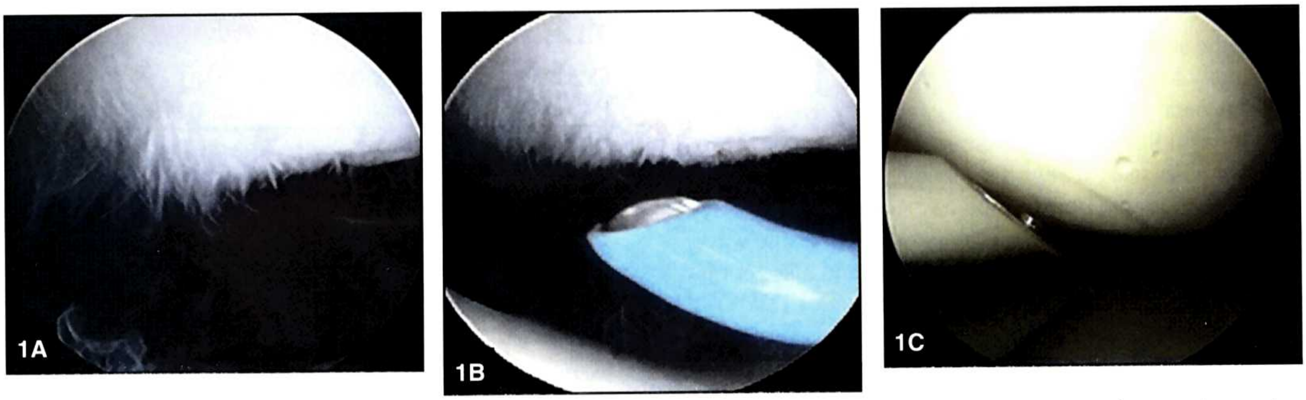

Figure 1. Arthroscopic photographs showing articular cartilage with grade 3 chondromalacia (A), articular cartilage after debridement and monopolar radiofrequency energy treatment (B), and the electromechanical indenter probe testing the stiffness of normal cartilage (C).

moved. In group 2, the biomechanical properties of the defective cartilage also were evaluated before and after treatment. An electromechanical indenter probe (Artscan Inc, Kuopio, Finland) was used to measure the stiffness of the chondromalacic articular surface. Measurements were obtained from the surrounding normal articular cartilage (control), the defect area prior to and after debridement, and the defect area after debridement and mRFE treatment (Dyonics, Smith & Nephew, Andover, Mass). Detailed descriptions of the indenter probe have been provided previously.[23-26] Stiffness measurements were taken by pressing the reference plate against the cartilage surface until a constant 10-N force was attained. This technique demonstrated >95% reproducibility in a previous study.[30] Two 60-second intervals were recorded for each measurement. In group 2 patients, the mechanical debridement was followed by mRFE application using a Vulcan EAS 3.12 with a TAC-C probe (Dyonics; Smith & Nephew) with temperature control setting (70°C, 30 watts); the total treatment time was recorded (Figures 1 and 2). The mRFE was applied in a light contact fashion over the lesion until smoothing of the surface was visualized, and the indenter measurements then were repeated.

In group 1, 8 patients had generalized chondromalacia and 6 patients had localized chondral defects. Defects were located in the medial femoral condyles in 10 patients and in the lateral femoral condyles in 4 patients. Four patients had grade 2 lesions, and 10 patients had grade 3 lesions (Table 1). The median defect size was 3.9 cm^2 (range: 0.3-6.3 cm^2).

In group 2, 8 patients had generalized chondromalacia and 7 patients had localized chondral defects. Defects were located in the medial femoral condyles in 12 patients and in the lateral femoral condyles in 3 patients. Seven patients had grade 2 lesions, and 8 patients had grade 3 lesions (Table 1). The median defect size was 4 cm^2 (range: 1-8 cm^2), and the average length of mRFE treatment was 59 seconds (range: 22-120 seconds). The mRFE probe was applied for an average of 14.1 seconds/cm^2.

Statistical Analysis

Baseline clinical scores were compared with follow-up data using the Wilcoxon signed rank test, whereas the change in score between the preoperative and postoperative periods was compared between the 2 groups using the Mann-Whitney test. Mean stiffness values of normal cartilage, defects prior to treatment, defects after mechanical debridement, and defects after debridement and mRFE were analyzed using the Wilcoxon signed rank test to compare the groups. Statistical analysis was performed using SPSS version 11.5 (SPSS Inc, Chicago, Ill). A P value <0.05 was considered significant.

RESULTS

In group 1, mean IKDC scores changed significantly from 36 preoperatively to 59 at mean follow-up of 16 months, with a mean improvement of 23 points (standard error of the mean [SEM]=3.2; P=0.001). In group 2, mean IKDC scores also changed significantly from 30 preoperatively to 49 at mean follow-up of 19 months, with a mean improvement of 20 points (SEM=5.5; P=0.003). However, a comparison of the mean improvement in scores between the two groups was not statistically significant (P = 0.444) (Table 2).

Intraoperative stiffness measurements also were recorded in group 2. Mean stiffness of normal cartilage was 2.7 N (SEM=0.26), which was significantly greater than mean stiffness of defects before treatment (1.07 N; SEM=0.28), after debridement only (0.94 N; SEM=0.17), and after debridement and mRFE (1.38 N; SEM=0.29) ($P<0.002$). However, the differences among the mean stiffness measurements of the chondromalacic cartilage were not significant for before treatment versus after de-

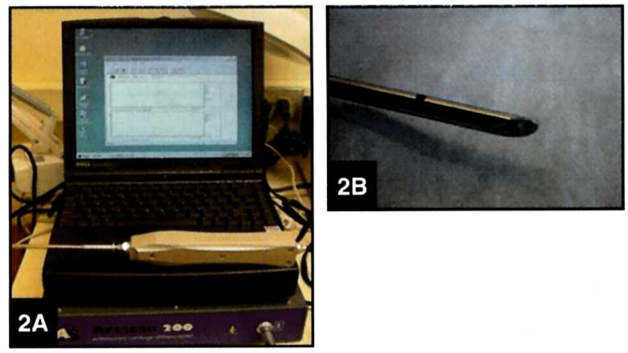

Figure 2. Photographs showing the Artscan (Kuopio, Finland) stiffness measurement system (A) and its indenter probe (B).

bridement only (P=0.57), before treatment versus after debridement and mRFE (P=0.134), and after debridement only versus after debridement and mRFE (P=0.059) (Figure 3). There was a trend toward significance in the stiffness measurements after debridement only versus after debridement and mRFE.

DISCUSSION

The findings of this study demonstrated subjective improvements in IKDC scores for both groups. However, this change in IKDC score was not significantly different between the 2 groups. Additionally, a comparison of the stiffness measurements of cartilage after debridement only versus cartilage after both debridement and mRFE demonstrated a trend toward significance.

Owens et al[29] reported on the benefits of bipolar radiofrequency energy (bRFE) in the debridement of Outerbridge grades 2 and 3 chondral lesions of the patella. The Fulkerson-Shea scores demonstrated radiofrequency ablation was superior to mechanical debridement at 12 and 24 months post-treatment. The success of radiofrequency energy in the treatment of patellar chondral lesions has provided the impetus behind applying similar technology to femoral condyle chondral lesions. Our study was a prospective, randomized trial that examined the clinical and biomechanical outcomes of mRFE in the debridement of grades 2 and 3 chondral lesions of the femoral condyles.

Monopolar RFE was used in this study because previous reports have shown advantages with mRFE compared to bRFE regarding depth of chondrocyte death.[19,21] One of those reports also demonstrated the efficacy of mRFE was comparable to bRFE regarding surface contouring, which is a major factor in the progression of chondromalacia.[21]

We chose to study the effects of mRFE on femoral condyle defects for 2 reasons. The first reason was to determine whether clinical benefits can be seen with radiofrequency energy debridement of femoral condyle lesions and to note any advantages compared with mechanical debridement alone. The second reason was that femoral condyles were more easily accessed than other locations to make accurate biomechanical analyses with the stiffness probe through arthroscopic portals.

The subjective scores were analyzed using the IKDC subjective knee form, which has been validated in prior studies.[30] As expected, both groups demonstrated clinical improvement after treatment. This can be explained at a microscopic level because debridement removes fibrillated cartilage, a source of chemical and mechanical irritation.[7,12,13,31] Because previous studies showed better surface contouring with radiofrequency compared with mechanical debridement,[21] we expected better clinical outcomes with the use of mRFE. However, this trial has not demonstrated a significant difference in IKDC score improvement between the 2 groups.

Our study is the first to analyze the effects of radiofrequency energy on the biomechanical properties of chondromalacic femoral condyles. Not surprisingly, we have shown the stiffness of defective cartilage is significantly less than that of normal cartilage. Although we could not demonstrate any significant changes in the stiffness of the defective cartilage after treatment with debridement only, we were able to demonstrate a trend toward significance after debridement and mRFE.

There were limitations to our study. Because the results of this study approached significance with a P value of 0.059, a larger number of patients potentially could have demonstrated significant differences in mechanical stiffness with mRFE application. However, a power analysis (with power of 0.8 and alpha of 0.05) revealed that a sample size of at least 28 patients in each group was needed to detect a statistically significant difference in the mechanical stiffness between the debridement only versus debridement and mRFE groups. Similar power analyses for before treatment versus after debridement and before treatment versus after debridement and mRFE comparisons revealed sample sizes needed to be 439 and 68, respectively. A power analysis comparing the mean improvement in scores between the 2 groups led to a sample size of 45.

We also did not conduct a direct comparison of mechanical debridement alone versus mRFE alone. The addition of mRFE to a cartilage surface already treated with mechanical debridement may not be as effective as using mRFE alone. Although we studied the intermediate clinical outcomes of mRFE treatment, the long-term outcomes should be studied as well. Additionally, the effects of mRFE should be studied through the use of magnetic resonance imaging and second-look arthroscopies to demonstrate any macroscopic changes. A second-look arthroscopy case report has been conducted after the application crease the stiffness of cartilage, thus restoring some of the previously lost biomechanical strength.[22,32]

The energy output of mRFE is easily controllable, thereby avoiding adverse effects such as charring.[14] Monopolar RFE uses a high-frequency alternating current that flows from the probe to the tissue and applies a force to the ions within the tissue as an unmodulated sine wave. An active electrode is used for treatment, and a larger dispersive electrode is attached to the patient.[28]

In this study, the International Knee Documentation Committee (IKDC) system was used to compare the outcomes of patients who underwent mechanical debridement alone versus patients who underwent debridement followed by mRFE. In addition, the change in biomechanical stiffness of the chondromalacic cartilage was measured in patients who underwent mechanical debridement followed by mRFE.

MATERIALS AND METHODS

Study Population

Prior to being enrolled in the study, informed consent was obtained from all participants, and the study was approved by the university's institutional review board. All of the patients enrolled in the study had failed a 6-month conservative treatment regimen that included activity modification, anti-inflammatory medications, and physical therapy. Between April 2001 and December 2003, a total of 70 patients who were scheduled for arthroscopic procedures (diagnostic, debridement and lavage, and meniscectomy) provided consent in the preoperative holding area for biomechanical cartilage stiffness testing and radiofrequency treatment.

In this single-blinded, randomized control trial, patients were randomized into 2 treatment groups. Patients in group 1 underwent mechanical debridement only, and patients in group 2 underwent mechanical debridement followed by mRFE. A simple randomization protocol was used in which envelopes containing the group designation were created prior to the study's patient enrollment phase. After patients provided consent and met the study's intraoperative inclusion criteria, an examiner picked an envelope to determine each patient's group designation. This information was known only by the examiners; patients were unaware of their group designation for the duration of the study.

Chondromalacia was graded intraoperatively using the following modified Outerbridge system[10,18]:

- Grade 1: softened cartilage surface.
- Grade 2: softened cartilage with fine fibrillations.
- Grade 3: fibrillated surface with pitting to subchondral bone.
- Grade 4: fibrillation of cartilage and exposed subchondral bone.

TABLE 1

COMPARISON OF DEMOGRAPHICS AND INTRAOPERATIVE FINDINGS BY TREATMENT GROUP

	Group 1[a] (n=14)	Group 2[b] (n=15)
Mean age±SD (y)	47±12	50±10
Degree of chondromalacia		
Localized	6	7
Generalized	8	8
Location		
Medial femoral condyle	10	12
Lateral femoral condyle	4	3
Grade of chondromalacia		
Grade 2	4	7
Grade 3	10	8
Treatment time per area (seconds/cm^2)	NA	14.1

Abbreviation: NA=not applicable.
[a] Mechanical debridement only.
[b] Mechanical debridement followed by monopolar radiofrequency energy.

Only cartilage with either grade 2 or 3 chondromalacia was selected for use in this study. Besides debridement of the defect area, the only concomitant procedure included in this study was partial meniscectomy of the involved compartment. Exclusion criteria were age <18 years, grade 1 or 4 defects, concomitant ligamentous or patellofemoral defects, indications for autologous chondrocyte transplantation, diffuse osteoarthritic changes, metabolic bone disease, joint infection, crystal deposition disease, inflammatory joint disease, periarticular or patella fracture, neoplastic disease, or permanent severe disability of the lower limbs (requiring a cane, crutches, or wheelchair).

Of the patients who gave consent, 29 patients had isolated grade 2 or 3 lesions of the femoral condyles and therefore were included in the study. As a result of the randomization, 14 patients (9 men and 5 women) comprised group 1 and 15 patients (5 men and 10 women) comprised group 2. Mean age was 47±12 years (range: 25-63 years) in group 1 and 50±10 years (range: 35-69 years) in group 2. After patients' eligibility was determined, lesions were characterized by grade, size, and location (Table 1). All surgeries were performed by a single surgeon (B.J.C.) at a single institution.

The clinical status of patients was evaluated using the IKDC subjective knee form.[15] Mean follow-up was 16 months (range: 10-28 months) for group 1 and 19 months for group 2 (range: 11-28 months).

In group 1, the chondromalacic area was debrided with a mechanical shaver until the fibrillations were re-

TABLE 2

COMPARISON OF PREOPERATIVE AND POSTOPERATIVE INTERNATIONAL KNEE DOCUMENTATION COMMITTEE (IKDC) SCORES BY TREATMENT GROUP

	Group 1[a] (n=14)	Group 2[b] (n=15)
Mean follow-up (months)	16	19
Mean IKDC score±SEM		
Preoperative	36±2.8	30±3.5
Postoperative	59±3.7	49±4.2
Change	23±3.2	20±5.5
	(P=0.001)	(P=0.003)

Abbreviation: SEM=standard error of the mean.
[a] Mechanical debridement only.
[b] Mechanical debridement followed by monopolar radiofrequency energy.

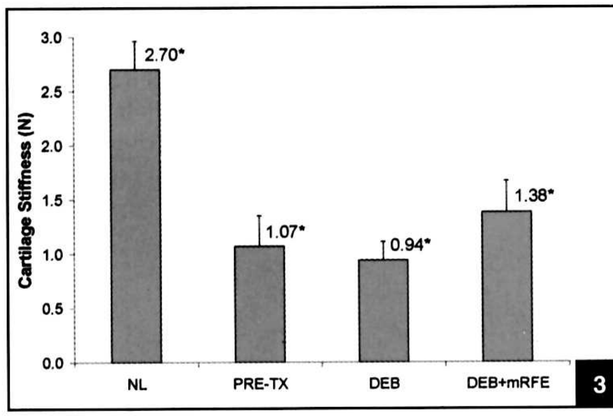

Figure 3. Graph showing mean stiffness measurements with SEM bars. Asterisks indicate significant difference versus normal cartilage stiffness; no other comparisons were statistically significant. (NL=normal cartilage, PRE-TX=chondromalacic cartilage pre-treatment, DEB=chondromalacic cartilage after debridement, DEB+mRFE=chondromalacic cartilage after debridement and monopolar radiofrequency.)

of bRFE. The results of this study are encouraging as it demonstrated fibrocartilage-like tissue filling the defect area previously treated with bipolar radiofrequency-based chondroplasty.[33]

Previous histologic studies have produced contradictory results. Turner et al[32] evaluated bRFE chondroplasty in a sheep model and found the bRFE-treated regions had better histologic grades than mechanically debrided regions at 6 months. Kaplan and Uribe[16] demonstrated radiofrequency had no detrimental effects on articular cartilage.

Conversely, Lu et al[22] found both mRFE and bRFE led to significant levels of chondrocyte death. Despite these findings, they also concluded mRFE application led to a stable cartilaginous surface 6 months post-treatment in a sheep model. Amiel et al[2] demonstrated the depth of chondrocyte death after radiofrequency application reached 100 to 200 μm, which approximates the depth of chondrocyte death caused by mechanical debridement (150-250 μm).[22] The combination of these two modalities may even produce further depths of chondrocyte death.

It is apparent that the biologic and mechanical effects of radiofrequency energy are not completely understood. Additional research is needed to investigate topics such as application technique, temperature settings, and fluid environment in greater detail.

CONCLUSION

The addition of radiofrequency energy to mechanical debridement led to a trend in increased stiffness of the lesion and yielded intermediate-term clinical outcomes that were equivalent to mechanical debridement alone. Additional clinical and basic science studies are required, especially to compare the effects of mRFE alone versus mechanical debridement alone in the treatment of femoral condyle chondral lesions, and also to evaluate long-term clinical and histologic outcomes.

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