Radiofrequency energy in the arthroscopic treatment of knee chondral lesions: a systematic review

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Abstract

Introduction: Cartilage debridement is one of the recommended procedures for the management of chondral defects. Radiofrequency probes allow to debride the cartilage, but may induce subchondral bone necrosis.

Sources of data: Medline, Cochrane and Google Scholar were searched to identify studies on arthroscopic debridement of the articular cartilage of the knee using radiofrequency chondroplasty. The methodological quality of the studies was assessed using the Coleman methodology score (CMS).

Areas of agreement: Monopolar and bipolar radiofrequency devices provide significantly better clinical outcomes, especially for patients with high-grade chondral lesions, compared with mechanical shaver only. Despite the original concerns regarding subchondral bone necrosis, low complication rates are reported.

Areas of controversy: Heterogeneity in terms of type of device does not allow sound comparison of the published results. There is lack of evidence on the long-term effects of radiofrequency chondroplasty.

Growing points: Study methodology should be improved: the average Coleman methodology score was 56.2 out of 100.

Research: More comparative, well-designed and larger cohort trials are needed to ascertain whether radiofrequency chondroplasty offers long-term benefits over other simpler and more economical alternatives.
**Introduction**

Lesions of the articular cartilage can be debilitating and have a high social impact, but treatment for such defects is still a challenge. Articular cartilage has a low healing potential, and, at present, none of the available surgical or conservative lines of treatments has proved to achieve durable optimal clinical outcomes.

Chondroplasty, a first-line surgical procedure used for the management of initial chondropathy, aims to mechanically remove chondral tissue through a motorized shaver.

During the 1990s, radiofrequency energy (RFE) instruments have been introduced into arthroscopic surgery to replace mechanical tools. RFE is based on the application of modulated thermal energy on cartilage injury to produce a compact and uniform biological scar, using thermal energy within a tightly set therapeutic range.

RFE instruments are able to perform a more effective removal of the impaired cartilage, gently than motorized shavers, with a more precise approach to the margins of healthy cartilage, thus avoiding further fragmentation of this tissue.

The use of this technology has quickly spread, but the opinions concerning their safety and effectiveness are still discordant. Some authors suggested that RFE, especially when bipolar frequency instrumentations are involved, could cause necrosis of the subchondral bone.

We systematically reviewed the literature to collect evidence about the effectiveness and safety of the use of RFE tools for arthroscopic treatment of cartilage lesion, analysing published studies presenting the clinical outcomes of this type of surgery.

**Methods**

The Medline (http://www.ncbi.nlm.nih.gov/pubmed), Cochrane (http://www.thecochranelibrary.com/view/0/index.html) and Google Scholar (http://scholar.google.it/) online databases were searched from inception to May 29, 2015. The following keywords [radiofrequency AND knee], [radiofrequency AND chondral lesions], [radiofrequency AND arthroscopic debridement], [chondral lesions management] were used alone and in all the various combinations to identify relevant articles. Clinical randomized trials, case series and prospective cohort studies reporting on the clinical outcomes of arthroscopic surgery using RFE instruments for the treatment of chondral lesions were taken into consideration, while biomechanical studies, cadaveric studies, laboratory studies, case reports, review articles and meta-analyses were not considered. All the cohorts of the included studies were composed of adult patients. Attention was focused on arthroscopic debridement of chondral lesions of the knee, comparing clinical outcomes of RFE debridement with the other types of intervention.

After the initial electronic search, by consulting the title and the abstract of the articles, only studies on human subjects were further considered for inclusion in this review. Of these, the full-text articles were carefully evaluated by two different reviewers (S.D. and R.P.). Given our language capabilities, studies in English, Spanish, French and German were considered in this process of inclusion. Once the pool of articles identified as suitable for inclusion was determined, outcome data reported were systematically collected, and all other features regarding characteristic of the investigated cohort and methodology of the investigation were searched and gathered to be analysed.

**Quality assessment of the studies**

The modified Coleman score was used to evaluate the methodological quality of the articles included. The score ranges from 0 to 100 and is divided into 10 categories. A perfect score of 100/100 would
indicate that the study taken into consideration features the best possible trial design and methodology of data analysis. Two different reviewers (G.T. and R.P.) separately scored each article. They later met and discussed the assigned scores when a difference of >5 points was present until consensus was reached.

**Results**

**Number and type of studies**

Ten studies met all the inclusion criteria and were included in this review. Seven of these are randomized controlled trials,8–15 and three are case series9,16,17 (Fig. 1).

**Included studies data**

The mean follow-up time was 32.5 months (range 6 months to 6 years), while the mean age at surgery was 39 years (range between 29.0 and 49.0).

Seven studies11–17 compared RFE debridement with mechanical debridement. One study compared RFE with chondral microfractures.11 Two studies also evaluated deterioration or osteonecrosis of the treated chondral area after radiofrequency treatment.9,17 A detailed overview of demographics and other data is given in Table 1.

**Classifications and measures**

All authors evaluated severity of the chondral lesion using the validated Outerbridge classification.18 As for the clinical outcome assessments, the IKDC score was adopted in three studies,8,10,11 the KOOS in the two studies,13,14 the Cincinnati score, Tegner, Lysholm, Womac and VAS scales were used in three further studies.8,11,15

**Coleman methodology score**

The mean CMS of the studies was 56.2 out of a maximum 100. The CMS categories that showed the highest scores were ‘type of the study’ (7 out of the 9 articles pooled were RCTs, scoring the highest possible value) and the ‘outcome criteria’ sections. The lowest subscores were shown for the ‘description of postoperative rehabilitation’ item, because only one study12 reported at least a brief description of the protocol adopted to rehabilitate the patients postoperatively. The total Coleman methodology scores and the details for each criterion of this assessment are given in Table 2.

**Comparison between RFE and mechanical debridement**

Barber and Iwasko8 performed a RCT with a mean follow-up of 19 months; arthroscopic debridement

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**Fig. 1** Study selection flow diagram.
of isolated Outerbridge Grade III lesions of the femoral condyle with mechanical shaver alone was compared with the same procedure performed with shaver and monopolar RFE. All the subjects had a Grade III lesion from 1.5 to 3.0 cm in diameter. The IKDC score was assessed preoperatively (shaver alone group = 35 and shaver plus RFE group = 36) and after the procedure (shaver alone group = 68 and shaver plus RFE group = 69), showing equivalent results (preoperative, \( P = 0.28 \); postoperative, \( P = 0.85 \)). The Lysholm score was also assessed, with similar findings (preoperative values, \( P = 0.37 \); postoperative values, \( P = 0.9 \)).

Owens et al.\(^ {12} \) performed a RCT to compare mechanical and bipolar RFE (bRFE) arthroscopic debridement of patellar cartilage lesions, graded II or III of the Outerbridge classification in moderate recreational athletes. The Fulkerson–Shea score was used to assess the outcomes preoperatively and at 12 and 24 months from the surgery (preoperatively, the Fulkerson–Shea score was 59.2 in the mechanical shaver group versus 59.2 in bRFE group; at 24 months, the Fulkerson–Shea score was 77.5 vs. 86.6, with a final \( P = 0.0006 \)).

Spahn et al.\(^ {13} \) in 2008 compared the outcomes of mechanical versus bRFE arthroscopic debridement in patients with idiopathic Grade III cartilage defects of the medial condyle of the femur. The KOOS and VAS scores were assessed at 1 year from the surgery, without significant difference (\( P < 0.001 \) for both) between the groups.

In 2010, Spahn et al.\(^ {14} \) carried out a further analysis to publish the 4-year average Tegner and KOOS scores of the same cohort, showing that the latter was 53.2 in the mechanical shaver group vs. 71.8 for the RFE-treated patients (\( P < 0.001 \)).

Stein et al.\(^ {15} \) published the findings of a RCT comparing mechanical chondroplasty and mechanical chondroplasty with RF. One hundred and forty-six patients with chondromalacia were included, and Outerbridge Grade II–IV lesions were treated after diagnostic arthroscopy. After treatment, the Lysholm score was used to evaluate the patients, showing significant improvements in the measured outcome for Grade III and IV lesions in the chondroplasty group compared with same type of lesions treated with associated techniques (\( P < 0.05 \) and \( P = 0.03 \), respectively).

Türker et al.\(^ {16} \) in a recent prospective study divided a cohort of 75 patients into three groups: the first group was treated with arthroscopic meniscectomy only, the second one with meniscectomy plus mechanical debridement of the lesions and the third one with meniscectomy plus radiofrequency debridement.

### Table 1 Details of the studies included

<table>
<thead>
<tr>
<th>Study</th>
<th>Coleman score</th>
<th>Type of study</th>
<th>Patients</th>
<th>Mean follow-up</th>
<th>Type of lesions</th>
<th>Type of radiofrequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barber and Iwasko(^ {8} )</td>
<td>52</td>
<td>CRT</td>
<td>60</td>
<td>19 months</td>
<td>Single Outerbridge Grade III femoral condyle lesion from 1.5 to 3.0 cm in diameter</td>
<td>M</td>
</tr>
<tr>
<td>Cetik et al.(^ {9} )</td>
<td>22</td>
<td>CS</td>
<td>50</td>
<td>Not reported</td>
<td>Outerbridge Grade II or III Group 1 included patients with Grade III–IV cartilage lesions; Group 2 included patients with Grade I–II cartilage lesions</td>
<td>B</td>
</tr>
<tr>
<td>Osti et al.(^ {11} )</td>
<td>76</td>
<td>CRT</td>
<td>78</td>
<td>6 years</td>
<td>Outerbridge Grade II or III, in patellar cartilage</td>
<td>B</td>
</tr>
<tr>
<td>Owens et al.(^ {12} )</td>
<td>72</td>
<td>CRT</td>
<td>48</td>
<td>24 months</td>
<td>Outerbridge Grade III cartilage defect(s) of the medial femoral condyle</td>
<td>B</td>
</tr>
<tr>
<td>Spahn et al.(^ {13} )</td>
<td>69</td>
<td>CRT</td>
<td>60</td>
<td>24 months</td>
<td>Outerbridge Grade III cartilage defect(s) of the medial femoral condyle</td>
<td>B</td>
</tr>
<tr>
<td>Spahn et al.(^ {14} )</td>
<td>75</td>
<td>CRT</td>
<td>60</td>
<td>4 years</td>
<td>MRI-visualized Grade III articular cartilage lesion</td>
<td>B</td>
</tr>
<tr>
<td>Stein et al.(^ {15} )</td>
<td>64</td>
<td>CRT</td>
<td>146</td>
<td>12 months</td>
<td>Outerbridge Grade II to III–IV</td>
<td>Not reported</td>
</tr>
<tr>
<td>Türker et al.(^ {16} )</td>
<td>68</td>
<td>CS</td>
<td>75</td>
<td>6 months</td>
<td>Outerbridge Grade II or III</td>
<td>M</td>
</tr>
<tr>
<td>Voloshin et al.(^ {17} )</td>
<td>8</td>
<td>CS</td>
<td>193</td>
<td>Not reported</td>
<td>Outerbridge Grade I–IV</td>
<td>B</td>
</tr>
<tr>
<td>Kang et al.(^ {10} )</td>
<td>50</td>
<td>CRT</td>
<td>70</td>
<td>17.5 months</td>
<td>Outerbridge Grade II or III</td>
<td>M</td>
</tr>
</tbody>
</table>
At 6 months from the surgery, findings suggestive of osteonecrosis were detected at MRI in two patients in the first group, two patients in the second group and one patient in the third one.

Kang et al.\textsuperscript{10} compared mechanical arthroscopic debridement of Grade II or III lesions of the knee cartilage, performed with or without monopolar RFE (mRFE). The IKDC score was used preoperatively and at latest follow-up (ranging from 10 to 28 months), with mean values of 59 vs. 49, in mechanical debridement only group and mechanical plus RFE debridement group, respectively.

Outcome of RFE alone surgery

Cetik et al.\textsuperscript{9} published a prospective case series to ascertain whether bRFE causes osteonecrosis of the bone close to the treated cartilage area. Outerbridge Grade II and III lesions were diagnosed in all participants, and only two patients (4\% of the whole cohort) developed extended bone osteonecrosis.

Voloshin et al.\textsuperscript{17} reported a case series to demonstrate how lesions treated with bRFE are not likely to develop further deterioration. Patients included had a history of previous RFE chondroplasty (Outerbridge Grade I–IV) and underwent a new arthroscopy procedure because of continued discomfort or to a new injury. At this second-look arthroscopy, three lesions (12\%) showed degeneration of the surrounding cartilage, eight (32\%) showed no further progression. Partial (8 patients, 32\%) or complete (6 patients, 24\%) filling with stable repair tissue was noted.

Comparison between RFE and other techniques

Osti et al.\textsuperscript{11} compared RFE with microfracture technique in patients with confined cartilage defect randomizing two groups of patients: the first one (Outerbridge lesions Grade III and IV) underwent microfracture treatment, and the second (Outerbridge lesions Grade I and II) underwent RFE debridement (Arthrocare RFE probe). The IKDC, Lysholm and Tegner scores were assessed at baseline, at 24 months and 5 years from surgery. At the latest follow-up, the mean IKDC was 81 in the first group, and 88 in the second; the mean Lysholm was 83 vs. 87, the mean
Tegner was of 6 vs. 7. The WOMAC questionnaire was used to complete the latest clinical evaluation, with a statistically significant difference between the groups ($P < 0.001$).

A detailed report of all clinical outcome data is given in Table 3.

### Discussion

Cartilage injuries cause at first simple softening of the involved tissue, then an initial disruption of the surface continuity occurs, and its gradual deepening causes degradation of the cartilage and exposure of the underlying bone evolving towards frank arthrosis.

The management of articular cartilage pathology is debated, and no solution ensures a perfect predictable clinical outcome. No surgical act except the simple palpation of the lesion is expected for Grade I chondral tears. In Outerbridge Grade II and III lesions, articular washout, debridement and shaving are undertaken to circumscribe the margins of the lesion and block the local release of cytokines responsible for the inflammatory processes and the consequent painful synovitis and joint effusions.

Throughout the second half of the 1990s, surgical instruments employing mRFE or bRFE were introduced for arthroscopic use as they were able to reach a more precise and anatomical delimitation of the lesioned margins to prevent further fragmentation of the cartilage. Monopolar radiofrequencies use an alternating current between the electrode and the plate which goes from the electrode to the cartilage.
through the plate producing a molecular dissociation from the rapid increase in temperature.\textsuperscript{4,23} On the other end, bRFE develops alternate current passing through the hand piece where there are one positive and one negative electrode. This energy propagates in the irrigation liquid producing a vaporization of the physiological saline solution to a temperature of $\sim100^\circ$C, consequently obtaining secondary changes in the biological properties of the tissues.

These instruments continued to be developed and researched, with particular attention to their safety and effectiveness. For example, Lu et al.\textsuperscript{6,24–26} performed several \textit{in vivo} studies on sheep, suggesting a cautious use of RFE for the potential risk, especially for bRFE, of causing chondrocyte necrosis. Other authors\textsuperscript{22,27} later demonstrated that radiofrequency treatment should be considered safe and effective. Its use may be especially suitable for low-grade cartilage lesions with unstable fragmented margins where the primary goal of the procedure is to avoid further fragmentation. At microscopy, the tissue surrounding the treated area appears to remain viable.\textsuperscript{9} Given the different views and the unsolved uncertainties involving the safe use of RFE to manage articular cartilage pathology, we systematically reviewed all the clinical trials reporting data on outcomes of patients with chondral lesions treated with this technique to determine the safety and effectiveness of this methodology.

Considerable attention was directed to determine the safety of this procedure, aiming to find any possible side effects in the use of it. In particular, RFE is suspected of causing postoperative osteonecrosis, as it produces a considerable amount of thermal energy which can reach also the inner bony core of the treated cartilage.\textsuperscript{3,19} However, the evidence excludes this possible detrimental effect.\textsuperscript{9} Based on these data, it appears that the use of RFE is efficient and safe in the surgical management of chondral lesions, especially Outerbridge Grade 2 and 3 lesions, even though the favourable clinical outcomes in the short-medium term may well worsen in the longer term as a result of evolving osteoarthritis changes. It should be remembered that, given the present evidence, Grade I lesions should be left alone, and Grade IV lesions are too advanced to benefit from simple debridement. Therefore, RFE is not indicated in these types of lesions. The physical and biologic effects of RFE are still not fully elucidated; thus, further basic science research is needed in this field. We suggest that such technology can be used confidently but with special caution.

The studies included in the present systematic review were evaluated using the Coleman methodology score, an evaluation score first developed to assess the methodological quality of studies on surgical management of patellar tendinopathy, but successfully used for other conditions and procedures, such as surgery for Achilles tendinopathy,\textsuperscript{28} knee arthroplasty,\textsuperscript{29} augmentation techniques for rotator cuff repair,\textsuperscript{30} etc. The average CMS in the present review was 56.2, showing a medium methodological quality of the studies examined.

To our knowledge, the present study is the only systematic review focusing on the effects of RFE applied to chondral lesions in the knee. However, this systematic review presents limitations: first, the clinical trials on the issue at hand are still too few, with small sample size. Moreover, there was a noticeable heterogeneity regarding the aims and design of the studies published, with lack of randomization and lack of control groups in most of the studies, making their conclusion very likely to be subject to evaluation bias. Finally, outcome was not assessed in a uniform fashion in the various studies, making it difficult to undertake a full and statistically reliable comparison of the data published.

**Conclusion**

Radiofrequency is a widely used tool for arthroscopic chondroplasty of the knee. Despite the reported risk of osteonecrosis of the subchondral bone, which RFE can lead to, clinical evidence shows clearly that only a few cases of necrosis occur. More clinical randomized and controlled trial should be carried out, with larger cohorts, appropriate outcome measures and longer follow-up.

**Conflict of interest statement**

The authors have no potential conflicts of interest.
References


