REVIEW ARTICLE

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A review of current concepts in radiofrequency chondroplasty

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Abstract

Radiofrequency (RF) chondroplasty is a promising treatment of chondral defects. The purpose of this study is to summarize current literature reporting the use of radiofrequency energy as an alternative treatment to mechanical shaving in chondroplasty. This review depicts the basic understanding of RF energy in ablating cartilage while exploring the basic science, laboratory evidence and clinical effectiveness of this form of chondroplasty. Laboratory studies have indicated that RF energy decreases inflammatory markers in the cartilage as well as providing optimal results with smoothing of chondral clefts. There have been concerns of chondrolysis due to heat damage of chondrocytes; however, this is unsubstantiated in clinical studies. These clinical trials have highlighted that RF energy is a safe and efficacious method of chondroplasty when compared to the mechanical shaving technique.

Introduction

Mechanical shaving has been used as the principal treatment in partial chondral tears. Progression of lesions due to sharp edges from the shaver and collateral damage to surrounding healthy cartilage has caused dissatisfaction in this treatment. Since partial thickness chondral defects are commonly seen in knee arthroscopies with up to 60% of procedures diagnosing a partial thickness chondral tear,[1] it is important that a treatment be developed that will stop progression and reduce the risk of removal of any healthy tissue. As a result, radiofrequency (RF) energy was hypothesized to be beneficial due to its tissue heating ability to temperatures that can cause ablation of the cartilage, thus smoothing the surface and removing defects. Since its development, the use of RF energy in chondroplasty has increased clinically. Superior results have been reported in studies comparing RF chondroplasty to mechanical shaving. This article will study these current concepts.

Chondral defects

Chondral defects are seen in 60% of all knee arthroscopy procedures[1,2] with injury to articular cartilage causing progressive and permanent damage.[2] These defects are described in terms of grading systems, such as the International Cartilage Research Society (ICRS) grading system.[1] In this system, cartilage damage is graded from grade 0 (normal) to grade 4 (severely abnormal).[3] Articular cartilage has little ability to repair defects with any repair response that does occur forming a disorganized and inadequate tissue mass.[4] This inability to repair can be attributed to a lack of vascular supply and reliance on synovial fluid for nutrients.[5]

Natural history

Grade 2 and 3 chondral lesions are generally associated with gross fibrillations and a rough surface[1] (examples of these defects can be seen in Figures 1 and 2 where magnetic resonance imaging (MRI) has been utilized to assess patient's knee pain). If left untreated, these can form greater cartilage damage with fibrillations breaking down to loose bodies (potentially causing reactive synovitis) and roughened surfaces disturbing joint movement while causing pain and crepitations.[1] It is important that treatment be undertaken on chondral defects to prevent the progression of joint damage, osteoarthritis and ensuing pain and disability. The natural history of these lesions is still relatively unknown with no effective means of checking disease progression currently present.[6] Radiological imaging may be used in clinical outcome studies to determine this in the future.

Treatment options

Treatment options of chondral lesions include both medical and surgical approaches to restoring chondral surfaces; however, the efficacy of these treatments clinically has not been fully confirmed.[6] Suitable treatment depends on the extent of damage to the cartilage, with treatment options being based on ICRS grades. Treatment options for partial thickness (Grade 2 and 3) defects remain controversial with no ideal treatment advocated. Medical approaches to chondral defect treatment include the use of chondral protective agents and pain management.[6] Traditional surgical approaches include joint lavage and mechanical shaving, which is capable of debridement, contouring and smoothing the articular cartilage.[7]

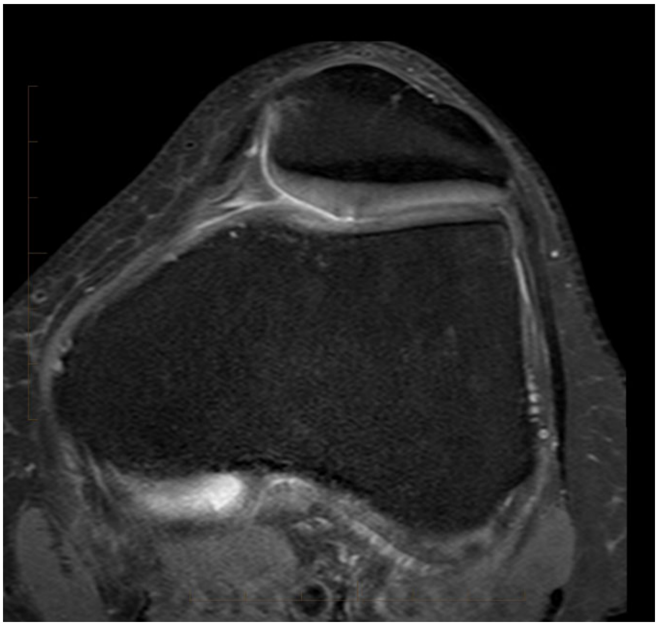

Fig. 1. A 43-year-old male with anterior knee pain. 3T MRI Proton density fat suppressed image in transverse plain, shows Grade 2 chondromalacia patellae at the patella apex.

However, one of the limitations of this method is that it is difficult to completely smooth the cartilage surface causing fine fibrillations at the edge of the tissue as well as removal of adjacent normal tissue from a lesion.[7] Continued degradation and long-term problems have been shown to occur following this procedure due to the presence of normal loading on these fine fibrillations and uneven surfaces.[7]

Radiofrequency use

Discontentment with traditional treatments to chondral lesions including mechanical shaving has led researchers to experiment with other means of smoothing cartilage.[2] One experimental treatment that was considered as a possible method was the utilization of lasers; however, it was soon recognized that these caused major damage including osteonecrosis to underlying bone as well as being difficult to manoeuvre the probe.[2] This led to research into the use of RF energy as an effective treatment in chondroplasty.

RF energy has been utilized for years in a range of medical specialties including general surgery, neurosurgery, cardiology and oncology. In these procedures, this energy is used for its ablative properties at higher temperatures to remove abnormal tissue.[8] In orthopaedics, RF energy is utilized in the treatment of ligamentous injuries where the energy is used to tighten a structure by reducing the tissues length, diameter or width.[2] These probes appeared to be the optimal treatment as the surgeon was able to gain instantaneous feedback both through tactile and visual stimuli. It was also believed that RF energy was a safe and inexpensive medium, with the surgeon easily manipulating the probe arthroscopically.[2]

RF probes work to ablate the cartilage by creating intense heat at the end of the probe. This is achieved by creating a plasma layer in a conductive fluid (e.g. isotonic saline) at the tip of the active electrodes.[4,6] The high voltage electrical current used to create the plasma layer can either be passed between two electrodes in the probe (bipolar) or between the probe and an electrode distally on the skin (monopolar).[2,4,6] Studies comparing these types of RF probes in chondroplasty have shown monopolar chondroplasty to be a more effective and safer treatment.[4,6,9] These studies have highlighted monopolar chondroplasty to create better cartilage smoothness and stiffness as well as less chondrocyte death when compared to bipolar chondroplasty.[6,9] Figure 3 (arthroscope) shows the application of RF chondroplasty in clinical practice.

The effects on cartilage

A study by Cook *et al.* into the effects of RF energy treatment on cartilage highlighted that there were both beneficial and harmful changes to cartilage permeability and inflammation mediators. Decreases in glycosaminoglycan, matrix metalloproteinase 13, interleukin 1 and nitric oxide caused significant changes to the cartilage. These contrasting effects are shown in Figure 4.[10–12]

Chondrocyte viability and heat exposure

In vivo and *ex vivo* studies into chondrocyte viability in relation to heat exposure have indicated that chondrocytes are particularly thermal sensitive.[13,14] With exposure to high temperatures, death of chondrocytes may occur leading to the degeneration of the articular cartilage. Laboratory testing into the threshold in which chondrocyte damage occurs in RF energy treatment showed that exposure to temperatures in the range of 50 to 55°C caused chondrocyte death.[5,15] These studies concluded that increased thermal stress leads to a decline in viability and function of articular cartilage with decreased metabolic activity and proteoglycan synthesis. This thermal stress can either be due to an increase in the temperature used or the exposure time.[5] Therefore, it is important that operators consider both temperature and exposure time variables when undertaking RF treatment clinically to decrease the risks of chondrocyte damage.

Kaplan *et al.* also studied the effects of increasing thermal stress on cartilage. They discovered that arthritic cartilage was more sensitive to thermal exposure than non-arthritic under the same conditions at higher thermal stress points (time and temperature). They highlighted that recovery of proteoglycan synthesis occurred at 1 week after lower levels of thermal stress were exposed to cartilage obtained from total knee arthroplasty.[5]

Shellock and Sheilds proposed that in order to reduce chondrocyte damage from heat exposure, it was important to determine the minimal power settings of the probe that could cause ablative changes to the cartilage and therefore exposing less energy (and therefore heat). They showed in treatment of cartilage with a bipolar probe that a power setting of 20 W did not have any visual affect on the cartilage where as 40 W was enough to produce ablative changes in the cartilage.[13] In 2008, Edwards *et al.* concluded that there was less chondrocyte death,[16] thicker cartilage[17] and better smoothing in a monopolar RF energy probe.[2,16] Ryan *et al.* found in an equine cartilage model that using a bipolar probe at energies above 20 W hindered cartilage viability and therefore proteoglycan synthesis.[18]

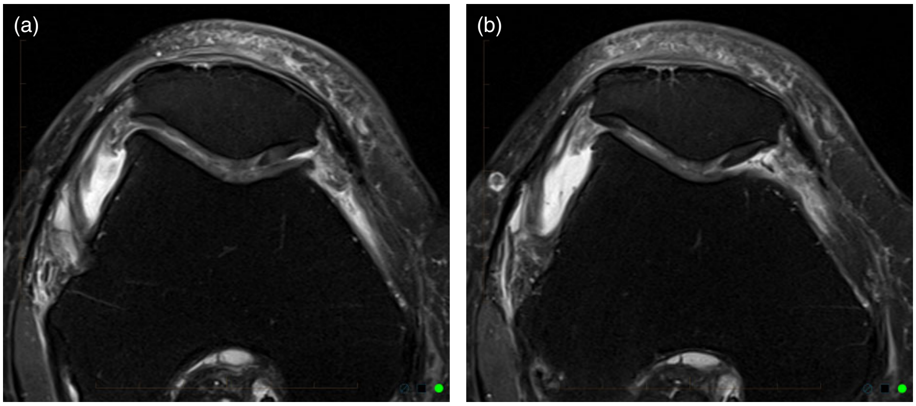

Fig. 2. A 71–year-old male with anterior knee pain and joint swelling. (a) 3T MRI Proton density fat suppressed image in transverse plain, shows Grade 2 and 3 focal cartilage lesions of both the patella and trochlear cartilage. (b) Shows additionally Grade 3 cartilage fissure extending from the patella apex into adjacent lateral patella facet. Small joint effusion and synovitis are also noted.

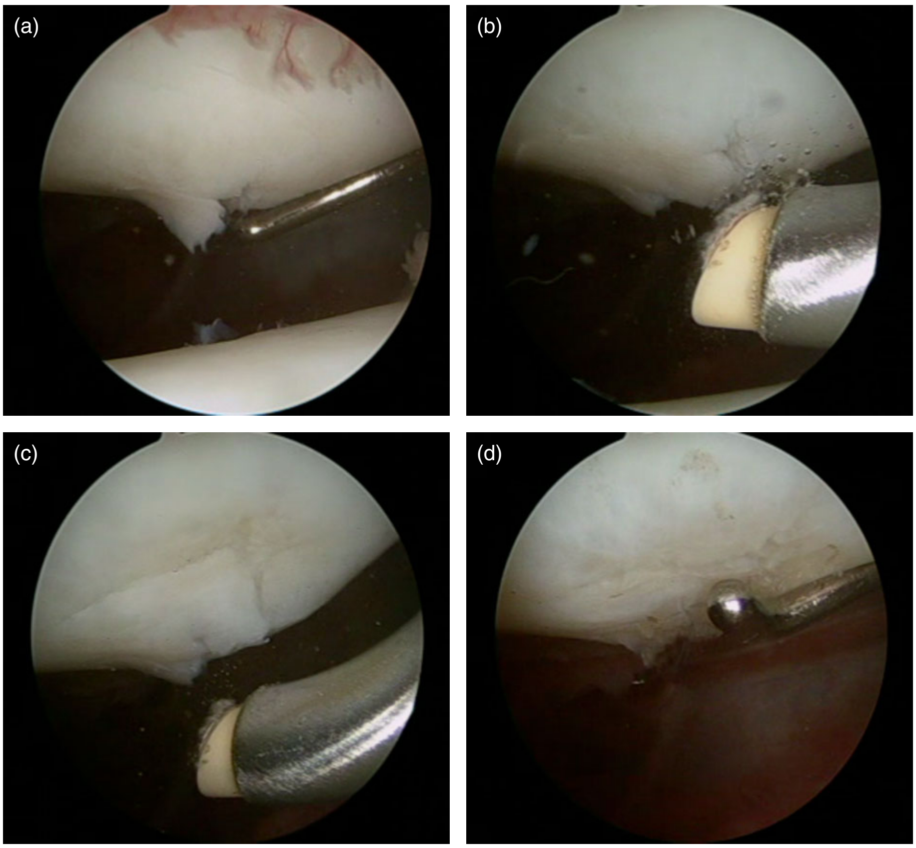

Fig. 3. Intraoperative images of a chondral lesion on the patella showing the lesion (a) before RF treatment showing an uneven surface. (b & c) During radiofrequency (RF) treatment noting progressive smoothing of the chondral surface. (d) Following RF chondroplasty leaving a congruent and stable surface.

Therefore, the lowest effective power settings should be utilized to decrease the potential risk of chondrocyte death and lesion progression.[14]

Another variable factor that influences chondrocyte heat exposure is the temperature of the lavage solution. Lu *et al*. examined the effects of using lavage temperatures of 22 and 37°C on cartilage while undertaking RF chondroplasty. After treatment, the samples were analysed with confocal laser microscopy to investigate cell viability. In their study, they were able to achieve optimal surface smoothing in both groups. They found that there was significantly less chondrocyte death in the samples where the lavage was heated to 37°C compared to the 22°C, with temperatures in the 37°C lavage staying more stable throughout treatment. This decreased chondrocyte death is a result of less energy utilized to heat the cartilage to the desired temperature for ablation to occur. The study concluded that approximately 40% less energy was delivered in the 37°C lavage compared to the 22°C medium.[7,9]

Potential side effects and complications

Surrounding cartilage damage

Both mechanical shaving and RF chondroplasty have been shown to have limitations. During mechanical shaving, health surrounding tissue is removed. While as discussed, heat exposure to the joint during RF chondroplasty may cause damage to the surrounding

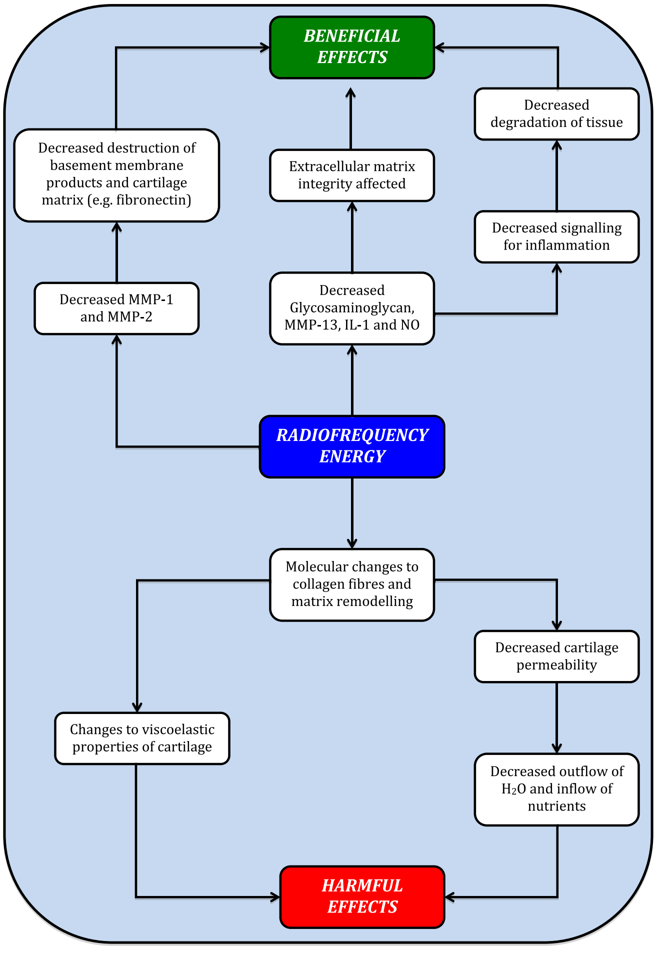

Fig. 4. Flowchart depicting the beneficial and harmful effects of radiofrequency energy on cartilage. IL, interleukin; MMP, matrix metalloproteinase; NO, nitric oxide.

cartilage.[5] However, Owens, Stickles and Busconi found in their study that heat declined exponentially with distance from the probe thus causing surrounding tissue to remain undamaged. Also, since there is constant lavage undertaken clinically, it is difficult to heat surrounding cartilage to the 50 to 55°C needed to cause damage to the chondrocytes.[19]

Progression of lesion

Ovine models treated with RF chondroplasty have reported progression of lesions.[2,20] Lesion progression has also been reported clinically in patients who have had repeat arthroscopic procedures.[4] In a study by Voloshin *et al*. of the 193 consecutive patients treated with bipolar RF, only 15 patients with 25 lesions required repeat arthroscopy for recurring or new injuries. Of these patients, only three lesions were shown to have progressive lesion damage with unstable borders.[4] Spahn *et al*. who analysed patients 4 years after their procedure found that midterm outcomes were greater in the bipolar RF group when compared to mechanical shaving in their randomized controlled study.[21] Mechanical shaving has been shown to cause sharp edges that with time and friction (from movement) can cause further fibrillations and progressive cartilage damage.[1,22] Whereas chondroplasty undertaken by RF ablation leaves the cartilaginous surface smooth theoretically stopping this progressive damage.

Osteonecrosis

It has been argued that due to the thermal exposure seen in RF chondroplasty that osteonecrosis of the underlying subarticular bone may occur. Studies have reported evidence of osteonecrosis in patients who have had an MRI undertaken within 12 months of RF chondroplasty.[17] Further to their earlier study, Barber and Iwasko showed via MRI analysis that no patients had developed osteonecrosis following RF chondroplasty.[17] Recently, Cetik *et al*. concluded that bipolar RF chondroplasty does not cause subchondral osteonecrosis.[23]

Discussion

RF energy in chondroplasty has been shown to be a suitable and effective method of treating partial thickness chondral tears. No clinical data has been published to date into the long-term outcomes and complications of this treatment. Laboratory studies into RF chondroplasty have shown concerns about chondrocyte death and chondrolysis due to heat exposure from 50 to 55°C. However, these concerns have not translated into clinical studies with insignificant amounts of chondrocyte death being reported in patients who have been analysed after treatment.[21] This is one limitation of laboratory research into RF with researchers not able to find an effective model to be able to translate their results into clinical data.

The use of chondroprotective agents to improve chondrocyte recovery after treatment was shown by Chu *et al*. to effectively help regain proteoglycan synthesis activity 1 week after 5 s of exposure to temperatures above 60°C.[11] Further research into this area could provide clinicians with a means to prevent the risk of chondrocyte death with further recovery proteoglycan synthesis and thus cartilage integrity.

Surgical approach is also an important consideration when undertaking RF chondroplasty. Correct probe settings must be used to reduce cartilage damage from excessive heat exposure assuring that temperatures do not rise to damaging levels. Exposure time must also be monitored to ensure a smooth surface and therefore optimal repair, while limiting the time of exposure to reduce the risk of chondrocyte death.

Further research should be undertaken to analyse the long-term results and effects of RF energy chondroplasty particularly focusing on the differences in outcomes between monopolar and bipolar RF compared to mechanical shaving. It is also recommended that research into chondroprotective methods be undertaken, including the use of different lavage temperatures perioperatively and chondroprotective agents postoperatively. Results of these studies will allow clinicians to limit chondrocyte damage in patients as a result of RF treatment and assist in recovery from thermal stress.

Conclusion

RF chondroplasty is an effective treatment for chondral tears providing optimal smoothing of chondral clefts and reductions in inflammatory mediators. Laboratory studies have shown that heat exposure during the procedure can cause chondrocyte death; however, these concerns have not translated to clinical studies. These studies have also highlighted RF ablation to be a superior treatment of chondral defects when compared to mechanical shaving with greater midterm outcomes in patients treated with RF energy.

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