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Risk of osteonecrosis of the femoral condyle after arthroscopic chondroplasty using radiofrequency: a prospective clinical series

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Abstract Radiofrequency (RF) energy can be used for treatment of intraarticular pathologies in knee joint. RF energy was found to be superior to mechanical techniques in smoothening the articular surface (chondroplasty), shortening the operation time and reducing the blood loss. As RF produces thermal energy it has been reported to be responsible for the postoperative osteonecrosis however, there is no clinical evidence in the literature supporting that RF causes osteonecrosis. The current study searches for an answer whether surgical arthroscopic modalities using RF energy causes osteonecrosis. We hypothesize in the presented study that chondroplasty with RF has no effect on increasing the incidence of osteonecrosis in knee joint. In a prospective clinical trial, arthroscopic chondroplasty was performed in 50 patients with degenerative changes of the articular cartilage, stage II and III according to Outerbridge. To be included in the study, the patients had to meet the following criteria: (1) Preoperative MRI and plain film radiographs showing no evidence of osteonecrosis. (2) Patients had to be symptomatic for at least 6 weeks before the preoperative MRI. (3) Arthroscopically confirmed stage II or III. Preoperative MRI was taken in all patients. For chondral lesions bipolar RF energy system (VAPR-DePuy Mitek, Norwood, USA) was used. The patients were examined at the end of the sixth month and we performed MRI. Fifty patients with an average of age 45.54 (between 18 and 64) (SD, 10.63). During arthroscopy, together with chondropathy 22 patients pure medial meniscus tears, 7 patients medial and lateral meniscus tears, 7 patients pure lateral meniscus tears, 2 patients medial plica, and 3 patients synovial hypertrophy were detected. Among all 50 patients, osteonecrosis were detected at only 2 (4%) in the postoperative period. Until now it was not clear that RF energy causes osteonecrosis; however, according to this study if proper method is used, bipolar RF energy used for arthroscopic chondroplasty does not causes subchondral osteonecrosis.

Keywords Radiofrequency · Bipolar · Osteonecrosis · Subchondral

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Introduction

Osteonecrosis is characterized by ischemic necrosis of bone marrow and trabecular cortex of the subchondral bone [11]. Osteonecrosis of the knee is commonly classified into two main categories as spontaneous and secondary. Spontaneous osteonecrosis of the knee was first described as a distinct clinicopathological entity by Ahlback in 1968 [1]. Although many causes have been proposed, the exact etiology of osteonecrosis is not certain [22, 24]. Possible causes include trauma and primary or secondary vascular insufficiency [13]. Secondary osteonecrosis caused by a number of well recognized predisposing factors, often acting alone but at times acting in harmony [24]. Metabolic diseases, alcohol abuse, trauma, hematological disorders are the main causes of secondary osteonecrosis. Additionally, therapeutic modalities like laser, radiofrequency, meniscectomy and steroid consumption have been accused of secondary osteonecrosis [3, 5, 8, 33].

Radiofrequency (RF) energy can be used for treatment of intraarticular pathologies of the knee joint [15]. RF energy is thought to be superior to mechanical techniques used for chondroplasty, by shortening the operation time and reducing the blood loss [7, 15, 17]. RF is accused of causing postoperative osteonecrosis as it produces thermal energy [5, 8]. However, there is no clinical evidence in literature supporting osteonecrotic effect of RF.

Experimental studies have revealed that penetration of thermal effect of RF may alter depending on the technique used [2]. Current study investigates for an answer whether surgical arthroscopic modalities using RF energy cause osteonecrosis or not. In the study presented here, we hypothesized that chondroplasty with RF does not have an impact on the incidence of osteonecrosis in knee joint.

Materials and methods

The current study was conducted under the approval of the Committee of Research Ethics in our institute. In a prospective clinical trial, arthroscopic chondroplasty was applied on 50 patients, 27 female and 23 male, with a mean age of 45.54 (SD 10.63). All patients had stage II and III degenerative changes of the articular cartilage according to Outerbridge arthroscopic classification system for chondral lesions [25] (Table 1).

Patients meeting the following criteria were included in the study: preoperative MRI and plain film radiographs showing no evidence of osteonecrosis, symptoms lasting for at least 6 weeks before the preoperative MRI, arthroscopically confirmed Outerbridge stage II or III chondral changes regardless of the extent of accompanying synovial hypertrophy or degenerative or traumatic changes in the menisci. Patients with abnormal lower extremity mechanical axis, ligamentous instability, osteochondritis dissecans, rheumatoid arthritis, metabolic diseases and those with the history of steroid consumption and alcohol abuse were excluded from the study. Patients with preoperative MRI findings of osteonecrosis were also excluded from the study.

Preoperative magnetic resonance imagination was performed for all patients. Under epidural anesthesia, using a tourniquet, we performed diagnostic arthroscopy. For debridement of chondral lesions, bipolar RF energy system (VAPR-DePuy Mitek, Norwood, USA) was used (with side effect probe). Based on the recommendation by the manufacturer of the bipolar equipment VAPR- 65°C and V2-20 in desiccation was used. The system was used in noncontact mode and in paintbrush manner. Partial synovectomy, partial meniscectomy, plica excision were performed with RF if necessary. Arthroscopic lavage was performed in all patients (arthro-pump was not used). Partial (50%) weight-bearing was allowed for all patients within postoperative 10 days.

Table 1 Outerbridge arthroscopic classification system for chondral lesions

Grade 0	Normal
Grade I	Softening of the cartilage
Grade II	Fibrillation
Grade III	Fissuring
Grade IV	Cartilage loss reaching the subchondral bone

The patients were examined at the end of the sixth month and MRI by 1.5 T MRI scanners (PHILIPS, Intera) were performed. Imaging sequences included sagittal T1-weighted/spin-echo BC (TR: 518–612, TE: 13), coronal T2-weighted/SPIR BC (TR: 2770–3047, TE: 60), coronal DUAL BC (TR: 1805–2035, TE: 20–90), coronal T2-weighted 3DFFE (TR: 34, TE: 18), sagittal T2-weighted 3DFFE (TR: 34, TE: 18), sagittal Dual BC (TR: 2031–2491, TE: 20–90), sagittal T2-weighted/SPIR BC (TR: 2768–2909, TE: 60), transverse T2-weighted/FFE BC (TR: 479–532, TE: 18).

The criteria for the diagnosis of osteonecrosis on an MRI included: a discrete area of low-intensity signal on the femoral condyle in the T1-weighted images, a low-signal-intensity area in the center of the lesion plus high-intensity around the margins in the T2-weighted images, presumably due to edema [4, 6, 13, 21, 27, 31].

A clinical follow-up form, including the age and gender of the patient, associated tears of medial or lateral menisci and presence of osteonecrosis was designed. This form was in accordance with the aim of study being performed.

Using the method of Lotke, the size of the osteonecrotic lesion was measured on T1-weighted images as the area of low-signal-intensity (referred as a percentage of the diameter of the medial femoral condyle) [16].

Results

Of the 50 patients, diagnostic arthroscopy and arthroscopic debridement was performed on 32 right knees (65%), 18 left knees (36%). During arthroscopy, together with chondropathy it was observed that 22 patients had pure medial meniscus tears, 7 medial and lateral meniscus tears, 7 pure lateral meniscus tears, 2 medial plica and 3 synovial hypertrophy.

Of the 50 patients, chondroplasty was performed in 14 (28%), chondroplasty and partial meniscectomy in 23 (46%), and partial meniscectomy in 13 (26%) with RF. Postoperatively, among all 50 patients osteonecrosis was detected only in 2 patients (4%) for whom both chondroplasty and partial meniscectomy was performed.

The first patient who had osteonecrosis was a 50-year-old man. During diagnostic arthroscopy, a grade II chondropathy in the medial compartment, a grade II chondropathy in the patellofemoral joint and a grade III chondropathy in the lateral compartment were determined. Chondroplasty by RF was performed for these lesions. Partial meniscectomy by RF was performed for the degenerative tear of the posterior horn of the medial meniscus. On the postoperative MR images, osteonecrosis of the medial femoral condyle was determined. The second patient with postoperative osteonecrosis was a woman of 45 years. During arthroscopy, a grade III chondropathy on the inferior surface of the patella, grade II chondropathy in the femoral trochlea and a 1 × 1 cm dimensioned grade II chondropathy on the femoral condyle were diagnosed. By RF chondroplasty for these lesions and partial meniscectomy for the degenerative medial meniscus tear was performed. On the postoperative MR images, subchondral osteonecrosis was detected only in the medial femoral condyle (Fig. 1a–d).

On MR images, the mean size of the osteonecrosis with regard to whole femoral condyle was measured as 27.5% (25–30%).

Discussion

Chondroplasty

The aim of arthroscopic chondroplasty is to create a smooth joint surface and to prevent mechanical irritation by irregular surface contact on both the cartilage tissue and menisci. In addition, arthroscopic attempts such as synoviectomy and joint lavage, with meniscectomy and plica resection, removes detritus and reduces enzymatic activity of the synovia resulting in pain relief. Therefore, the reduction of secondary synovitis based on the transient elimination of mediators could be understood as the treatment of chondromalacia only in a transferred sense [10]. The most common method for arthroscopic chondroplasty is the mechanical shaving of joint surface. Normal femoral condylar cartilage thickness is about 2–4 mm, and arthroscopic debridement with mechanical shavers result in 300–800 μm of chondrocyte loss due to the tissue removal and subsequent chondrocyte death. In addition, after mechanical shaving cartilaginous surface still continues to be rough against optimum surgical technique, which results in recurrence of fibrillation and degradation of the chondral tissue with weight bearing [20].

Recently, thermal methods such as laser energy and RF energy are accepted as new surgical techniques for chondroplasty. However, laser energy is now rarely used due to its high iatrogenic injury potential and introduction of subchondral osteonecrosis [9, 12, 28, 32]. Therefore, RF energy becomes a popular treatment modality in arthroscopic surgery [2]. RF is advantageous against mechanical chondroplasty resulting in a smoother surface architecture, limited injury to adjacent untreated cartilage tissue, and more easy avoidance of iatrogenic damage. In addition, defective cartilage can be more rapidly and easily countered which results in shortened operative time [15, 20]. When compared with mechanical shaving, debridement with RF gives cause to less chondrocyte death [36], and patients report less clinical symptoms at the postoperative period [37]. Thermal chondroplasty can be used for shrinking, smoothing of the joint surface, sealing and debridement by controlled application of heat for the treatment of grade II and III chondromalacia [34].

Osteonecrosis (diagnosis and classification)

Osteonecrosis of the joint space, especially the femoral condyles is an etiological factor for degenerative joint disease. It starts with bone marrow edema, which is visible by MRI. However, bone marrow edema may also be caused by ischemic factors, mechanical factors and reactive reasons [11]. But the etiology of the edema cannot be identified by MRI at the early stages. In addition, as the edema is limited in the bone marrow at this period, it cannot be visualized either with computed tomography or conventional radiograms [11, 27]. Bone scintigraphy can detect early changes in vascularization, but its spatial anatomic resolution is poor, and differentiation from other disorders characterized by increased tracer uptake is generally impossible [11]. Bone scintigraphy has proven to be much more sensitive, but not specific [21, 29]. Therefore, MRI seems to be the ideal diagnostic technique for bone marrow edema and osteonecrosis, especially at early stages. It includes both high sensitivity and specifications of osteonecrosis of the femoral condyle, and also provides a simultaneous evaluation of chondral pathology, the size of the lesion, and the viability of bone marrow [21, 27]. Bone marrow edema is characterized by a low-signal intensity compared with unaffected bone marrow on T1-weighted images. On T2-weighted images, especially when fat-suppression techniques are used, high-signal-intensities in the low-signal areas of the T1-weighted images are typical for bone marrow edema [11]. Hence, we preferred MRI for the identification of osteonecrosis in our study. However, against its multiple advantages, MRI has the disadvantage of late visualization of the lesion, sometimes 4–6 weeks later than the onset of symptoms. This period is known as ‘window period’ [22, 23]. Thus, in our study, preoperative MR imaginations were performed at least 6 weeks after the onset of symptoms. Postoperatively, MRI was performed at least minimum 6 months after the treatment.

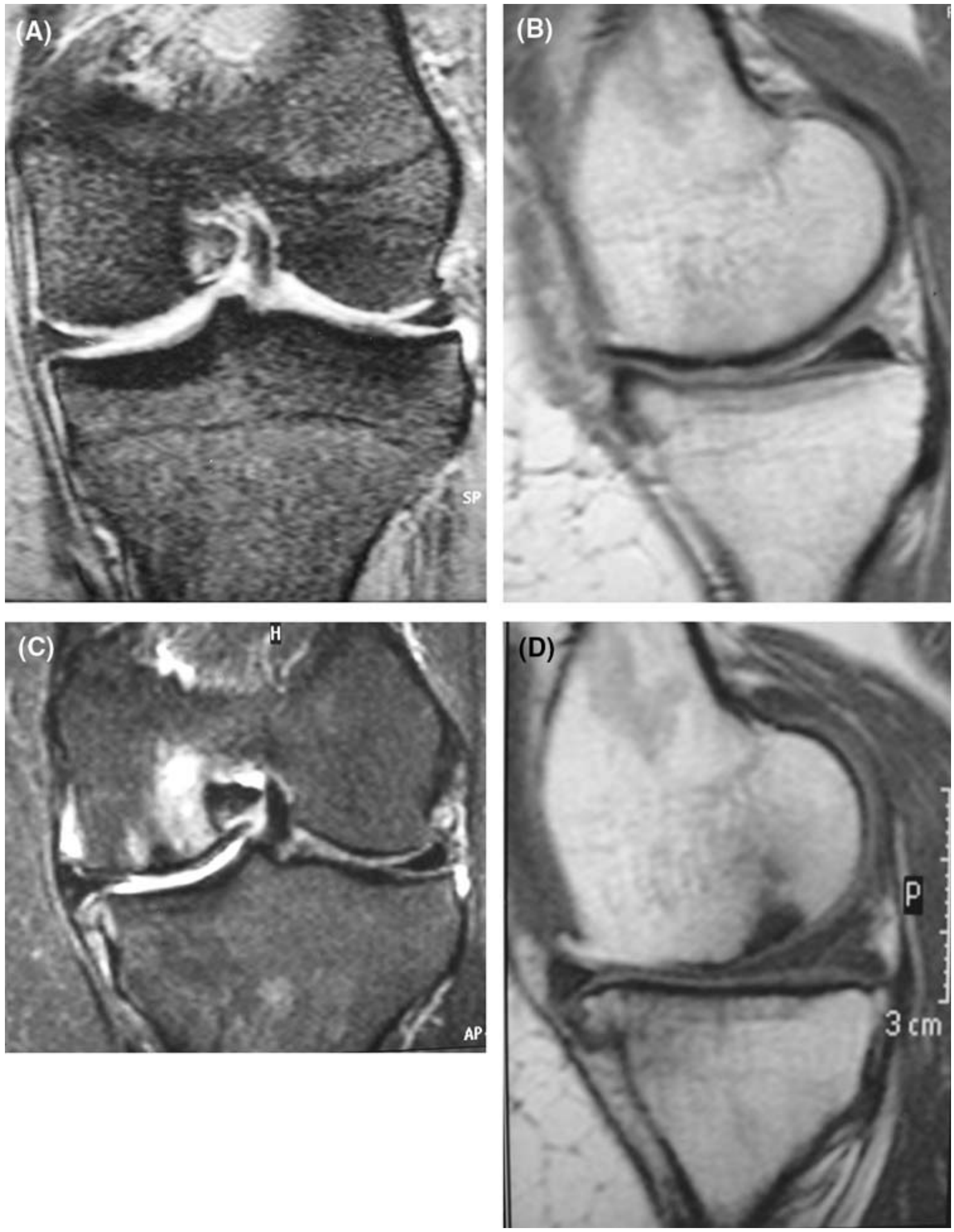

Fig. 1 **a** Preoperative T2-weighted coronal magnetic resonance image showing normal signal intensity in the subchondral bone and both meniscal tear, **b** preoperative sagittal T1-weighted image showing normal signal intensity in the subchondral bone, **c** on the postoperative T2-weighted coronal sequences, the subchondral lesion demonstrating a low-signal intensity area in the center of the lesion plus high-intensity about the margins, presumably due to edema, **d** postoperative T1-weighted sagittal sequences showing a low-signal femoral subchondral lesion

Clinically osteonecrosis of the medial femoral condyle can be classified into four stages based on symptomatic and radiologic criteria [35] (Table 1). Overall, all four stages have similar clinical signs and symptoms like pain, tenderness, effusion and synovitis. Stage I is the early stage of the osteonecrosis. This stage continues approximately of 6–8 weeks. X-rays are normal in this stage, and osteonecrosis can only be diagnosed by MRI. Stage II continues approximately 2–4 months. A slight flattening can be detected on the medial femoral condyle through X-rays [35]. Osteonecrosis in stage I or II can spontaneously heal and these stages continue approximately 4–6 months. Stages III and IV are irreversible stages and damage on the joint surface is permanent [35]. Thus, for definite diagnosis, we preferred performing MRI check controls minimum 6 months after the operation.

RF advantages and side effects

Against its well recognized advantages mentioned above, there no agreement on the side effects of RF energy in literature. Results of studies investigating these effects are controversial. Kaplan et al. [14], in their study with fresh human cartilage obtained from arthroplasty report no collagen abnormality and remaining of viable chondrocytes. Also Turner et al. [36] report less histological changes with bipolar RF compared with mechanical shaving on ewes cartilage tissue. However, Amiel et al. [2], report a well controlled debridement and smooth edges with RF, but chondrocyte termination extending in to the treatment area. In another in vitro study by Lu et al. [18], significant chondrocyte death with bipolar RF, which was only visible with confocal laser microscopy, is reported.

RF energy is applied in two different ways: monopolar and bipolar. In literature, there is controversy in the results of the studies analyzing the effects of monopolar and bipolar RF energy [15, 19, 34]. The two most important causes of increased chondrocyte death in joint cartilage are the amount of heat that RF energy creates in cartilage and the depth of penetration. However, there are also different views for monopolar and bipolar RF energy on these subjects. According to Lu et al. [19] bipolar RF system penetrates to 78–92% of the total depth of the cartilage, which is deeper than the monopolar system, and causes more chondrocyte death and a larger thermal lesion than the monopolar system. The author reported penetration of the energy deep to the subchondral bone in all osteochondral sections during arthroscopically guided paintbrush pattern treatment with the bipolar system, while penetration never reached the subchondral bone during treatment with the monopolar system [19]. In his study practiced on bovine cartilage, Shellock [34] detected that monopolar systems create more heat than bipolar systems. Encalada et al. [8] report a case of osteonecrosis of the both condyles after partial meniscectomy by bipolar RF. Although they relate development of osteonecrosis to RF energy, it does not explain osteonecrosis of both condyles against a laterally performed intervention, because Vangsness et al. [38] showed maximum penetrance of thermal effect of RF about 2 mm throughout the depth of the cartilage tissue. In addition, it is well known that partial meniscectomy is an independent etiological factor for osteonecrosis performed with either RF or mechanical shaving [22, 36]. They also report a normal preoperative T1 weighted MR imagination, performed 1 month after the initial trauma, at a possible window period for osteonecrosis due to trauma. Thus, postoperative osteonecrosis would be secondary to trauma which is misdiagnosed preoperatively. If T2 weighted images were performed, a bone marrow edema (an early finding of osteonecrosis) would be viewed preoperatively.

Bonutti et al. [5], in a review of 2,386 patients who underwent knee arthroplasty report osteonecrosis as the reason for 24. Of the 24 patients, 10 patients had a history of arthroscopic debridement with RF energy. The mean age is reported to be 69 years. They report osteonecrosis on post-arthroscopic MR images, while preoperative MR imaginations were normal. With this finding, the authors relate arthroscopic RF effect with postoperative osteonecrosis. In this series, it is not clear that the MR imaginations were performed at the window period or not. In addition, partial meniscectomy may be the etiological factor for post-arthroscopic osteonecrosis rather than RF. Furthermore, Pape [26] reports the probability of spontaneous osteonecrosis about 3.4% over 50 years of age, and 9.4% over 65 years of age. Thus, when the mean age of patients reported by Bonutti is considered, the incidence of spontaneous osteonecrosis in his series is expected to be much higher than it is mentioned. As a result, it seems that there are many other reasons for osteonecrosis other than RF for Bonutti's series.

Meniscectomy

Two patients with postoperative osteonecrosis in our series also had partial meniscectomy, a possible etiological factor for osteonecrosis. The relation between RF and osteonecrosis for these patients is not meaningful.

It seems that, the studies carried out up to date do not clarify the etiology of osteonecrosis which emerges after arthroscopic surgery. Many factors which cause osteonecrosis after arthroscopic procedure were identified; especially meniscal tears and partial meniscectomy are thought to be associated with the occurrence of osteonecrosis [5, 13, 22, 30]. The important role of the menisci in force transmission can be appreciated when the menisci are removed and the weight-bearing forces are no longer distributed over a wide area of the tibia and the femur [5]. Both arthroscopic meniscectomy and meniscal tears lead to this alteration of the weight bearing area, resulting in an increase in tibiofemoral contact pressure. The increase in pressure on chondral tissue may provoke chondral damage and micro fractures of the subchondral bone with a resultant intraosseous leakage of synovial fluid [32]. However, as there is no proof of any correlation between arthroscopic meniscectomy, meniscal tears, and osteonecrosis, it is possible that these entities merely share a simple association [5].

In order to conclude that osteonecrosis emanates from RF energy, while ignoring all other factors, subchondral osteonecrosis must be observed in the areas which is only exposed to RF energy.

Conclusion

Until now RF energy was not clearly defined as a cause for osteonecrosis. However, according to our study we can conclude that, bipolar RF energy used for arthroscopic chondroplasty does not cause subchondral osteonecrosis if proper surgical techniques are carried out.

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