Systematic Review

Radiofrequency Chondroplasty of the Knee Yields Excellent Clinical Outcomes and Minimal Complications: A Systematic Review

Trevor Tuthill, B.S., Garrett R. Jackson, M.D., Sabrina F. Schundler, B.S., Jonathan S. Lee, B.A., Sachin Allahabadi, M.D., Luis M. Salazar, M.D., Johnathon R. McCormick, M.D., Harkirat Jawanda, B.S., Anjay Batra, B.S., Zeeshan A. Khan, B.A., Enzo S. Mameri, M.D., Jorge Chahla, M.D., Ph.D., and Nikhil N. Verma, M.D.

Purpose: To evaluate reported clinical outcomes and complications following radiofrequency (RF) ablation for the treatment of knee chondral lesions. **Methods:** A literature search was performed according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines by querying EMBASE, PubMed, and Scopus computerized databases from database inception through October 2022. Level I to IV clinical studies that reported outcomes or complications following RF-based chondroplasty were included. Postoperative outcome scores and complications were aggregated. Study quality was assessed via the Newcastle−Ottawa Scale. **Results:** Ten articles from 2002 to 2018 consisting of 1,107 patients (n = 1,504 lesions) were identified. Four studies were of Level I evidence, 3 studies were Level II, 1 study was Level III, and 2 studies were Level IV. The mean patient age was 41.8 ± 6.3 years (range, 12-87). Seven studies (n = 1,037 patients) used bipolar RF devices, and 3 studies (n = 70 patients) used monopolar RF devices. The overall mean postoperative Lysholm, Tegner, and IKDC scores ranged from 83 to 91, 3.8 to 7, and 49 to 90, respectively, in lesions ranging from grade I-IV according to the Outerbridge Classification. Monopolar RF devices reported qualitatively similar mean changes in Lysholm scores (83), Tegner scores (3.8), and IKDC scores (range, 49-69) compared with bipolar RF devices (range, 86.4-91, 4.5-7, 90, respectively). The incidence of complications ranged from 0% to 4%. The most commonly reported complication was osteonecrosis (range, 0% to 4%). The incidence rate of patients undergoing additional surgery ranged from 0% to 4.5%. **Conclusions:** The available literature on RF-based chondroplasty shows its efficacy and safety for the treatment of knee chondral lesions, with good clinical outcome scores and low complication and reoperation rates. **Level of Evidence:** Level IV, systematic review of Level I-IV studies.

Chondral or osteochondral lesions are an extremely common finding, reported in approximately 60% of patients undergoing knee arthroscopy.[1] Although varying degrees of chondroplasty can often be asymptomatic, several instances of focal chondral defects result in pain and functional impairment, negatively impacting quality of life to the same extent as in patients with severe osteoarthritis scheduled for knee replacement.[2] When left untreated, articular cartilage lesions have been reported to be a significant risk factor

From Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, Illinois, U.S.A. (T.T., G.R.J., S.F.S., J.S.L., S.A., L.M.S., J.R.M., H.J., A.B., Z.A.K., E.S.M., J.C., N.N.V.); Instituto Brasil de Tecnologia da Saúde, Rio de Janeiro, Brazil; and Department of Orthopedics and Traumatology, Federal University of São Paulo (EPM-UNIFESP), São Paulo, Brazil (E.S.M.).

The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received January 29, 2023; accepted May 22, 2023.

Address correspondence to Dr. Nikhil N. Verma, M.D., Director of Sports Medicine, Department of Orthopaedic Surgery, Rush University Medical Center, 1611 W Harrison St., Suite 300, Chicago, IL 60612. E-mail: Nikhil.verma@rushortho.com

2666-061X/23144

https://doi.org/10.1016/j.asmr.2023.05.006

for the progression of knee osteoarthritis.[3] In cases in which nonoperative treatment is insufficient, an array of surgical procedures is currently available to treat symptomatic chondral lesions.[4] A chondroplasty procedure can be performed in a staged treatment (before an osteochondral transplant of membrane-based repair) to assess the lesion, dimensions, and the opposing articulating cartilage while debriding unstable portions of the cartilage which can improve symptoms in 62% of the cases.[5]

Chondroplasty includes a variety of techniques to address cartilage defects. For many years, arthroscopic mechanical debridement has demonstrated successful symptom relief through the removal of damaged and unstable cartilage, with abrasion to a stable rim.[6] However, mechanical shavers can also create a "tearing" effect on the cartilage, causing a significant risk of iatrogenic damage to the adjacent healthy cartilage and consequent lesion progression.[7,8] Radiofrequency (RF) ablation has been proposed as a safe method to address the inadequacies associated with the use of a mechanical shaver.[7] Previous studies suggest that the use of RF ablation can generate a smoother cartilage surface, limit injury to surrounding healthy cartilage, and potentially decrease the incidence of iatrogenic damage, in addition to shortened operative time, and reduced intra-articular bleeding comprising its main advantages.[9] With the acceptance of RF energy use in chondroplasty, monopolar and bipolar systems have been used in instrument development. The active electrode of monopolar devices passes currents through the patient's body to reach the target lesion, and the current exits through a return electrode. Bipolar devices only pass currents through tissue that is located between its 2 electrodes.[10] It has been shown that bipolar RF systems can penetrate 78% to 92% deeper than monopolar frequency systems.[11] In RF procedures, surgeons are generally apprehensive regarding chondrotoxic thermal damage, postoperative chondrolysis, and osteonecrosis to the adjacent subchondral bone.[8,9,12] Therefore, it is important to compare the use of the present RF systems available for use in chondroplasty procedures to determine how to minimize complications and provide therapeutic relief of knee symptoms and if complications have been reported.

Although the use of RF chondroplasty has been widely published, the literature comparing the efficacy of various RF devices is scant. Previous investigations have assessed the effects of bipolar and monopolar RF devices in vitro, although there is still a relative paucity of reports on the in vivo effects and clinical outcomes.[11] The purpose of this study was to evaluate reported clinical outcomes and complications following RF ablation for the treatment of knee chondral lesions. The authors hypothesized that RF ablation results in improved clinical outcomes with low complication and re-operation rates.

Methods

Search Strategy and Eligibility Criteria

A systematic review was conducted according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[13] An independent and comprehensive database search was conducted by 2 independent authors (T.T., G.J.) using PubMed and Scopus databases on October 31, 2022. The following search terms with Boolean operators were used: ((thermal) AND (chondroplasty) AND (knee) OR (radiofrequency) AND (chondral defect) OR (articular cartilage) OR (cartilage) AND (ablation) OR (coblation).

The inclusion criteria consisted of Level I to IV studies reporting clinical outcomes following RF ablation, including both monopolar and bipolar RF devices for the treatment of knee chondral lesions published in English or with English-language translation. Exclusion criteria consisted of chondroplasty in joints other than the knee, in vitro studies, ex vivo studies using animal models, cadaveric studies, case reports, non-full text articles, letters to editors, surveys, review articles, abstracts, and studies reporting data that does not contain clinical outcome scores. A minimum mean age or follow-up was not used as inclusion/exclusion criteria. Concomitant intra-articular procedures such as the treatment of meniscal pathology did not constitute an exclusion criterion in order to reflect clinical practice. In contrast, cohorts with concomitant ligament reconstruction or osteotomies were excluded.

Data Extraction

Data extraction was conducted by 2 independent authors (S.S., T.T.) from the included studies and entered into a Microsoft Excel, version 16.63 (Microsoft Corp, Redmond, WA) spreadsheet for further analysis. Data consisted of the first author's name, title, year of publication, Level of Evidence, patient demographics, chondral lesion characteristics (location, dimension, Outerbridge classification) RF device, RFE polarity, energy setting, probe temperature, time of application, distance of probe, Lysholm score, Tegner score, International Knee Documentation Committee Score (IKDC), reoperation rates, and all reported complications.

Risk of Bias Assessment

Study quality was assessed by 2 independent authors (S.S., J.L.) via the Modified Coleman Methodology Score. This quality assessment tool uses 10 criteria to score each study from 0 to 100. A maximum score of

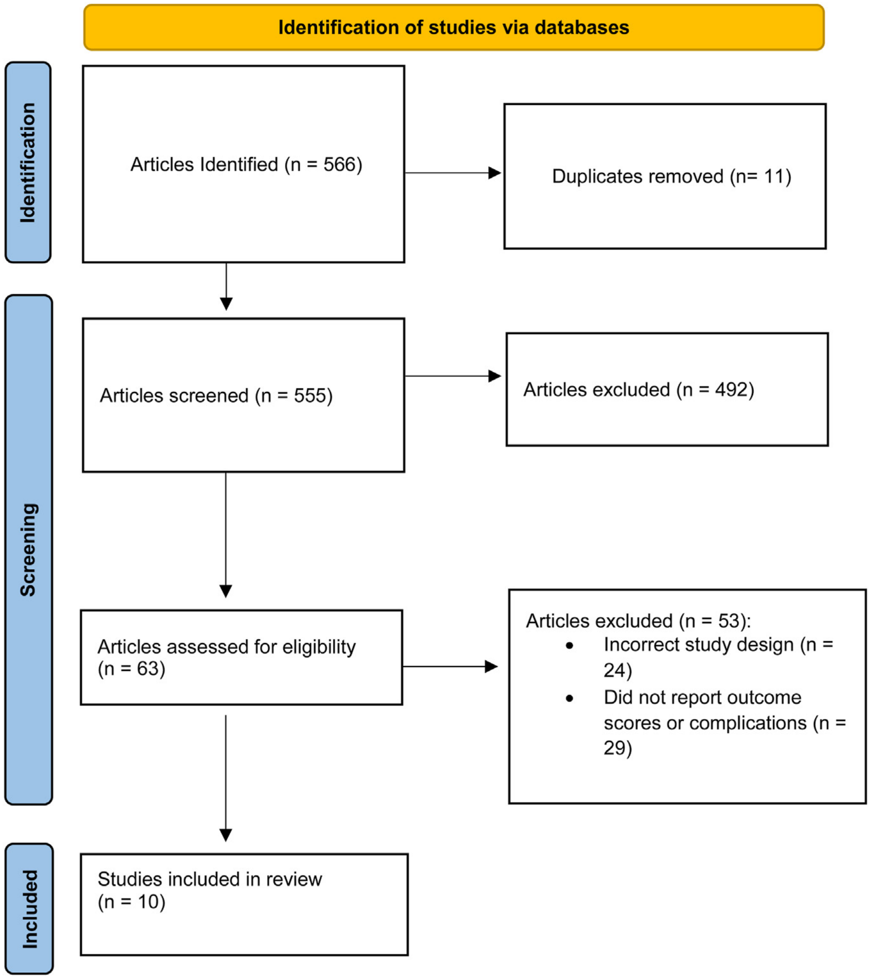

Fig 1. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram.

100 indicates a study that avoids bias, confounding factors, and chance.

Statistical Analysis

Data pooling and formal metanalysis were avoided due to the high risk of bias, heterogeneity, and low level of evidence of the included studies.

Results

After conducting an initial search, 566 studies were identified, with 555 remaining after duplicate removal. Sixty-three full-text articles were ultimately evaluated for eligibility. Following the full-text review, 10 studies[9,14-22] consisting of 1,107 patients (n = 1,504 lesions) met the inclusion/exclusion criteria and were included in the analysis (Fig 1). Four studies[16,19,20,22] were of Level I evidence, 3 studies[15,18,21] were Level II, 1 study[14] was Level III, and 2 studies[9,17] were Level IV.

The mean patient age was 41.8 ± 6.3 years (range, 12-87). The mean Coleman score was 68.2 (range, 50-80). Mean follow-up ranged from 6 to 72 months. Seven studies[9,14,16-20] (n = 1,037 patients) reported using bipolar RF devices, and 3 studies[15,21,22] (n = 70 patients) reported using monopolar RF devices. Four studies[14,16,17,19] (n = 884 patients) used coblation, whereas 6 studies[9,15,18,20-22] (n = 223 patients) used ablation. The locations of the treated lesions, and n-values where available, were the medial femoral condyle[14-17,21] (23.9%; n = 359/1,504 lesions), lateral femoral condyle[15,17,18,21] (0.8%; n = 12/1,504 lesions), patella[14] (11.7%; n = 176/1,504 lesions), trochlea[14,17] (5.7%; n = 85/1,504 lesions), medial patellar facet[17] (0.2%; n = 3/1,504 lesions), central patella, and lateral tibial plateau[17] (0.07%; n = 1/1,504 lesions) (Table 1). Five studies[15,16,18,20,22] reported postoperative outcome scores. The overall mean postoperative Lysholm, Tegner, and IKDC scores ranged from 83 to 91, 3.8 to 7, and 49 to 90, respectively (Table 2). Of studies that met inclusion criteria, 6.8% (n = 75/1107) reported concomitant treatment of meniscal lesions, which included meniscectomy (n = 72) and meniscus repair (n = 3).

Table 1. Study Demographics

Study	LoE	Patient No.	Sex (M/F)	Mean Age, y	Mean Follow-up, mo	Location of Lesion	Outerbridge Classification	RF Polarity	Coleman Score
Gharaibeh et al., 2018[14]	III	824 (n = 840 knees; n = 1,211 lesions)	503/321	47 (12-87)	NR	MFC (n = 327), patella (n = 254), trochlea (n = 109), NR (n = 521)	NR	Bipolar	60
Cetik et al., 2009[9]	IV	50	23/27	45.5 ± 10.6	NR	NR	II-III	Bipolar	72
Spahn et al., 2010[16]	I	25	11/14	43.5 ± 10.7	48	MFC (n = 25)	III	Bipolar	67
Voloshin et al., 2007[17]	IV	15 patients (n = 25 lesions)	9/6	38.5 ± 7.2 (27-52)	NR	MFC (n = 10), trochlea (n = 5), MPF (n = 3), central patella (n = 3), LFC (n = 3), LTP (n = 1)	II (n = 1), III (n = 23), IV (n = 1)	Bipolar	65
Osti et al., 2010[18]	II	25	NR	28 (17-29)	72	MFC (n = 19), LFC (n = 2), trochlea (n = 4)	I-II	Bipolar	72
Owens et al., 2002[19]	I	20	0/20	36.9 (30-45)	24	patella (n = 20)	II (n = 8) III (n = 12)	Bipolar	50
Stein et al., 2002[20]	I	78	NR	NR	12	patella, femoral trochlear, MFC, LFC, MTP	II-IV	Bipolar	72
Barber and Iwasko, 2006[15]	II	30	28/32	49 ± (22-76)	19	MFC (n = 57), LFC (n = 3)	III	Monopolar	77
Türker et al., 2015[21]	II	25	NR	40 ± 13	6	MFC (n = 21), MFC + LFC (n = 4)	II	Monopolar	80
Kang et al., 2008[22]	I	15	5/10	47 ± 12 (25-63)	17.5	MFC (n = 12), LFC (n = 3)	II-IV	Monopolar	67

LFC, lateral femoral condyle; LoE, Level of Evidence; LTP, lateral tibial plateau; MFC, medial femoral condyle; MPF, medial patellar facet; MTP, medial tibial, plateau; NR, not reported; RF, radiofrequency.

Monopolar Versus Bipolar

The postoperative Lysholm and Tegner scores were reported in 1 monopolar RF study[15] and were 83 and 3.8, respectively. Among the Bipolar RF studies, 2 studies[18,20] reported postoperative Lysholm scores ranging from 86.4 to 91, and 2 studies[16,18] reported postoperative Tegner scores ranging from 4.5 to 7. The postoperative IKDC score was reported in 2 monopolar studies and ranged from 49 to 69. One bipolar RF study[18] reported a postoperative IKDC score of 90.

Coblation Versus Ablation

The postoperative Tegner score was reported in 1 coblation study[16] and was reportedly 4.5. The postoperative Tegner score was reported in 2 ablation studies[15,18] and was 3.8 and 7. The postoperative Lysholm score was reported in 3 ablation studies[15,18,20] and ranged from 8 to 91. The postoperative Tegner score was reported in 2 ablation studies[15,18] and was 3.8 and 7. The postoperative IKDC score was reported in 3 ablation studies[15,18,22] and ranged from 49 to 90.

Postoperative Complications

Among the 7 studies[9,14,16-20] that used bipolar RF devices, the most commonly reported complication was osteonecrosis with an incidence rate ranging from 0% to 4%, followed by persistent pain (range, 0%-0.71%), deep vein thrombosis (range, 0%-0.59%), infection (range 0%-0.36%) (Table 3). The incidence rate of patients undergoing additional surgery ranged from 0% to 4.5%. Among the 3 studies[15,21,22] which used monopolar RF devices, the only reported complication was osteonecrosis (range, 0%-4%).

Discussion

The main finding of this systematic review was that RF chondroplasty of the knee results in good patient-reported Lysholm, Tegner, and IKDC scores. In addition, the collated literature yielded an overall complication rate ranging from 0% to 4%, with the most reported complication being osteonecrosis. In total, 0% to 4.5% of patients required additional surgeries after a mean follow-up ranging from 6 to 72 months.

Traditionally, chondroplasties have been performed using mechanical shavers; however, this technique excessively removes adjacent healthy tissue, resulting in the progression of cartilage lesions.[8] Alternatively, RF instruments have gained popularity because of their precision and ability to avoid damaging healthy cartilage.[11] In a study by Barber and Iwasko,[15] the authors investigated Outerbridge grade III patients with femoral condyle lesions 1.5 to 3.0 cm in diameter treated with a mechanical shaver and mechanical shaver plus RF. The difference in pre- and

Table 2. Outcome Scores

Outcome Score	Barber and Iwasko[15] (Monopolar)	Kang et al.[22] (Monopolar)	Spahn et al.[16] (Bipolar)	Osti et al.[18] (Bipolar)	Stein et al.[20] (Bipolar)
Lysholm					
Preoperative	50	–	–	39	–
Postoperative	83	–	–	91	86.4
Tegner					
Preoperative	2.3	–	2.4	–	–
Postoperative	3.8	–	4.5	7	–
IKDC					
Preoperative	36	30	–	–	–
Postoperative	69	49	–	90	–

IKDC, International Knee Documentation Committee

postoperative IKDC and Lysholm scores among patients was found to be insignificant.[18] Similarly, Kang et al.[22] studied patients with grade II or III lesions who underwent mechanical chondroplasty with and without monopolar RF. When comparing IKDC scores preoperatively and at the latest follow-up, the authors found no significant difference between the 2 groups (P = .444).[22] Lastly, Osti et al. found comparable mid-term follow-up outcomes between RF chondroplasty and microfracture, which is typically the standard for comparison in cartilage surgery studies. The authors compared IKDC, Lysholm, and Tegner scores at baseline and 5 years from surgery, finding no significant differences in outcome scores.[23] According to these studies, the benefits of using RF chondroplasty compared with traditional mechanical chondroplasty on outcomes scores remain inconclusive.[18] The paucity of research quantifying the benefits of either technique warrants further investigation on this topic.

Previous literature has investigated the minimal clinically important difference (MCID) following autologous chondrocyte implantation and cartilage repair, which can be used to further evaluate the clinical outcomes within this systematic review.[23,24] In a study from Ogura et al.,[24] they found that MCID mean improvements for IKDC scores in patients following autologous chondrocyte implantation was 34.4. Similarly, Jones et al.[23] reported that cartilage repair procedures (osteoarticular transfer system, osteochondral allograft transplantation, and autologous chondrocyte implantation/matrix-induced autologous chondrocyte implantation) for the treatment of knee chondral defects met MCID values for IKDC (MCID = 16.7) and Lysholm (MCID = 10.1). When comparing these MCID levels with the reported preoperative to postoperative change in clinical outcomes within this systematic review, Barber and Iwasko,[15] Kang et al.,[22] and Osti et al.,[18] suggests patients undergoing RF chondroplasty meet MCID for both Lysholm and IKDC scores.

Although there is ample evidence on the effectiveness of RF energy in chondroplasty, it remains widely unknown whether monopolar and bipolar systems result in significantly different clinical outcomes and complication rates. The active electrode of monopolar devices passes currents through the patient's body to reach the target lesion, and the current exits through a return electrode. Bipolar devices only pass currents through tissue that is located between its 2 electrodes.[10] In their 2017 study investigating the in vitro effects of RF energy devices, Lu et al.[11] found that bipolar RF systems penetrated 78% to 92% deeper than monopolar frequency systems when tested on bovine femoral osteochondral sections. The authors concluded that RF energy should not be used for thermal chondroplasty until achieving a smooth articular surface while reducing chondrocyte death is possible. The results of our review report good clinical outcomes but inconclusive to compare the 2 devices due to the lack of comparative studies and low sample size of monopolar studies relative to bipolar studies. More prospective comparative studies are needed to make conclusive decisions on superiority among bipolar vs monopolar use in knee chondral lesions.

A form of thermal chondroplasty known as coblation recently has emerged for the treatment of chondral lesions. Coblation generates a plasma-based RF current that transfers energy to contact tissue.[25] However, no direct contact with the tissue is made. Although no studies exist comparing coblation versus ablation, the more novel coblation technique has been proven to be a viable option for the treatment of cartilage defects demonstrating improved patient outcomes and

Table 3. Overall Incidence of Complications

	Incidence Rate, Range (%)
Total complications	0-4
Infection	0-0.4
DVT	0-0.6
Persistent pain	0-0.7
Osteonecrosis	0-4
Additional surgery	0-4.5

DVT, deep-vein thrombosis.

decreased reoperation rates when compared with mechanical chondroplasty.[14,17,19,25,26] In a recent investigation by Adeyemi et al.[27] comparing cost and outcomes between coblation and mechanical debridement for the treatment of knee chondral lesions, the authors found that coblation resulted in a lower revision rate (14% vs 48%) and had a net savings of $380 per revision. When comparing coblation vs ablation in our review, the lack of comparative studies and low sample size among coblation studies reporting outcomes makes it difficult to make a conclusive decision on superiority. Future prospective comparative studies are needed to make a conclusive decision on superiority among coblation versus ablation use in knee chondral lesions.

Our findings indicate that RF chondroplasty of the knee is associated with a low rate of postoperative complications. Among studies reporting the incidence rate of osteonecrosis, monopolar and bipolar RF devices both ranged from 0% to 4%. Although osteonecrosis can be due to predisposing factors such as metabolic diseases, alcohol abuse, trauma, and hematological disorders, past literature[9] reports that RF energy, despite no clinical evidence, also contributes to the development of osteonecrosis. In a prospective clinical series by Cetik et al.,[9] the authors concluded that when performed correctly, RF energy does not cause subchondral osteonecrosis. Among their 2 patients (4%, n = 2/50) who developed osteonecrosis, both underwent partial meniscectomy for the degenerative tear of their meniscus. In addition, the incidence of persistent pain (range, 0%-0.71%), deep vein thrombosis (range, 0%-0.59%), infection (range, 0%-0.36%), and patients requiring additional surgery (0%-4.5%) for bipolar RF patients was also low. The additional surgeries that patients received ranged from total knee arthroplasty to second-look arthroscopy, unicompartmental knee replacement, anterior cruciate ligament reconstruction, osteotomy, hardware removal, synovectomy, partial lateral meniscectomy, partial medial meniscectomy, collagen medial meniscal implant, chondroplasty, microfracture, and removal of loose bodies.

Limitations

This study is not without limitations. First, the low level of evidence of the included studies precluded meta-analysis of pooled data and support the need for additional prospective studies with control groups and larger sample sizes. Second, many patients (74.4%, n = 842/1,107) came from one study—from Gharaibeh et al.[14] This resulted in a significantly lower population of patients using a monopolar (6.3%, n = 70/1,107) RF device compared with bipolar (93.7%, n = 1037/1,107). Third, complications were not explicitly reported in 8 of the 10 studies. Furthermore, it is important to note that other factors such as lesion size, knee alignment, and patient weight contribute to the healing ability of chondral defects. The authors assumed that major complications such as osteonecrosis and infection did not occur during patient follow-up; however, their absence was not reported.

Conclusions

The available literature on RF-based chondroplasty shows its efficacy and safety for the treatment of knee chondral lesions, with good clinical outcome scores and low complication and reoperation rates.

References

1. Hjelle K, Solheim E, Strand T, Muri R, Brittberg M. Articular cartilage defects in 1,000 knee arthroscopies. *Arthroscopy* 2002;18:730-734.
2. Heir S, Nerhus TK, Røtterud JH, et al. Focal cartilage defects in the knee impair quality of life as much as severe osteoarthritis: A comparison of knee injury and osteoarthritis outcome score in 4 patient categories scheduled for knee surgery. *Am J Sports Med* 2010;38:231-237.
3. Cicuttini FM, Jones G, Forbes A, Wluka AE. Rate of cartilage loss at two years predicts subsequent total knee arthroplasty: A prospective study. *Ann Rheum Dis* 2004;63:1124-1127.
4. Montgomery SR, Foster BD, Ngo SS, et al. Trends in the surgical treatment of articular cartilage defects of the knee in the United States. *Knee Surg Sports Traumatol Arthrosc* 2014;22:2070-2075.
5. Riboh JC, Cvetanovich GL, Cole BJ, Yanke AB. Comparative efficacy of cartilage repair procedures in the knee: A network meta-analysis. *Knee Surg Sports Traumatol Arthrosc* 2017;25:3786-3799.
6. Anderson DE, Rose MB, Wille AJ, Wiedrick J, Crawford DC. Arthroscopic mechanical chondroplasty of the knee is beneficial for treatment of focal cartilage lesions in the absence of concurrent pathology. *Orthop J Sports Med* 2017;5:2325967117707213.
7. Kosy JD, Schranz PJ, Toms AD, Eyres KS, Mandalia VI. The use of radiofrequency energy for arthroscopic chondroplasty in the knee. *Arthroscopy* 2011;27:695-703.
8. Piper D, Taylor C, Howells N, Murray J, Porteous A, Robinson JR. Use of a novel variable power radiofrequency ablation system specific for knee chondroplasty: Surgical experience and two-year patient results. *Cureus* 2021;13:e12864.
9. Cetik O, Cift H, Comert B, Cirpar M. Risk of osteonecrosis of the femoral condyle after arthroscopic chondroplasty using radiofrequency: A prospective clinical series. *Knee Surg Sports Traumatol Arthrosc* 2009;17:24-29.
10. Shinmura K, Ikematsu H, Kojima M, et al. Safety of endoscopic procedures with monopolar versus bipolar instruments in an ex vivo porcine model. *BMC Gastroenterol* 2020;20:27.
11. Lu Y, Edwards RB 3rd, Cole BJ, Markel MD. Thermal chondroplasty with radiofrequency energy. An in vitro comparison of bipolar and monopolar radiofrequency devices. *Am J Sports Med* 2001;29:42-49.

12. Lu Y, Edwards RB 3rd, Nho S, Cole BJ, Markel MD. Lavage solution temperature influences depth of chondrocyte death and surface contouring during thermal chondroplasty with temperature-controlled monopolar radiofrequency energy. *Am J Sports Med* 2002;30:667-673.
13. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Rev Esp Cardiol (Engl Ed)* 2021;74: 790-799.
14. Gharaibeh M, Szomor A, Chen DB, MacDessi SJ. A retrospective study assessing safety and efficacy of bipolar radiofrequency ablation for knee chondral lesions. *Cartilage* 2018;9:241-247.
15. Barber FA, Iwasko NG. Treatment of grade III femoral chondral lesions: Mechanical chondroplasty versus monopolar radiofrequency probe. *Arthroscopy* 2006;22: 1312-1317.
16. Spahn G, Klinger HM, Mückley T, Hofmann GO. Four-year results from a randomized controlled study of knee chondroplasty with concomitant medial meniscectomy: Mechanical debridement versus radiofrequency chondroplasty. *Arthroscopy* 2010;26:S73-S80.
17. Voloshin I, Morse KR, Allred CD, Bissell SA, Maloney MD, DeHaven KE. Arthroscopic evaluation of radiofrequency chondroplasty of the knee. *Am J Sports Med* 2007;35:1702-1707.
18. Osti L, Papalia R, Del Buono A, Amato C, Denaro V, Maffulli N. Good results five years after surgical management of anterior cruciate ligament tears, and meniscal and cartilage injuries. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1385-1390.
19. Owens BD, Stickles BJ, Balikian P, Busconi BD. Prospective analysis of radiofrequency versus mechanical debridement of isolated patellar chondral lesions. *Arthroscopy* 2002;18:151-155.
20. Stein DT, Ricciardi CA, Viehe T. The effectiveness of the use of electrocautery with chondroplasty in treating chondromalacic lesions: A randomized prospective study. *Arthroscopy* 2002;18:190-193.
21. Türker M, Çetik Ö, Çırpar M, Durusoy S, Cömert B. Postarthroscopy osteonecrosis of the knee. *Knee Surg Sports Traumatol Arthrosc* 2015;23:246-250.
22. Kang RW, Gomoll AH, Nho SJ, Pylawka TK, Cole BJ. Outcomes of mechanical debridement and radiofrequency ablation in the treatment of chondral defects: A prospective randomized study. *J Knee Surg* 2008;21:116-121.
23. Jones KJ, Kelley BV, Arshi A, McAllister DR, Fabricant PD. Comparative effectiveness of cartilage repair with respect to the minimal clinically important difference. *Am J Sports Med* 2019;47:3284-3293.
24. Ogura T, Ackermann J, Barbieri Mestriner A, Merkely G, Gomoll AH. Minimal clinically important differences and substantial clinical benefit in patient-reported outcome measures after autologous chondrocyte implantation. *Cartilage* 2020;11:412-422.
25. Anderson SR, Faucett SC, Flanigan DC, Gmabardella RA, Amin NH. The history of radiofrequency energy and Coblation in arthroscopy: A current concepts review of its application in chondroplasty of the knee. *J Exp Orthop* 2019;6:1.
26. Spahn G, Kahl E, Mückley T, Hofmann GO, Klinger HM. 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* 2008;16: 565-573.
27. Adeyemi A, Nherera L, Trueman P, Ranawat A. Cost-effectiveness analysis of coblation versus mechanical shaver debridement in patients following knee chondroplasty. *Cost Eff Resour Alloc* 2020;18:44.