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Original Article / Özgün Makale

# Comparative effectiveness of intra-articular corticosteroid injection and radiofrequency ablation for advanced hip osteoarthritis: A retrospective cohort study

## İleri evre kalça osteoartritinde intra-artiküler kortikosteroid enjeksiyonu ile radyofrekans ablasyonun karşılaştırmalı etkinliği: Retrospektif kohort çalışması

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### ABSTRACT

**Background:** This study aims to compare the clinical effectiveness and safety of intra-articular corticosteroid (IAC) injections versus radiofrequency ablation (RFA) of the femoral and obturator articular branches in patients with advanced hip osteoarthritis (OA).

**Patients and Methods:** This single-center, retrospective cohort study included a total of 93 patients including 62 who received IAC and 31 who received RFA between January 2022 and May 2025. Pain severity (Numeric Rating Scale, NRS), clinical improvement (Global Perceived Effect, GPE), and analgesic use were evaluated at baseline, one month, and six months. Longitudinal changes were analyzed using the Generalized Estimating Equations (GEE) adjusted for age, sex, body mass index (BMI), and opioid use.

**Results:** Of a total of 93 patients included in the study, 17 were male and 76 were female with a mean age of 66.8±12.3 (range, 27 to 89). Both groups exhibited significant reductions in NRS scores at one and six months compared to baseline ($p < 0.001$). No significant inter-group differences were observed in absolute NRS scores or the proportion of patients achieving a good clinical response (GPE ≥ 6). At six months, the RFA group demonstrated numerically greater improvement; however, differences in absolute (median 2.0 *vs.* 0.0; $p = 0.052$) and percentage change (median 25.0% *vs.* 0.0%; $p = 0.054$) did not reach statistical significance. Longitudinal analyses using GEE confirmed a significant main effect of time, with no treatment group effect or group-by-time interaction after adjusting for age, sex, BMI, and baseline opioid use.

**Conclusion:** Both IAC and RFA provide meaningful and comparable pain relief in patients with refractory hip OA. While the analgesic effect of IAC injections appears to diminish by the sixth month, RFA may offer a safe alternative with a potentially more sustained clinical trajectory.

**Keywords:** Chronic pain management, hip osteoarthritis, intra-articular corticosteroid injection, radiofrequency ablation.

### ÖZ

**Amaç:** Bu çalışmada, ileri evre kalça osteoartriti (OA) olan hastalarda intra-artiküler kortikosteroid (İAK) enjeksiyonları ile femoral ve obturator artiküler dallara uygulanan radyofrekans ablasyonunun (RFA) klinik etkinliği ve güvenliliği karşılaştırıldı.

**Hastalar ve Yöntemler:** Bu tek merkezli, retrospektif kohort çalışmasına Ocak 2022 - Mayıs 2025 tarihleri arasında İAK uygulanan 62 ve RFA uygulanan 31 hasta olmak üzere toplam 93 hasta dahil edildi. Ağrı şiddeti (Sayısal Derecelendirme Ölçeği, NRS), klinik iyileşme (Genel Algılanan Etki, GPE) ve analjezik kullanımı başlangıçta, birinci ayda ve altıncı ayda değerlendirildi. Boylamsal değişimler, yaş, cinsiyet, vücut kitle indeksi (BMI) ve opioid kullanımı için düzeltilmiş Genelleştirilmiş Tahmin Denklemleri (GEE) ile analiz edildi.

**Bulgular:** Çalışmaya dahil edilen toplam 93 hastanın 17'si erkek, 76'sı kadın olup, ortalama yaş 66.8±12.3 (dağılım, 27-89) yıl idi. Her iki grupta da başlangıca kıyasla birinci ve altıncı aylarda NRS skorlarında anlamlı azalma görüldü ($p < 0.001$). Mutlak NRS skorları veya iyi klinik yanıt (GPE ≥ 6) elde eden hasta oranı açısından gruplar arasında anlamlı fark saptanmadı. Altıncı ayda RFA grubunda sayısal olarak daha fazla iyileşme görülmekle birlikte, mutlak değişim (medyan 2.0'a kıyasla 0.0; $p = 0.052$) ve yüzdesel değişim (medyan %25.0'a kıyasla %0.0; $p = 0.054$) açısından fark istatistiksel anlamlılığa ulaşmadı. Genelleştirilmiş Tahmin Denklemleri ile yapılan boylamsal analizler, zamanın anlamlı ana etkisini doğrularken, yaş, cinsiyet, BMI ve başlangıç opioid kullanımı için düzeltme sonrası tedavi grubu etkisi veya grup-zaman etkileşimi saptanmadı.

**Sonuç:** Hem İAK hem de RFA, dirençli kalça OA'sı olan hastalarda anlamlı ve benzer düzeyde ağrı kontrolü sağlamaktadır. İntra-artiküler kortikosteroid enjeksiyonlarının analjezik etkisinin altıncı ayda azalma eğiliminde olduğu görülürken, RFA daha sürdürülebilir bir klinik seyir sunabilecek güvenli bir alternatif olabilir.

**Anahtar sözcükler:** Kronik ağrı yönetimi, kalça osteoartriti, intra-artiküler kortikosteroid enjeksiyonu, radyofrekans ablasyon.

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Osteoarthritis (OA) is the most prevalent degenerative joint disorder globally and constitutes a major cause of chronic pain and disability, particularly when weight-bearing joints such as the hip and knee are involved.[1] Epidemiological data indicate that the prevalence of symptomatic hip OA is approximately 4% in individuals over 50 years of age,[2] and up to one-quarter of adults may develop symptomatic hip OA over their lifetime.[3] These findings reflects the increasing clinical and socioeconomic burden of hip OA within aging populations.[4]

Clinically, hip OA is characterized by activity-related joint pain, stiffness, gait disturbances, muscle weakness, and sleep impairment, collectively contributing to substantial psychosocial and physical disability.[5,6] Patients commonly report ipsilateral groin pain radiating to the anterior thigh, gluteal region, knee, or even the distal lower extremity. The pain is often intermittent and exacerbated during or following physical activity.[7] Anatomically, the anterior hip joint capsule is considered the primary pain-generating region due to its high density of nociceptive and mechanoreceptive fibers. This region is innervated by the articular branches of the femoral (FN), obturator (ON), and accessory obturator nerves (AON).[8] This neuroanatomical framework provides a strong rationale for targeted interventional pain-management strategies.[9]

The primary therapeutic goals in hip OA management are effective pain control and preservation of joint function, ultimately improving overall quality of life.[7,10] Management commonly follows a stepwise approach, beginning with conservative strategies such as lifestyle modification, physical therapy, and pharmacological treatment.[11] Although non-steroidal anti-inflammatory drugs (NSAIDs) are considered first-line analgesics, their long-term use is frequently limited in older adults due to gastrointestinal, renal, and cardiovascular adverse effects.[12] While intra-articular corticosteroid (IAC) injections represent a long-standing minimally invasive option, current evidence suggests that their analgesic effect is typically transient.[13,14] Total hip arthroplasty (THA) remains the definitive treatment for advanced hip OA; however, it may be unsuitable for many patients due to significant comorbidities, increased perioperative risk or personal preference. Furthermore, concerns regarding implant longevity often lead clinicians and patients to postpone surgery in younger.[15]

In recent years, minimally invasive interventional procedures have gained increasing attention as alternative treatment options for patients with refractory hip OA pain or those who are unsuitable surgical candidates.[16] Radiofrequency ablation (RFA) is an image-guided technique that modulates nociceptive signaling by creating controlled thermal lesions in targeted sensory nerve fibers.[17] When applied to the articular branches of the FN and ON, RFA has been shown to provide meaningful pain reduction and functional improvement with a favorable safety profile in hip OA.[18,19] These procedures are typically performed under fluoroscopic and/or ultrasonographic guidance, which enhances needle placement accuracy and reduces procedural risk.

Despite its expanding clinical use, real-world data directly comparing intra-articular injections and RFA targeting the hip OA, particularly regarding effectiveness, safety, and patient-reported outcomes, remain limited. In the present study, we, therefore, aimed to evaluate clinical outcomes, safety profile, and patient satisfaction in patients with advanced hip OA who underwent IAC or RFA.

## PATIENTS AND METHODS

This single-center, retrospective, observational cohort study was conducted at Ankara Bilkent City Hospital, Department of Pain Medicine between January 2022 and May 2025. In our clinical practice, the choice between IAC and RFA was determined primarily by shared decision-making, considering patient preference, the treating physician's clinical judgment, the duration and response of prior treatments, and contraindications to either procedure. All consecutive patients aged ≥18 years who received treatment for chronic hip pain attributable to hip OA were retrospectively identified through the institutional electronic medical record system by confirming receipt of either a hip IAC injection or hip joint RFA. Inclusion criteria required a diagnosis of hip OA established according to the American College of Rheumatology (ACR) clinical and radiographic criteria, with radiographic severity classified as Kellgren-Lawrence Grade 3-4. Patients with inaccessible or incomplete medical records, those in whom the interventional procedure resulted in technical failure, and those who had undergone any other hip-targeted interventional procedure within the preceding or subsequent six months were excluded. Those with neuropsychiatric conditions that precluded reliable self-reported pain

assessments or clinical feedback were also excluded. This criterion inherently excluded patients who received both IAC and RFA on the same hip within the six-month follow-up period, as well as those with overlapping bilateral procedures involving different treatment modalities. Of a total of 129 medical records which were screened initially, 24 were excluded due to incomplete data; one due to uremic encephalopathy resulting in unreliable self-report; two who died during follow-up; five with a prior surgical intervention involving the hip joint; and four who underwent another interventional pain procedure within the preceding six months. Finally, a total of 93 patients including 62 who received IAC and 31 who received RFA and met the inclusion criteria were recruited. The study flowchart is shown in Figure 1. Informed consent was waived due to the retrospective nature of the study. The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (Date: 24.09.2025, No: TABED 1-25-1708). The study was conducted in accordance with the principles of the Declaration of Helsinki.

### Data collection

Demographic, clinical, and treatment-related data were extracted from electronic medical records. These parameters had been recorded using a standardized study form as part of the institution's routine clinical practice. Consequently, outcome measures were followed systematically within this clinical framework. In cases where the electronic records were incomplete, the missing information was supplemented by contacting patients via telephone to ensure data continuity.

The following baseline parameters were collected: demographic data (age, sex, height, weight, body

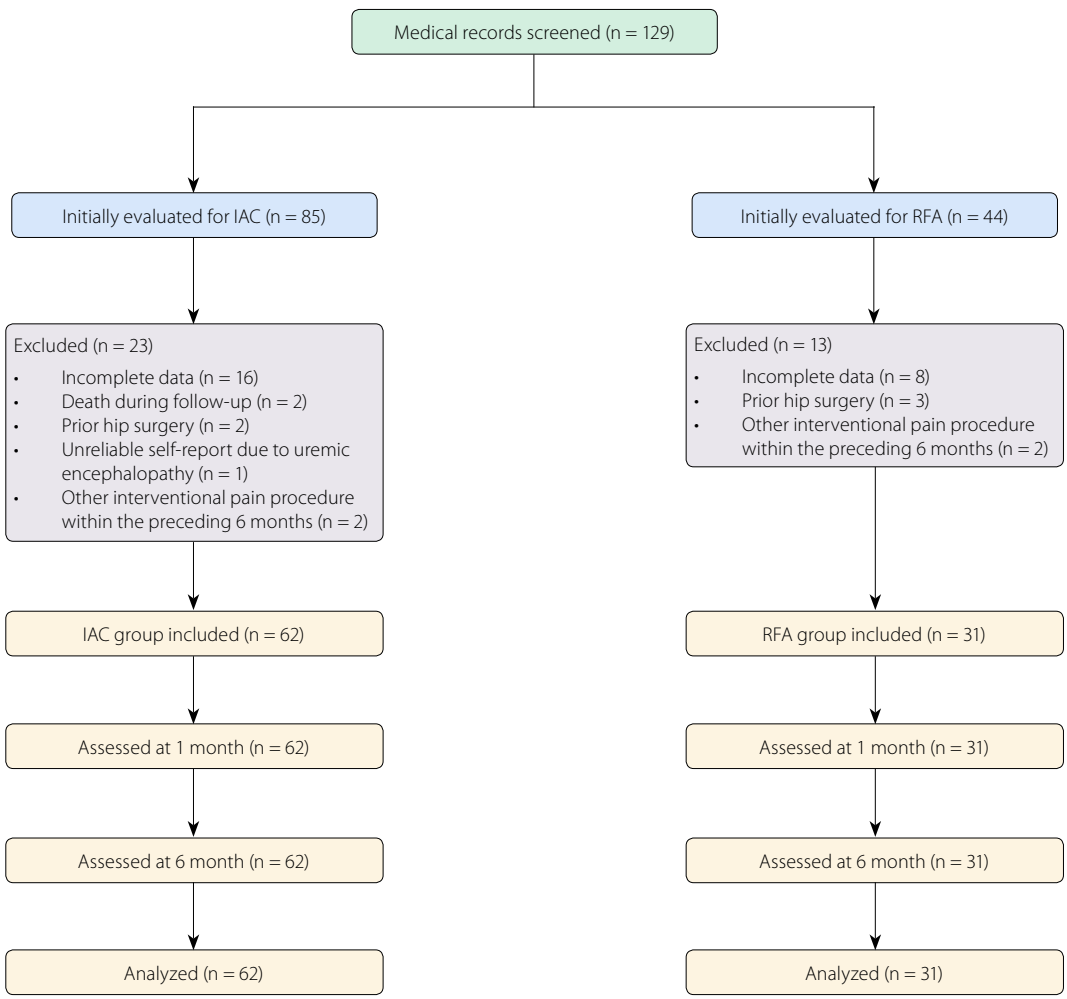


**Figure 1.** Study flowchart according to STROBE guidelines.
IAC, intra-articular corticosteroid; RFA, radiofrequency ablation.

mass index [BMI]), medical history (presence of malignancy or autoimmune disease), previous treatments (pharmacological treatments such as opioid and non-opioid analgesics, antidepressants, gabapentinoids, and physical therapy modalities), pain characteristics (duration, localization, and baseline pain severity), and interventional procedure details (type of procedure performed [IAC or RFA] and laterality of the intervention).

**Outcome measures**

Treatment effectiveness was evaluated by comparing baseline assessments with follow-up measurements at one month and six months after the intervention.

Pain severity was measured using the Numeric Rating Scale (NRS), ranging from 0 (no pain) to 10 (worst imaginable pain). The Global Perceived Effect (GPE) scale was used to assess overall clinical improvement. This scale is a well-established and validated patient-reported outcome measure that has been widely used in musculoskeletal and pain research to assess patients' overall perception of change following treatment.[20] Patients rated their perceived change relative to baseline on a seven-point ordinal scale, where 7 indicated ≥ 75% improvement (very good), 6 indicated 50-74% improvement (good), 5 indicated 25-49% improvement (moderately improved), 4 indicated 0-24% change, 3 indicated 25-49% worsening (moderately worse), 2 indicated 50-74% worsening (poor), and 1 indicated ≥ 75% worsening (very poor).

Patient satisfaction was assessed using a five-point Likert scale (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied). Changes in analgesic use were evaluated using a four-point Likert scale (increased, unchanged, decreased, discontinued). The duration of analgesic benefit was categorized into predefined intervals: < 1 week, 1 week-1 month, 1-3 months, 3-6 months, and ≥ 6 months. All adverse events and procedure-related complications were recorded, including their type and duration.

**Procedures**

All procedures were performed in an operating room under continuous monitoring, with patients in the supine position and under C-arm fluoroscopic guidance. After sterile preparation of the entry site, cutaneous anesthesia was achieved using 2% prilocaine.

For the obturator articular branch, the target point was identified using the anteroposterior (AP) fluoroscopic teardrop landmark (acetabular notch-acetabular wall-pelvic wall configuration). A 22-gauge RF cannula with a 10-mm active tip (SMK™, 22 GA×10 cm, Abbott Medical, Plymouth, MN, USA) was advanced to the inferior margin of the teardrop until firm bony contact was achieved (Figure 2a). For the femoral articular branch, an identical cannula was advanced to the 12 o'clock

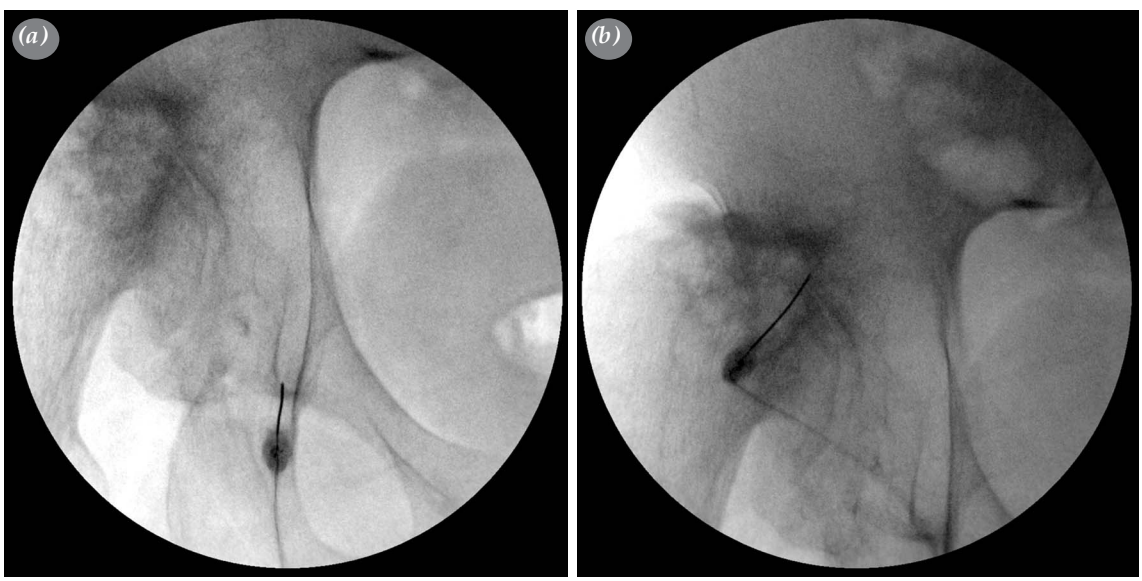


**Figure 2. (a)** Fluoroscopy-guided needle placement targeting the sensory articular branch of the obturator nerve for RFA. **(b)** Fluoroscopy-guided needle placement targeting the sensory articular branch of the femoral nerve for RFA.
RFA, radiofrequency ablation.

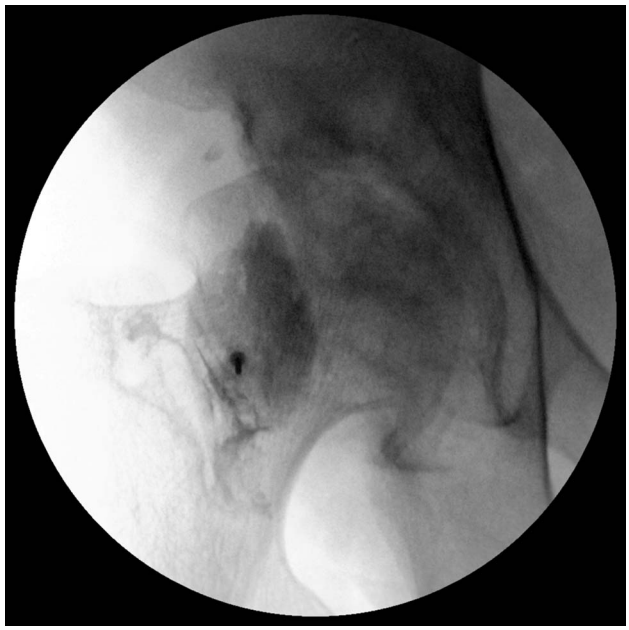

**Figure 3.** Contrast spread after hip intraarticular corticosteroid injection by fluoroscopy.

position of the superior acetabulum, and osseous contact was confirmed (Figure 2b). Correct cannula placements were verified using sensory stimulation (0.5 V, 50 Hz) and confirmed by the absence of motor activation during motor stimulation (2 Hz, 2 V). After the injection of 1% lidocaine, continuous RF thermocoagulation was applied at 80°C for 90 sec. Each lesion site then received 0.25% bupivacaine plus 2 mg dexamethasone to minimize post-procedural neuritis.

For the intra-articular injection, a 22-gauge, 90-mm spinal needle was advanced toward the femoral neck under AP fluoroscopic guidance. After confirming adequate contrast spread within the joint space, 40 mg of methylprednisolone acetate was injected (Figure 3). All patients were routinely monitored in an observation unit for at least 60 min after the procedure and were discharged following completion of general and neurological assessments.

**Statistical analysis**

Statistical analysis was performed using the Python version 3.11 software (Python Software Foundation, Wilmington, DE, USA) within a Jupyter Notebook environment. The distribution of continuous variables was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots. Normally distributed variables were presented in mean ± standard deviation (SD), whereas non-normally distributed variables were presented in median and interquartile range (IQR). Categorical variables were presented in number and frequency. Inter-group comparisons were performed for absolute and percentage changes in NRS scores from baseline, as well as other continuous variables. The independent samples t-test was used for normally distributed data, while the Mann-Whitney U test was employed for non-normally distributed variables. Inter-group differences among the categorical variables were evaluated using the chi-square test or Fisher exact test. Longitudinal changes in NRS scores (baseline, one month, six months) were analyzed using Generalized Estimating Equations (GEE) to examine the effects of group, time, and group-by-time interaction. The model was adjusted for age, sex, BMI, and baseline opioid use. All effect estimates are reported with their 95% confidence intervals (CI). For the 93 patients included in the final analysis, there was no missing data for the primary outcome (NRS scores at baseline, one month, and six months) or for any of the covariates used in the adjusted models. Nevertheless, the GEE framework is inherently robust to data missing completely at random (MCAR), as it utilizes all available observations without requiring complete cases. A two-sided $p$ value of $< 0.05$ was considered statistically significant.

## RESULTS

Of a total of 93 patients included in the study, 17 were male and 76 were female with a mean age of 66.8±12.3 (range, 27 to 89) years. There were 62 patients in the IAC group and 31 patients in the RFA group. No significant differences were observed between the IAC and RFA groups regarding age, sex, BMI, pain duration, laterality, or baseline NRS scores ($p > 0.05$ for all). Similarly, the groups were comparable in terms of malignancy and autoimmune disease prevalence, as well as the use of concomitant analgesics or adjuvant medications ($p > 0.05$ for all). However, opioid use at baseline was significantly more frequent in the RFA group compared with the IAC group (54.8% *vs.* 30.6%, $p = 0.042$). Baseline demographic and clinical characteristics of both groups are presented in Table 1.

Post-treatment outcomes are summarized in Table 2. Median NRS scores at one and six months decreased significantly from baseline in both groups. However, there were no statistically significant differences inter-group differences in absolute NRS scores at either follow-up time point (Month 1: $p = 0.607$; Month 6: $p = 0.281$) (Figure 4).

**Table 1.** Baseline characteristics of the IAC and RFA groups

| Variables | IAC (n = 62) | | | | | RFA (n = 31) | | | | | *p* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | Median | IQR | n | % | Mean±SD | Median | IQR | |
| Age (year) | | | 67.9±11.9 | | 61.0-74.0 | | | 64.6±13.0 | | 55.5-74.5 | 0.235 |
| Sex, male | 11 | 17.7 | | | | 6 | 19.4 | | | | 1.000 |
| Body mass index (kg/m$^2$) | | | 29.5±5.1 | | | | | 29.9±4.8 | | | 0.728 |
| Autoimmune disease | 7 | 11.3 | | | | 1 | 3.2 | | | | 0.261 |
| NSAID use | 52 | 83.9 | | | | 26 | 83.9 | | | | 1.000 |
| Opioid use | 19 | 30.6 | | | | 17 | 54.8 | | | | 0.042 |
| Antidepressant use | 16 | 25.8 | | | | 6 | 19.4 | | | | 0.666 |
| Gabapentinoid use | 12 | 19.4 | | | | 7 | 22.6 | | | | 0.928 |
| Physical therapy | 45 | 72.6 | | | | 27 | 87.1 | | | | 0.188 |
| Pain duration (year) | | | | 3.5 | 2.0-5.0 | | | | 3.0 | 2.0-5.0 | 0.660 |
| Pain laterality | | | | | | | | | | | |
| Right | 37 | 59.7 | | | | 15 | 48.4 | | | | |
| Left | 24 | 38.7 | | | | 12 | 38.7 | | | | |
| Bilateral | 1 | 1.6 | | | | 4 | 12.9 | | | | |
| Baseline NRS score | | | | 7.0 | 6.2-8.0 | | | | 7.0 | 7.0-8.0 | 0.185 |

IAC, intra-articular steroid; RFA, radiofrequency ablation; SD, standard deviation; IQR, interquartile range; NSAID, nonsteroidal anti-inflammatory drug; NRS, Numeric Rating Scale. Inter-group differences were assessed using the Mann-Whitney U test for continuous variables and the Chi-square or Fisher exact test for categorical variables. Normality was assessed using the Shapiro-Wilk test.

**Table 2.** Comparison of treatment outcomes between the IAC and RFA groups

| Variables | IAC (n = 62) | | | | RFA (n = 31) | | | | *p* |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Median | IQR | n | % | Median | IQR | |
| NRS scores | | | | | | | | | |
| 1$^{st}$ month | | | 4.0 | 2.2-6.0 | | | 4.0 | 2.0-4.5 | 0.607 |
| 6$^{th}$ month | | | 6.0 | 3.2-7.0 | | | 5.0 | 3.0-7.0 | 0.281 |
| Absolute NRS change | | | | | | | | | |
| 1$^{st}$ month | | | 3.0 | 1.0-5.0 | | | 4.0 | 2.0-6.0 | 0.208 |
| 6$^{th}$ month | | | 0.0 | 0.0-3.8 | | | 2.0 | 0.0-4.0 | 0.052 |
| Percentage NRS change (%) | | | | | | | | | |
| 1$^{st}$ month | | | 50.0 | 14.3-70.2 | | | 50.0 | 33.3-70.8 | 0.271 |
| 6$^{th}$ month | | | 0.0 | 0.0-50.0 | | | 25.0 | 0.0-53.6 | 0.054 |
| Good outcome (GPE ≥ 6) | | | | | | | | | |
| 1$^{st}$ month | 35 | 56.5 | | | 19 | 61.3 | | | 0.824 |
| 6$^{th}$ month | 17 | 27.4 | | | 12 | 38.7 | | | 0.384 |
| Other outcomes | | | | | | | | | |
| Patient satisfaction (satisfied/very satisfied) | 23 | 37.1 | | | 18 | 58.1 | | | 0.089 |
| Effect duration score | | | 2.0 | 1.0-4.0 | | | 3.0 | 1.0-4.0 | 0.180 |
| Analgesic reduction (decreased/dropped) | 24 | 38.7 | | | 16 | 51.6 | | | 0.336 |

IAC, intra-articular steroid; RFA, radiofrequency ablation; IQR, interquartile range; NRS, Numeric Rating Scale; GPE, global perceived effect. Inter-group differences in NRS scores and effect duration were assessed using the Mann-Whitney U test. Categorical outcomes (GPE, patient satisfaction, analgesic use) were compared using the Chi-square test.

Similarly, neither absolute nor percentage changes in NRS scores differed significantly between the groups. Although the RFA group demonstrated a trend toward greater improvement at six months, both in absolute change (median 2.0 *vs.* 0.0; $p = 0.052$) and percentage change (median 25.0% *vs.* 0.0%; $p = 0.054$).

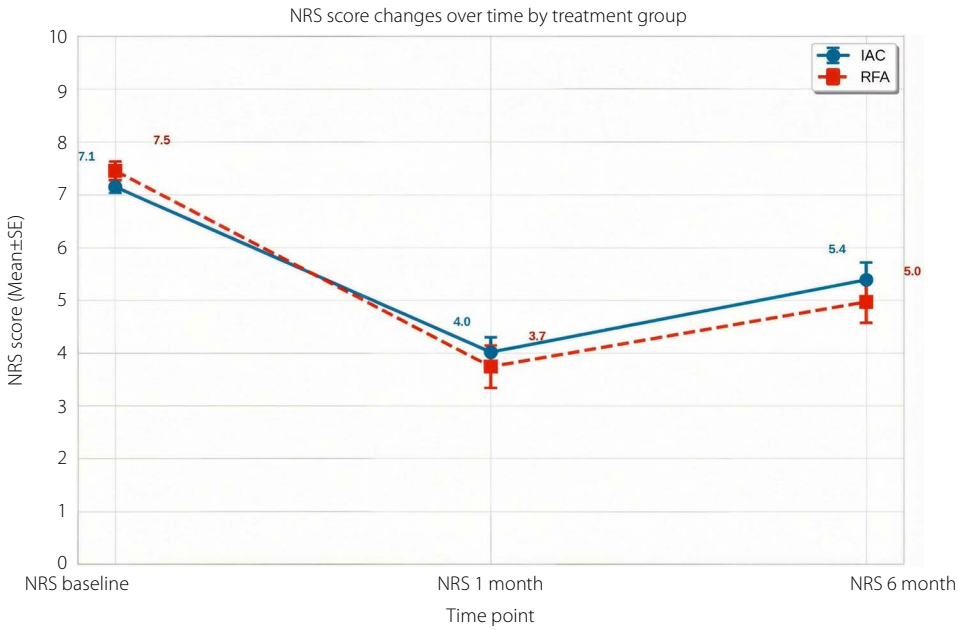


**Figure 4.** Mean (±SE) NRS scores at baseline, 1st month, and 6th month by treatment group. Longitudinal analysis was performed using a GEE model with exchangeable correlation structure, adjusted for age, sex, BMI, and baseline opioid use.

IAC, intra-articular corticosteroid; RFA, radiofrequency ablation, SE, standard error; NRS, Numeric Rating Scale; GEE, Generalized Estimating Equations; BMI, body mass index.

The proportion of patients achieving a good clinical outcome (GPE ≥ 6) was comparable between the groups at both one month (56.5% *vs.* 61.3%, $p = 0.824$) and six months (27.4% *vs.* 38.7%, $p = 0.384$) (Figure 5). Likewise, patient satisfaction (satisfied/very satisfied), effect-duration scores (Figure 6), and reductions or discontinuation of analgesic use were similar between the groups ($p > 0.05$ for all).

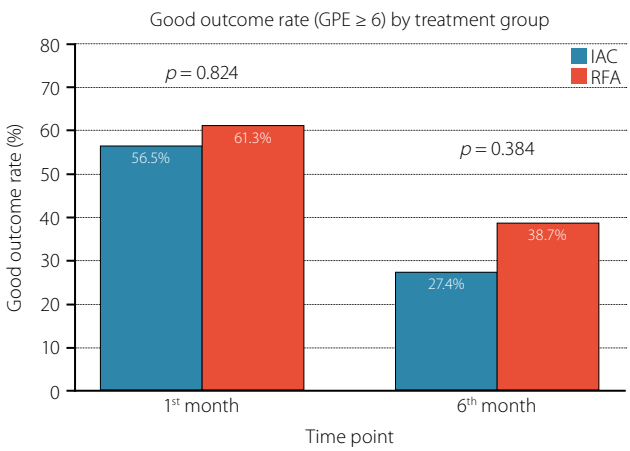


**Figure 5.** Proportion of patients achieving a good clinical outcome (GPE ≥ 6) at 1st and 6th month. Inter-group differences were assessed using the Chi-square test.

IAC, intra-articular corticosteroid; RFA, radiofrequency ablation, GEE, Generalized Estimating Equations.

A GEE model with exchangeable correlation structure was used to analyze NRS score changes over time between treatment groups, adjusted for age, sex, BMI, and baseline opioid use. Both treatment groups demonstrated significant reductions in NRS scores from baseline. In the IAC group, NRS scores decreased significantly from baseline to the first month (β = −3.13, 95% CI: −3.75 to −2.51, standard error [SE] = 0.32, $p < 0.001$) and from baseline to the sixth month (β = −1.76, 95% CI: −2.41 to −1.11, SE = 0.33, $p < 0.001$). Similarly, the RFA group showed significant reductions from baseline to the first month (β=−3.71, 95% CI: −4.38 to −3.04, SE = 0.37, $p < 0.001$) and from baseline to sixth month (β = −2.48, 95% CI: −3.25 to −1.71, SE = 0.39, $p < 0.001$). However, both groups exhibited a significant increase in NRS scores from the first month to sixth month (IAC: β = 1.37, 95% CI: 0.88 to 1.86, SE = 0.25, $p < 0.001$; RFA: β = 1.23, 95% CI: 0.83 to 1.63, SE = 0.20, $p < 0.001$), indicating partial regression of treatment effects over time.

No significant difference was observed between treatment groups at any time point. At baseline, the adjusted mean difference between RFA and IAC was

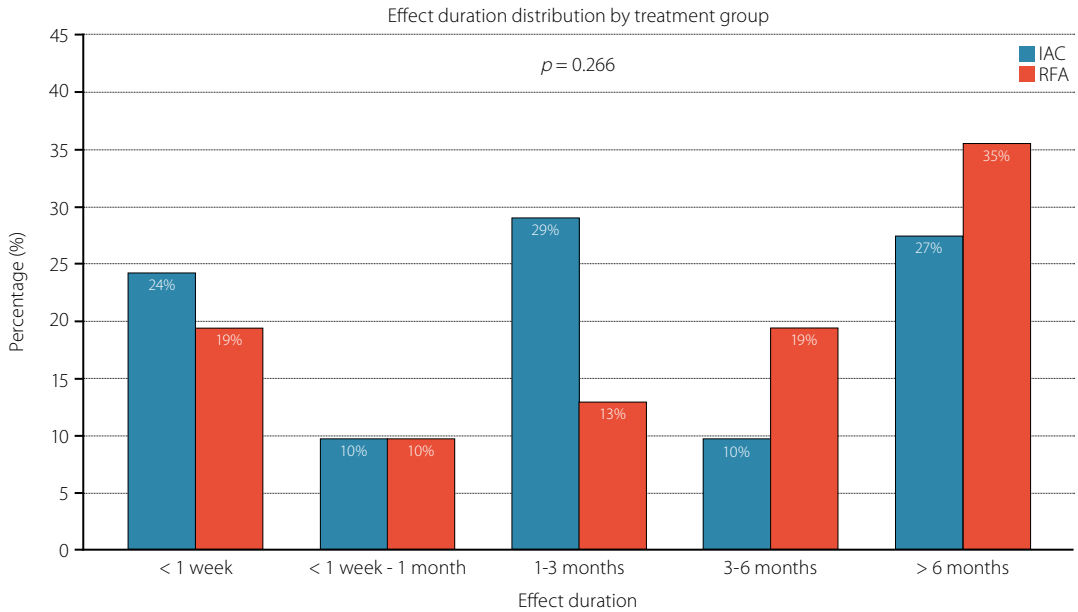


**Figure 6.** Effect duration distribution by treatment group (Mann-Whitney U test, $p = 0.180$).

0.12 points (SE = 0.21, $p = 0.560$). At one month, RFA showed a non-significant lower NRS score compared to IAC (difference = −0.46, SE = 0.43, $p = 0.292$). This trend persisted at six months (difference = −0.60, SE = 0.44, $p = 0.172$), but remained statistically non-significant. The group×time interaction terms were not significant (Month 1: β = −0.58, 95% CI: −1.53 to 0.37, $p = 0.229$; Month 6: β = −0.73, 95% CI: −1.70 to 0.25, $p = 0.146$), indicating that the trajectory of NRS score changes over time did not differ significantly between the IAC and RFA groups.

Among the adjustment variables, male sex was associated with higher NRS scores compared to females (β = 0.78, 95% CI: 0.03 to 1.54, SE = 0.39, $p = 0.043$). Baseline opioid use was also a significant predictor of higher NRS scores throughout the follow-up period (β=0.85, 95% CI: 0.26 to 1.45, SE = 0.30, $p = 0.005$). Age (β = 0.003, 95% CI: −0.03 to 0.03, $p = 0.844$) and BMI (β = −0.008, 95% CI: −0.07 to 0.06, $p = 0.817$) were not significantly associated with NRS scores.

In terms of safety, both procedures were well tolerated, with no serious adverse events observed. The most frequently reported adverse effect in the RFA group was transient procedural pain, and no cases of permanent neurological deficit were noted.

The adjusted estimated marginal means for NRS scores were as follows: at baseline, IAC 7.21 *vs.* RFA 7.33; at one month, IAC 4.08 *vs.* RFA 3.62; and at six months, IAC 5.45 *vs.* RFA 4.84. These values were adjusted for mean age (66.8 years), sex distribution (18% male), mean BMI (29.6 kg/m$^2$), and baseline opioid use (39%).

## DISCUSSION

In the present study, we evaluated clinical outcomes, safety profile, and patient satisfaction in patients with advanced hip OA who underwent IAC or RFA. Our study results showed that both treatments provided significant reductions in pain intensity at one and six months. Similarly, neither absolute nor percentage changes in NRS scores differed significantly between groups. Although the RFA group demonstrated a trend toward greater improvement at six months, these differences did not reach statistical significance. No significant differences were observed in the proportion of patients achieving a good clinical response (GPE ≥ 6).

The prevalence of hip OA increases markedly with age and is often accompanied by comorbidities such as cardiovascular disease, chronic kidney disease, and frailty.[7] These conditions complicate pain management and limit the long-term use of conventional pharmacotherapies, including NSAIDs and opioids.[16] Although THA is the gold standard for advanced hip OA, many patients are ineligible for surgery due to high perioperative risks, advanced age, anticoagulant use, or personal preference. Conversely, concerns regarding prosthesis longevity and potential

revision surgery often lead to postponement of THA in younger individuals. Given these challenges, there is an increasing demand for minimally invasive alternatives that provide effective and sustained relief. Interventional strategies such as RFA and image-guided intra-articular therapies emerge as vital options to address these unmet clinical needs.

Extensive evidence, including randomized-controlled trials and meta-analyses, consistently demonstrates that IAC provides short-term analgesia (typically 1 to 12 weeks) in hip OA.[21,22] Our findings corroborate this transient efficacy pattern. The proportion of patients achieving ≥ 50% clinical improvement (GPE ≥ 6) declined from 56.5% at one month to 27.4% at six months, indicating the waning effect over time.

In general, RFA serves as a minimally invasive alternative for patients who are refractory to conservative management or ineligible for surgery.[23] By targeting the articular sensory branches of the FN and ON, RFA interrupts nociceptive signaling while preserving motor function.[17] Anatomical studies indicate that nociceptive and mechanoreceptive fibers contributing to pain are predominantly localized in the anterior hip capsule.[24] Therefore, selective ablation of the FN and ON articular branches provides a rational framework for achieving high-level pain control with minimal complications.

Various studies have reported pain reduction rates ranging from 30 to 80% following RFA.[18,25] The relatively modest response rates observed in our study compared with those reported in some prior studies may be attributed to several technical and clinical factors. First, given the substantial anatomical variations in the hip innervation, the number and localization of lesions are critical determinants of successful denervation. Studies reporting higher success rates often utilize multiple lesion points for each nerve to capture these variations.[26,27] In our protocol, applying a single lesion to each of the FN and ON may have resulted in incomplete denervation of their articular branches.

Furthermore, the RFA technology employed is a significant factor. Compared to conventional thermal RFA, cooled RFA systems generate larger lesion volumes, increasing the likelihood of capturing variable nerve branches and providing more durable analgesia.[28] Our use of conventional thermal RFA, which produces smaller lesions, may have allowed for more rapid nerve regeneration or left some nociceptive fibers outside the lesion field unaffected.

Beyond technical factors, baseline patient characteristics may also influence outcomes. A notable factor in our study was the higher rate of baseline opioid use in the RFA group. Evidence suggests that patients with chronic pre-procedural opioid use are less likely to achieve meaningful clinical improvement following interventional pain treatments than opioid-naïve patients.[29] This may be due to mechanisms such as central sensitization or opioid-induced hyperalgesia, which may attenuate the expected efficacy of RFA. Taken together, RFA group was potentially more refractory or had higher pain sensitization at baseline, which makes the comparable outcomes even more impressive for RFA.

Despite these technical and clinical challenges, the statistically and clinically significant pain reduction observed over six months in both groups reaffirms the relevance of these methods in hip OA management. That a substantial proportion of patients achieved meaningful improvement, despite the single-lesion RFA protocol and higher baseline opioid use, underscores the potential utility of the RFA procedure. However, longer follow-up, such as 12-month assessments, may have revealed divergent durability of treatment effects between modalities. In addition, a more balanced sample size between groups might have increased statistical power to detect inter-group differences. Overall, these findings indicate that optimizing patient selection, standardizing procedural techniques, and incorporating longer-term follow-up may further strengthen the evaluation and comparative assessment of non-surgical interventional options for chronic hip pain.

The impact of interventional procedures on analgesic use varies across studies.[27-30] Although no significant inter-group differences were observed, 38.7% of IAC patients and 51.6% of RFA patients reduced or discontinued their analgesic medications. While not statistically significant, this finding represents a clinically meaningful improvement in analgesic burden. Moreover, in frail older patients with a high prevalence of polypharmacy, a decrease in analgesic use may be considered an important and favorable clinical outcome. The greater reduction in analgesic use observed in the RFA group may partly explain the absence of significant inter-group differences in pain intensity scores, as patients may elect to taper or discontinue analgesics once pain reaches a tolerable level, potentially resulting in comparable NRS scores despite differential treatment effects.

Nonetheless, this study has several limitations that should be acknowledged. The retrospective, single-center design of this study inherently introduces risks of selection bias, unmeasured confounding, and limited generalizability. Treatment allocation was not randomized but determined by shared clinical decision-making, which may have introduced indication bias. Although we adjusted for baseline differences using a multivariable GEE model, residual confounding from unmeasured variables cannot be excluded. The single-center nature of the study limits the generalizability of our findings to other clinical settings with different patient populations, procedural protocols, or operator experience. Although robust statistical model such as GEE were used to adjust for baseline imbalances, including the higher rate of opioid use in the RFA group, prospective randomized-controlled trials are needed to validate these findings. Propensity score matching or weighting could theoretically strengthen causal inference, this approach was not pursued given that only one baseline variable (opioid use) differed significantly between groups and was already adjusted for in the multivariable GEE model. Furthermore, propensity score matching in a study with an unbalanced sample (IAC: n = 62; RFA: n = 31) would have further reduced the effective sample size and statistical power. Conventional thermal RFA with a single-lesion protocol was used; novel techniques such as cooled or multi-lesion RFA may yield larger denervation zones and potentially superior long-term outcomes. Therefore, our results reflect the efficacy of a specific RFA approach rather than the entire spectrum of RFA modalities. Finally, the follow-up duration was limited to six months. Although this helps characterize the waning effect of IAC and the medium-term efficacy of RFA, longer-term studies (≥ 12 months) are needed to evaluate the durability of RFA and the potential need for repeat procedures. Additionally, no cost-effectiveness analysis was performed, despite its importance in chronic disease management.

In conclusion, our study results demonstrate that IAC and RFA targeting the femoral and obturator articular branches provide significant and comparable pain relief in patients with refractory hip OA. Despite the lack of a statistically significant inter-group difference over time, the numerically greater reduction in pain at six months in the RFA group is noteworthy in this study. Taken together, these findings support both interventional approaches as effective and safe non-surgical options for pain control, particularly in patients who are not suitable candidates for surgery or who prefer to postpone surgical intervention. Future multi-center, large-scale, prospective studies are warranted to clarify the role of these modalities in clinical practice.

**Author Contributions**

G.B., T.K.: Concept, literature search, writing; G.B., T.K., Ü.S.: Design; E.Y.A., Ş.Ş.: Supervision; Ü.S., Ş.D., A.Ç.: Resources; Ş.D., A.Ç.: Materials; G.B., T.K., Ş.D., A.Ç.: Data collection and/or processing; G.B., T.K., Ü.S., E.Y.A.: Analysis and/or interpretation; Ü.S., Ş.Ş., E.Y.A.: Critical review.

**Conflict of Interest**

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**Data Sharing Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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