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Research Article

Efficacy, safety, and short-term follow-up results of CT-guided radiofrequency and microwave ablation in the treatment of Osteoid Osteoma

BT kılavuzluğunda radyofrekans ve mikrodalga ablasyonun Osteoid Osteoma tedavisindeki etkinliği, güvenliği ve kısa dönem takip sonuçları

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Abstract

Introduction: The use of Computed Tomography-guided (CT-guided) percutaneous thermal ablation (PTA) techniques in the treatment of osteoid osteoma (OO) has been increasingly adopted worldwide. This study aims to evaluate the efficacy and safety of thermal ablation techniques in OO treatment, with a particular focus on short-term clinical success rates.

Methods: A retrospective analysis was conducted on 19 patients who underwent radiofrequency ablation (RFA) or microwave ablation (MWA) CT-guided in the Interventional Radiology Department of Pamukkale University Faculty of Medicine Hospital between October 2018 and December 2024. Data were obtained from hospital records. All procedures were performed under sedation by a single interventional radiologist, and follow-up evaluations were recorded on post-procedure day 1 and month 1. Visual Analog Scale (VAS) scores and lesion characteristics were reviewed from medical records. Technical success was defined as complete ablation of the nidus, while clinical success was defined as a post-procedure VAS score of ≤3.

Results: The mean age of the 19 patients who underwent thermal ablation was 13.6 years. Of the cohort, 36.8% (n=7) were female, and 63.2% (n=12) were male. The mean nidus diameter was 4.57 mm. The mean pre-procedure VAS score was 8.32, which significantly decreased to 1.11 on the first day post-procedure and 0.37 at the first-month follow-up. The technical success rate was 100%, while the clinical success rate was 95%. Minor complications were observed in 10.53% of cases, and major complications were reported in 5.26% of cases. Subgroup analyses revealed significant differences in pain perception between pediatric and adolescent patients before the procedure, but all groups showed statistically significant reductions in VAS scores post-procedure.

Conclusion: CT-guided PTA techniques are effective, safe, and minimally invasive treatment options for osteoid osteoma. In addition to high technical and clinical success rates, they offer a rapid recovery period. The findings support the use of PTA techniques as a first-line treatment option for OO. However, due to the retrospective study design, larger, multi-center, prospective randomized studies are required to confirm and expand these findings.

Keywords: Osteoma, Osteoid, Ablation Techniques, Visual Analog Scale

Öz

Giriş: Osteoid Osteom (OO) tedavisinde Bilgisayarlı Tomografi (BT) kılavuzluğunda uygulanan perkütan termal ablasyon (PTA) teknikleri tüm dünyada giderek yaygınlaşmaktadır. Bu çalışmanın amacı OO tedavisinde termal ablasyon tekniklerinin etkinliğini, güvenilirliğini ve özellikle klinik başarı oranlarının kısa dönem takip sonuçları değerlendirmektir.

Yöntem: Ekim 2018 ile Aralık 2024 tarihleri arasında Pamukkale Üniversitesi Tıp Fakültesi Hastanesi Girişimsel Radyoloji bölümünde BT kılavuzluğunda PTA teknikleri olan Radyofrekans Ablasyon (RFA) ve Mikrodalga Ablasyon (MDA) uygulanan 19 hasta retrospektif olarak değerlendirildi. Veriler hastane kayıtlarındaki hasta dosyalarından elde edildi. Tüm işlemler, sedasyon altında, tek bir girişimsel radyolog tarafından gerçekleştirilmiş olduğu ve işlem sonrası 1. gün ve 1. ayda takipleri kayıtlardan elde edildi. Hastaların Görsel Analog Ölçek (GAÖ) skorları ve lezyon özellikleri kayıtlardan incelendi. Teknik başarı nidusun tamamen ablasyonuyla, klinik başarı ise işlem sonrası GAÖ skorunun ≤3 olmasıyla tanımlandı.

Bulgular: Termal ablasyon uygulanan 19 hastanın yaş ortalaması 13,6 olup, hasta grubunun %36,8'ini (n=7) kadın, %63,2'sini (n=12) erkek hastalar oluşturmuştur. İşlem öncesinde ortalama nidus çapı 4,57 mm olarak saptanmıştır. GAÖ skorları işlem öncesinde ortalama 8,32 olarak kaydedilirken, işlem sonrası 1. günde 1,11'e ve 1. ayda 0,37'ye anlamlı düzeyde azalma göstermiştir. Teknik başarı oranı %100, klinik başarı oranı ise %95 olarak saptanmıştır. Minör komplikasyon oranı %10,53, majör komplikasyon oranı ise %5,26 olarak gözlenmiştir. Alt grup analizlerinde çocuk ve ergen hastalar arasında işlem öncesi ağrı algısında belirgin farklılıklar tespit edilmiş olmakla birlikte, tüm gruplarda işlem öncesine göre GAÖ skorlarında istatistiksel olarak anlamlı azalmalar kaydedilmiştir.

Sonuç: BT kılavuzluğunda uygulanan PTA teknikleri osteoid osteom tedavisinde etkili, güvenli ve minimal invaziv yöntemlerdir. Yüksek teknik ve klinik başarı oranlarına ek olarak, hızlı iyileşme süresi sağlamaktadır. Bulgular OO tedavisinde PTA tekniklerinin birinci basamak tedavi seçeneği olarak kullanımını desteklemektedir. Ancak, çalışmanın retrospektif tasarımı nedeniyle elde edilen sonuçların doğrulanması ve genişletilmesi için daha büyük hasta grupları ile yapılacak çok merkezli prospektif randomize çalışmalar gerekmektedir.

Anahtar Kelimeler: Osteom, Osteoid, Ablasyon Teknikleri, Görsel Analog Ölçek

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Key Points

1. PTA techniques have high technical and clinical success rates in the treatment of Osteoid Osteoma (OO).
2. These minimally invasive techniques are effective and safe with rapid recovery times.
3. The dramatic decrease in VAS scores at post-procedure first day and first month makes these techniques candidates for first-line treatment in OO.

Introduction

OO is a benign and painful neoplasm that accounts for approximately 3% of primary bone tumors and is most commonly observed in individuals aged between 5 and 25 years. It predominantly arises in the long tubular bones of the lower extremities, particularly in the diaphyseal or metaphyseal regions, but can also occur in any part of the axial or peripheral skeleton. OO is classified into three types: cortical, medullary, and subperiosteal. The most common form, cortical OO, consists of a central nidus surrounded by prominent peripheral sclerosis, whereas medullary and subperiosteal types exhibit less distinct peripheral sclerosis. Its clinical and radiographic features often facilitate diagnosis. Despite its small size, the pain it induces is remarkable, typically worsening at night and responding dramatically to acetylsalicylic acid (ASA) and other non-steroidal anti-inflammatory drugs (NSAIDs) [1- 4].

Until 1992, the only treatment option for OO was surgery. In 1989, Tillotson et al. demonstrated the efficacy of RFA in animal models. Subsequently, Rosenthal, a member of Tillotson's team, along with his colleagues, published a groundbreaking study in 1992, proving for the first time that RFA was a safe and effective alternative to surgery in the treatment of osteoid osteoma in humans [3,5].

Among PTA techniques used in OO treatment, RFA has long been the sole option due to its effectiveness, efficiency, and safety, and it is still considered the gold standard PTA technique. However, in recent years MWA has gained popularity due to its potential advantages over RFA, such as achieving higher temperatures within the target lesion and being less sensitive to changes in tissue composition [1,6].

This study aims to evaluate the efficacy and safety of CT-guided PTA techniques in the treatment of osteoid osteomas, particularly by assessing short-term follow-up outcomes regarding clinical success rates.

Methods

This retrospective study was approved by the Pamukkale University Ethics Committee (Pamukkale University Non-Interventional Clinical Research Ethics Committee, 21/01/2025, file number: E-60116787-020-643270). Informed consent was obtained from all patients aged 18 years and older, and from the parents or legal guardians of patients under 18 years of age, as documented in their medical records. This study involves a retrospective review of the medical records and archived radiological images of patients diagnosed with OO and treated with CT-guided percutaneous MWA or RFA at Pamukkale University Faculty of Medicine Hospital between October 2018 and December 2024. The cohort includes all patients who underwent these procedures since their implementation at our institution. Data obtained from the ablation procedures performed on 19 patients were included in the analysis.

Patients included in the study were those who presented with nocturnally exacerbated pain, had cross-sectional imaging findings consistent with osteoid osteoma, and had a recorded VAS score of ≥5. Additionally, it was confirmed that these patients had no contraindications such as uncorrectable coagulopathy, platelet count <50,000/mm³, or active infection.

For all included patients, cross-sectional imaging available in the hospital's Picture Archiving and Communication System (PACS) was reviewed to plan lesion access and determine the optimal patient positioning. Nidus diameters of the lesions, pre-procedure VAS scores, as well as first-day and first-month post-procedure follow-up VAS scores, were obtained from the hospital information system.

Given the retrospective nature of this study, all ablation procedures were performed at the study's initiation by a single interventional radiologist (H.S.A.), who had 10 years of experience in musculoskeletal interventions. Patient positioning on the CT table was optimized for lesion access, and visible markers were placed on the skin surface overlying the lesion CT-guiede to facilitate procedural planning. Once the needle entry trajectory was determined, sedation was administered by the anesthesia team, while local anesthesia was performed by the interventional radiologist. According to patient records, under sterile conditions, 2% prilocaine hydrochloride (20 mg/mL) was applied to the skin, subcutaneous tissues, muscles, and periosteum, with the dose adjusted according to the patient's weight (Figure 1).

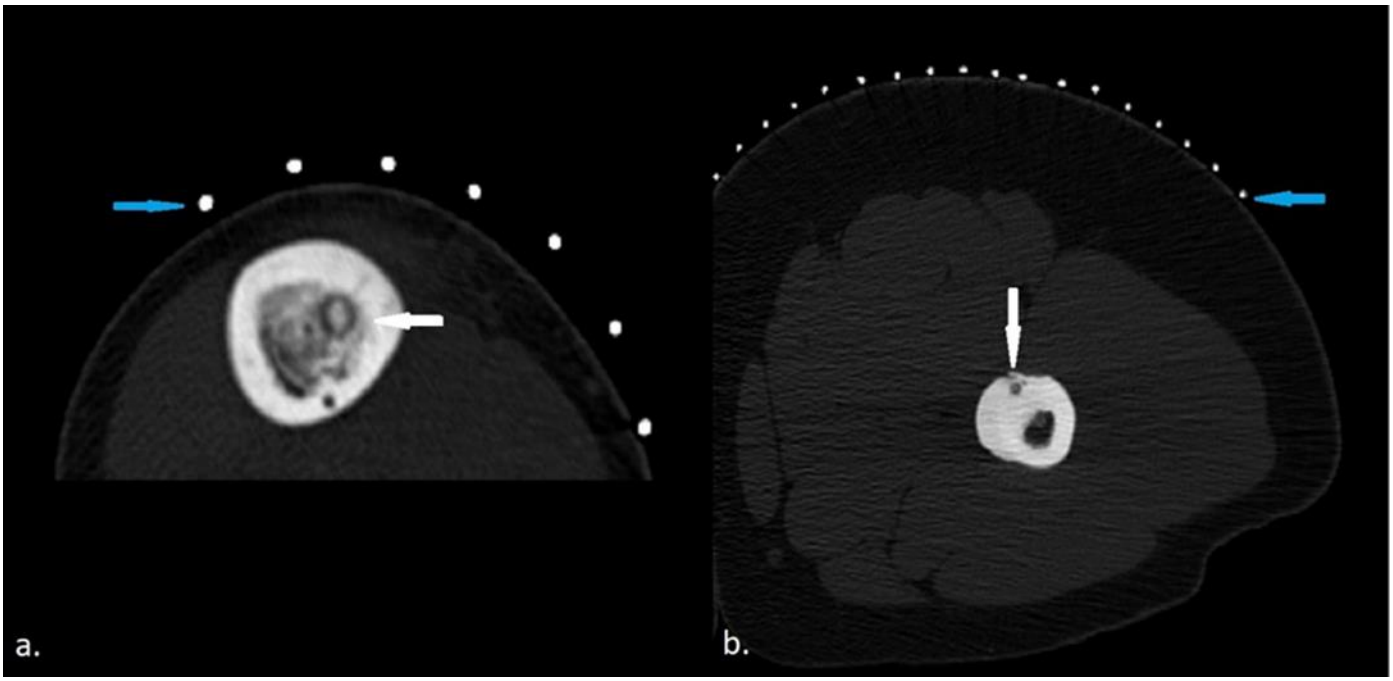

Figure 1. a) A 6-year-old female patient with an osteoid osteoma in the medullary region of the proximal tibia (white arrow). Markers positioned for planning the skin entry point are visible (blue arrow). b) The image shows an osteoid osteoma in the right proximal diaphysis of the femoral cortex (white arrow) in an 18-year-old male patient. Markers positioned for planning the skin entry point are visible (blue arrow).

A 11-gauge bone trocar (Bon-Core Trephine Bone Biopsy Needle, Egemen International, İzmir, Turkey) was percutaneously advanced into the cortical bone under the guidance of a multi-detector CT system (Brilliance 16, Philips Medical Systems). The trocar was maintained in a stable position during repeated imaging and was advanced toward the lesion to ensure the complete inclusion of the nidus within the ablation zone. An RFA probe (Starmed RF Ablation Systems, Goyang, South Korea) or an MWA antenna (Canyon Medical Inc., Nanjing, China) was placed at the center of the nidus. Ablation durations were determined according to the lesion size based on the manufacturer's guidelines (Figure 2).

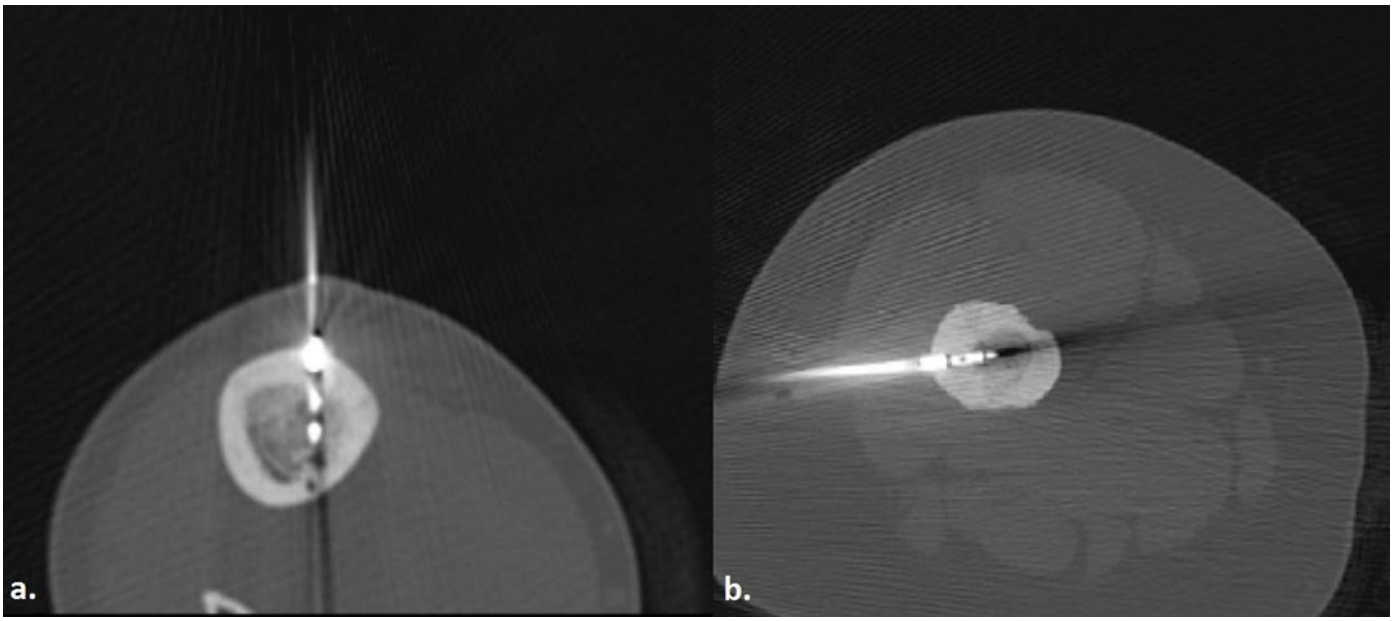

Figure 2. a) A sclerotic nidus located in the anteromedial proximal medulla of the tibia in a 6-year-old female patient is observed. The image shows an ablation probe placed at the center of the nidus. **b)** A nidus located in the cortical region of the proximal diaphysis of the femur in an 18-year-old male patient is observed, with an ablation probe positioned at the center of the nidus.

For all patients treated with RFA or MWA, follow-up data were collected, including procedure-related complications, first-day and first-month VAS scores, and the evaluation of the efficacy and safety of the ablation procedures. Technical success was defined as the precise placement of the RFA probe or MWA antenna, confirmed by CT, with its distal tip completely traversing the nidus and extending beyond the lesion. Clinical success was characterized by pain relief (VAS score ≤3) and the ability to fully resume daily activities without the need for medication. Minor complications were classified as those not leading to permanent effects, whereas major complications were defined as events requiring prolonged hospitalization or resulting in permanent sequelae. The cohort and subgroups were analyzed for VAS scores recorded pre-procedure, on the first day post-procedure, and at the first-month follow-up. Additionally, technical success, clinical success, and complications were systematically assessed across the entire cohort.

Ethical Approval, Informed Consent, and Permissions

Permission was obtained from Pamukkale University Non-Interventional Clinical Research Ethics Committee for the study (permission date: January 21, 2025, permission number: E-60116787-020-643270).

Statistical Analysis

Statistical analyses were performed using SPSS (SPSS Inc., Chicago, IL, USA) version 22. Continuous variables were expressed as mean ± standard deviation along with minimum and maximum values, while categorical variables were presented as frequencies and percentages (%). The Shapiro-Wilk test was used to assess the normality of data distribution. For non-normally distributed data, the Wilcoxon signed-rank test was applied for comparisons within dependent groups, whereas the Mann-Whitney U test was used for comparisons between independent groups. A p-value <0.05 was considered statistically significant.

Results

This retrospective study includes 19 patients who underwent CT-guided percutaneous RFA or MWA for OO at our clinic between October 2018 and December 2024. The cohort was divided into two subgroups based on age: <12 years (n=6) and ≥12 years (n=13).

The mean age of the patients was 13.58 ± 4.83 years, ranging from 3 to 20 years. Males accounted for 63.2% (n=12) of the cohort, while females comprised 36.8% (n=7). The most common lesion site was the right proximal diaphysis of the femur (3 patients, 15.8%), followed by the left proximal diaphysis of the tibia (2 patients, 10.5%). Lesions in other locations were observed at a frequency of 5.3% each. The mean nidus diameter was 4.57 ± 0.95 mm, ranging from 1.9 to 6.1 mm (Table 1).

Table 1. Patient demographic features and clinical data

Variables		n	%
Gender	Female	7	36.80
	Male	12	63.20
Bone location of nidus	Femur	11	57.89
	Tibia	6	31.58
	Humerus	1	5.26
	İliac	1	5.26
Depth of nidus	Cortical	18	94.74
	Intramedullary	1	5.26
Procedures	RFA	12	63.15
	MWA	7	36.85
Technical success (%)	RFA	100	100
	MWA	100	100
Clinical success (%)	RFA	91.66	91.66
	MWA	100	100
Complications (minor and major)	RFA	2 minors	10.53
	MWA	1 major	5.26

Shapiro-Wilk test

Pain levels were assessed using VAS at three time points: pre-procedure, first day post-procedure, and first-month follow-up. These evaluations were conducted for both the entire cohort and the defined subgroups.

In the cohort, the mean pre-procedure VAS score was 8.32 ± 0.96 (range: 7–10). On the first day post-procedure, the mean VAS score significantly decreased to 1.11 ± 1.17 (range: 0–5) and further declined to 0.37 ± 0.72 (range: 0–3) at the first-month follow-up. A statistically significant difference was found between the pre-procedure VAS scores and those recorded on the first day post-procedure (p = 0.00000381, Wilcoxon signed-rank test). Similarly, the difference between pre-procedure and first-month follow-up VAS scores was also statistically significant (p = 0.00000381, Wilcoxon signed-rank test). Additionally, a significant reduction in pain levels was observed between the first day post-procedure and the first-month follow-up (p = 0.0018, Wilcoxon signed-rank test) (Table 2).

Table 2. Pre- and post-procedural VAS scores in the cohort and ptaient demographics of nidus diameters

Variables		n	Average	Range	SD
Age (Years)		19	13.60	3-20	4.83
Nidus Size (mm)		19	4.68	1.90-6.10	0.95
VAS Scores	Pre-Procedure	19	8.32	7-10	0.96
	Post-Procedure First Day	19	1.11	0-5	1.17
	Post- Procedure First Month	19	0.37	0-3	0.72

Shapiro-Wilk test, Wilcoxon signed-rank

In the <12-year-old group, the mean pre-procedure VAS score was 9.83 ± 0.41, which decreased to 1.33 ± 1.03 on the first day post-procedure and further declined to 0.50 ± 0.76 at the one-month follow-up. For patients aged ≥12 years, the mean pre-procedure VAS score was 7.54 ± 0.66, which decreased to 0.92 ± 1.19 on the first day post-procedure and further dropped to 0.31 ± 0.63 at the first-month follow-up. A comparative analysis of the subgroups revealed a statistically significant difference in the change in VAS scores between the first day post-procedure and the first-month follow-up, with the <12-year-old group showing a greater reduction in pain compared to the ≥12-year-old group (p = 0.0058, Mann-Whitney U test). In the ≥12-year-old group, a statistically significant difference was also observed between the first day post-procedure and the first-month follow-up, suggesting a continued improvement in pain levels (p = 0.007, Mann-Whitney U test). However, in the <12-year-old group, the difference between the first day post-procedure and the first-month follow-up was not statistically significant (p = 0.081, Mann-Whitney U test) [Table 3]. In both age groups, there were statistically significant differences in VAS scores between pre-procedure, first day post-procedure, and first-month follow-up, indicating that the procedure had a significant impact on pain levels.

Table 3. Analysis of pre- and post-procedure VAS scores between children and adolescent groups and comparison of p-values

Age Groups	VAS Scores			P Values		
	Pre-procedure	Post-day 1	Post-month 1	Pre-procedure vs post-day 1	Pre-procedure vs post-month 1	Post-day 1 vs post-month 1
<12 years	9.83 ± 0.41	1.33 ± 1.03	0.50 ± 0.76	0.006	0.007	0.081
≥12 years	7.54 ± 0.66	0.92 ± 1.19	0.31 ± 0.63	0.0001	0.0001	0.007

Mann-Whitney U test

In all CT-guided procedures performed in the cohort, technical success, defined as the accurate central placement of the probe within the nidus, was achieved in 100% of cases. At the first-month follow-up, clinical success, characterized by a post-procedure VAS score of ≤3, was observed in 95% of cases. The average time to return to daily activities was one day. Regarding complications, minor complications such as skin redness and itching were reported in 2 patients (10.5%), while a major complication occurred in 1 patient (5.3%), presenting as a skin burn at the procedure site, which required hospitalization.

Discussion

OO, accounting for 11–14% of all benign bone tumors, was first described by Henry L. Jaffe in 1935 (8). OO is a benign and painful lesion, representing approximately 3% of primary bone tumors, predominantly affecting individuals aged 5–25 years and most commonly involving the long bones of the lower extremities. The most frequent form, cortical OO, consists of a central nidus surrounded by a prominent sclerotic bone rim. Despite its small size, it causes characteristic pain, which is exacerbated at night and responds well to ASA and NSAIDs [1- 4].

Until 1992, surgery was the only treatment option for osteoid osteoma. However, following experimental studies on animal models in 1989, Rosenthal et al. published a groundbreaking study, demonstrating for the first time that RFA was a safe and effective alternative to surgery in the treatment of OO in humans [3,5]. Since this pivotal study, extensive research and multiple datasets have confirmed the effectiveness of RFA as a gold-standard PTA treatment for OO [6]. In recent years, MWA has also gained attention as an alternative technique. This study contributes to the growing body of literature by evaluating the outcomes of CT-guided percutaneous thermal ablation procedures, including RFA and MWA, in a cohort of 19 patients with OO at various skeletal locations.

This study demonstrates that PTA techniques are highly effective for treating OO, achieving a 100% technical success rate and a 95% clinical success rate. Specifically, the observed technical and clinical success rates in our study were 100% and 91.66% for RFA, and 100% and 100% for MWA, respectively. A meta-analysis by Shanmugasundaram et al. reported a similar clinical success rate for MWA in 44 patients, although their technical success rate was lower compared to our findings. Similarly, in the same meta-analysis, the technical and clinical success rates for RFA in 1,133 patients were slightly lower but comparable to our study results [7]. A systematic review by Su et al. reported technical and clinical success rates for both RFA and MWA, consistent with our findings [8]. A recent study by Mutlu et al., which included 59 patients treated exclusively with MWA, reported technical and clinical success rates of 96.6% [9]. The slightly lower success rates for RFA compared to MWA in our study may be attributed to the limited sample size of only seven patients in the MWA group.

Our cohort consisted of 11 males and 8 females, with the youngest patient being 3 years old and the oldest 20 years old. To our knowledge, no previous study has specifically examined pre- and post-procedure VAS scores in children younger and older than 12 years. According to Jean Piaget's cognitive development theory (1952), children under 12 years are in the concrete operational stage, whereas adolescents aged 12 and older transition into the formal operational stage, allowing them to make more objective decisions, similar to adults. In contrast, children in the concrete operational stage tend to make more subjective judgments. In our study, the younger group (<12 years) had higher pre-procedure VAS scores, suggesting that children might exhibit greater subjectivity when reporting pain levels before the procedure. However, the post-procedure VAS scores reached similar levels in both age groups, indicating that the subjectivity in pain assessment diminished once the pain-free period was achieved.

In our study, two minor and one major complication were identified, with a minor complication rate of 10.53% and a major complication rate of 5.26%. Minor complications included transient redness and itching at the procedure site following RFA. The major complication, observed after MWA, was a second-degree skin burn at the procedure site, requiring hospitalization. In this case, a secondary infection developed at the burn site one week after the procedure, leading to hospital admission. The treatment involved intravenous antibiotics and wound debridement, ultimately resulting in healing with mild residual scarring. A similar complication was reported by Reis et al., while Mutlu et al. recently recommended percutaneous hydrodissection with 0.9% sodium chloride solution as an effective approach for managing such complications [9,10]. The percutaneous hydrodissection technique may serve as an important strategy for reducing complications in future procedures. Overall, the minor and major complication rates associated with PTA techniques in our study are consistent with those reported in the literature.

This study evaluates the efficacy, safety, and feasibility of CT-guided PTA techniques in the treatment of OO. Our findings demonstrate that these minimally invasive techniques achieve high technical and clinical success rates. In our study, the clinical success rate of RFA was found to be 91.66%, while MWA achieved a 100% success rate. The superior success rate of MWA may be attributed to its ability to reach higher temperatures and create a larger ablation zone. Notably, the significant reduction in post-procedure VAS scores and the rapid recovery times provide strong evidence supporting ablation techniques as an effective treatment option for OO. While RFA remains the gold-standard PTA technique for OO, the increasing use of MWA suggests that it may become more widely incorporated into future treatment guidelines.

Limitations

Our study has several limitations. The retrospective and single-center nature of the study may limit the generalizability of our findings. One of the most significant limitations of our study is the small sample size. This single-center study, which includes a total of 19 patients, may not fully reflect the results that could be obtained in larger populations. Additionally, the heterogeneous distribution of age groups within our study population adds complexity to the analysis process. Lastly, although we observed a statistically significant difference in pre-procedure VAS scores between children and adolescents, the lack of supporting data in existing literature remains a major limitation.

Conclusion

Our study demonstrates that CT-guided PTA techniques, including RFA and MWA, are safe, effective, and minimally invasive treatment options for osteoid osteoma. These techniques have achieved high technical and clinical success rates in pediatric and adolescent populations, leading to a significant reduction in pain levels and rapid recovery from the first post-procedure day. In conclusion, our findings support the use of thermal ablation techniques as a first-line treatment option for OO. While our study contributes valuable insights to the growing body of literature, the retrospective study design necessitates further validation and expansion of the results. Therefore, larger, multi-center, prospective randomized studies are required to confirm and extend our findings.

Conflict of interest: No conflict of interest was declared by the authors.

Author Contributions	Author Initials
SCD Study Conception and Design	HSA, KHA
AD Acquisition of Data	HSA, KHA, ANA
AID Analysis and Interpretation of Data	HSA, KHA
DM Drafting of Manuscript	HSA, KHA, ANA
CR Critical Revision	HSA, KHA, ANA

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