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Periapical healing after single-visit non-surgical endodontic retreatment in patients with hypertension: a retrospective study

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This retrospective observational study aimed to investigate whether controlled hypertension (HT) is associated with radiographic periapical healing after single-visit non-surgical endodontic retreatment (Re-RCT) compared with systemically healthy individuals. Two groups were formed according to predefined inclusion and exclusion criteria ($n = 22$). The HT group consisted of periapical radiographs from 22 teeth of 22 patients (mean age 53.31 ± 9.22 years; 10 females, 12 males) with no systemic diseases other than controlled HT, while the control group included 22 teeth of 22 systemically healthy patients (mean age 41.68 ± 12.13 years; 16 females, 6 males). All teeth were single-rooted mandibular premolar teeth with apical periodontitis that underwent single-visit Re-RCT and had a minimum radiographic follow-up of six months. Radiographic periapical status was evaluated using the Periapical Index (PAI), and lesions were additionally assessed by quantitative measurement of the periapical lesion size. Appropriate statistical tests, including multivariable logistic regression, were used to compare periapical healing and treatment success between the two groups and identify potential prognostic factors. The results demonstrated no statistically significant difference in radiographic periapical healing and re-RCT success between HT patients and healthy individuals ($p > 0.05$), whereas a smaller preoperative lesion size was associated with a higher probability of complete healing. These findings suggest that, under adequate medical control, HT alone does not adversely affect periapical healing after single-visit Re-RCT and contributes to a better understanding of the prognosis of Re-RCT in patients with controlled HT.

Keywords Hypertension, Periapical periodontitis, Treatment outcome, Root canal treatment, Root canal preparation

Systemic factors that may affect the healing of pulp or periapical lesions include cardiovascular diseases, hypertension (HT), diabetes, smoking, genetic factors, inherited coagulation disorders, impaired immune response, osteoporosis, alterations in bone turnover, vascularization, and changes in oxygen supply[1]. These systemic conditions have been reported to increase host susceptibility to infection and the frequency of apical periodontitis (AP), impair the immune response, and cause the inflammatory process and bone resorption to persist after root canal treatment[2]. Consequently, periapical healing may be delayed, resulting in persistent AP and potentially leading to treatment failure and even tooth extraction[3].

Cardiovascular diseases involve disorders of the heart and blood vessels, with the most common being HT and coronary heart disease. HT is a chronic medical condition characterized by elevated blood pressure in the arteries[1]. Current European guidelines[4] define arterial hypertension as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg based on repeated measurements, whereas the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guideline[5] adopts a lower diagnostic threshold of ≥ 130/80 mmHg, reflecting the growing evidence of the cardiovascular risk associated with mildly elevated blood pressure. HT is associated with alterations in bone metabolism, a decrease in bone mineral density, and impaired mineralization ability due to calcium loss in the bones[6]. In addition to its systemic effects, HT has been implicated in oral and endodontic pathologies. Messing et al.[7] reported a significant relationship between

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a history of HT and endodontic pathologies. Martins et al.[8] found that HT promotes greater osteoclastic differentiation, potentially affecting the outcomes of root canal treatment. Similarly, studies reporting an increased risk of extraction in root-filled teeth among hypertensive patients suggest that HT negatively impacts treatment outcomes[9]. Therefore, evaluating the treatment outcomes of teeth with AP in hypertensive patients is of clinical significance.

Persistent intraradicular infections, inadequate root canal obturation, missed canals, and procedural errors can lead to persistent AP[10]. In such cases, endodontic treatment may fail, and non-surgical endodontic retreatment (Re-RCT) is generally the preferred conservative treatment option[11]. Re-RCT can be completed in a single visit using enhanced irrigation methods and advances in endodontic technology, such as electronic apex locators, nickel-titanium (Ni-Ti) rotary instruments, and endodontic motors. Furthermore, single-visit endodontic treatment is gaining increasing acceptance due to its advantages such as reduced risk of reinfection between appointments, greater patient preference, and lower cost[12]. However, randomized controlled clinical studies have reported no significant differences in AP healing between single-visit and multiple-visit Re-RCT[13].

Previous investigations have explored the impact of systemic health on the outcomes of primary RCT. Segura-Egea et al.[1] demonstrated that systemic diseases, such as diabetes and cardiovascular disorders, may impair periapical healing by altering immune regulation, bone turnover, and vascularization. Similarly, Aminoshariae et al.[14] reported that while HIV infection and bisphosphonate therapy showed no apparent association with endodontic prognosis, diabetes and cardiovascular disease could adversely affect treatment outcomes, although the causal link remains unclear. Laukkanen et al.[15] further revealed that diabetes diminished the success of root canal treatment, particularly in teeth with preoperative AP, while cardiovascular disease had no significant effect; however, their analysis was confined to primary RCT cases. In contrast, the present study investigates the healing response of periapical tissues following single-visit Re-RCT in hypertensive patients, thereby addressing an underexplored area in endodontics.

Following our comprehensive literature review, this study is the first to evaluate AP healing following single-visit Re-RCT in hypertensive patients. Only one previous study reported that successful endodontic treatment within two years after Re-RCT and periapical surgery significantly reduced serum levels of cardiovascular disease biomarkers, such as C-reactive protein, asymmetric dimethylarginine, and matrix metalloproteinase-2[13]. This retrospective observational study aimed to investigate whether HT is associated with periapical healing after single-visit Re-RCT in comparison to systemically healthy individuals. The null hypothesis of this study was that there would be no statistically significant difference in post-treatment radiographic periapical healing between HT patients and systemically healthy individuals who had undergone single-visit Re-RCT.

Materials and methods

This retrospective study was written in accordance with the Preferred Reporting Items for Observational Studies in Endodontics (PROBE) 2023 guidelines[16]. Patient records from the Department of Endodontics, Faculty of Dentistry, Bolu Abant İzzet Baysal University, involving individuals diagnosed with AP who had previously undergone root canal treatment elsewhere but presented to our department due to treatment failure and subsequently received single-visit Re-RCT, were reviewed. Patients were categorized into two groups: systemically healthy individuals and patients diagnosed only with HT. However, these patients were evaluated using PAI scoring and lesion size based solely on periapical radiographs. Various methods were used to minimize loss to follow-up. Patients with preoperative, postoperative, and at least six-month follow-up periapical radiographs taken using the parallel technique were included. Patients who had their teeth extracted during the follow-up period, were diagnosed with vertical root fractures, or underwent Re-RCT in more than one visit after a minimum of six months were excluded. Additionally, patients with missing data were not included, ensuring all data used in this retrospective study were complete. All cases were selected by an experienced endodontist (MIA). The study's flowchart is presented in Fig. 1.

Ethical approval

This observational study is a single-center, retrospective study using digital periapical radiographs of patients collected from the archives of Bolu Abant İzzet Baysal University Faculty of Dentistry. All patients provided verbal and written informed consent. The study was reviewed and approved by the Ethics Committee for Non-Interventional Studies of Bolu Abant İzzet Baysal University, in accordance with the principles of the Declaration of Helsinki and the International Ethical Guidelines for Health-Related Research Involving Human Subjects (approval number: 2023 – 204).

Sample size calculation

To determine the required sample size, a power calculation was performed based on a previous study[17] with a similar design, and it was decided to include 22 teeth per group in the study (G*Power 3.1 software; Heinrich Heine University, Düsseldorf, Germany; with a = 0.05 and b = 0.80).

Inclusion criteria

- Teeth with single root and single canal and applied Re-RCT in single visit,
- Teeth with adequate technical quality root filling of up to 2 mm within the radiographic apex after Re-RCT,
- Teeth with adequate coronal restoration,
- Teeth with periapical lesion size less than 5 mm,
- Teeth with at least 6 months of follow-up with periapical radiography after Re-RCT,

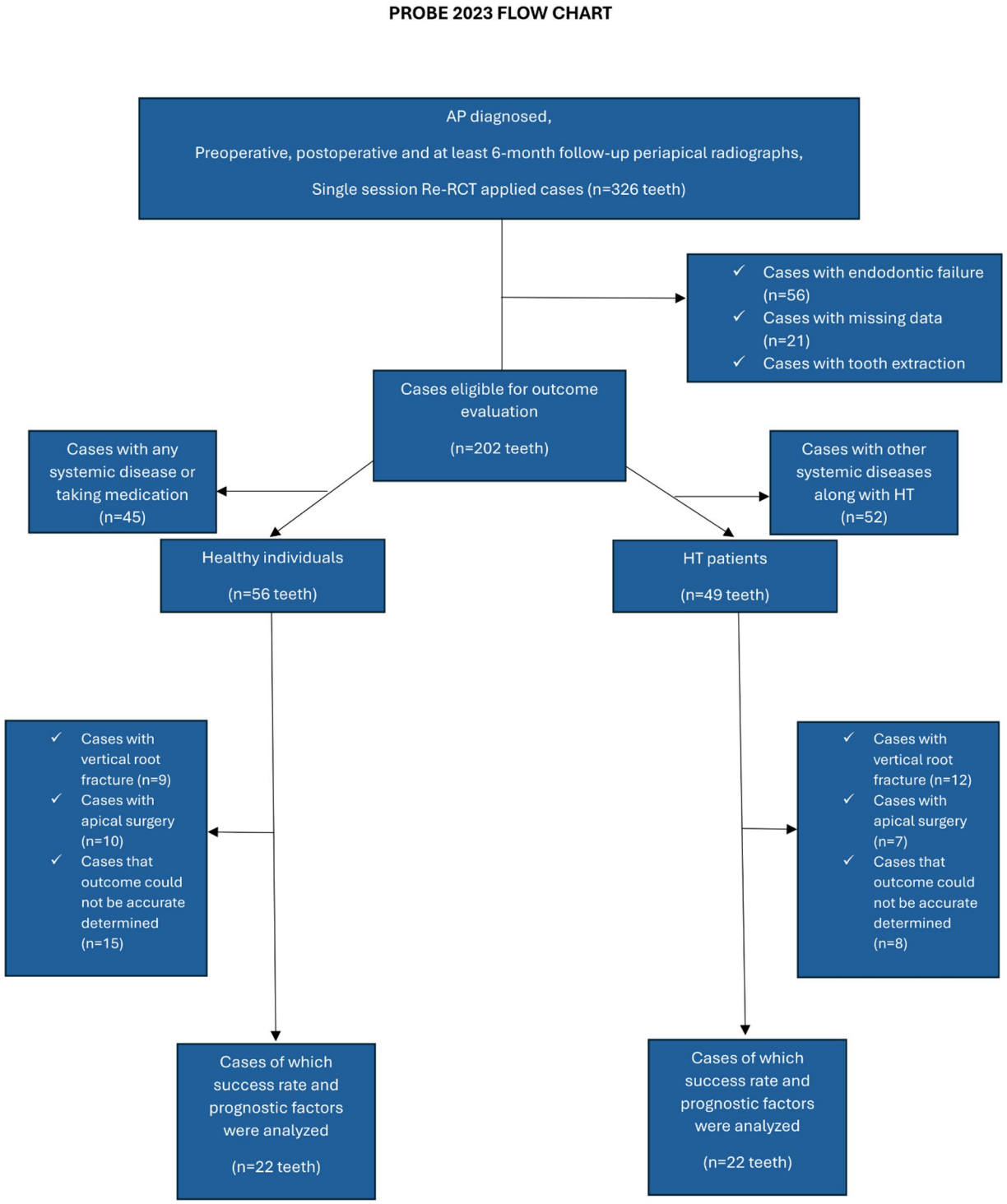

Fig. 1. Flowchart of this study.

- Mandibular teeth with pre- and post- Re-RCT standard periapical radiographs taken with the same intraoral x-ray device (Kodak 2100 230 V; Carestream Health Inc Rochester, New York, USA) and parallel technique with the same parameters (60 KVp, 6 mAs),
- Patients with the ages of 18–65,
- Patients without acute pain or extraoral swelling,
- Patients without sinus tract and acute apical abscess.

Exclusion criteria

- Teeth with artifacts, superimpositions or image distortion in the relevant area on the periapical radiograph,
- Teeth with instrument fracture and calsified root canal after Re-RCT,
- Teeth with periapical lesion size greater than 5 mm,
- Teeth with internal or external root resorption,
- Teeth with vertical root fracture or open apex,
- Patients with acute pain and therefore using analgesic medication in the last 24 h,
- Patients who had used antibiotics within two weeks prior to treatment.

Two study groups were formed from patients meeting the inclusion criteria:

1. HT group: Periapical radiographs of a total of 22 teeth of 22 patients (53.31 ± 9.22 years old, 10 females, 12 males) who did not have any systemic disease other than controlled HT were included. HT diagnosis for all patients was based on the documented evaluation of an internal medicine or cardiology specialist, and each patient had been on regular antihypertensive therapy for at least one year using either an angiotensin receptor blocker (ARB) or an angiotensin-converting enzyme inhibitor (ACE inhibitor). These patients were not taking any medications affecting bone metabolism; therefore, individuals using antihypertensive agents known to have minimal effects on bone turnover (such as calcium channel blockers, beta blockers, or diuretics) were excluded[18]. All hypertensive patients had stable blood pressure (below 140/90 mmHg) at the preoperative clinical assessment, were non-obese, non-smokers, had no kidney disease, and were regularly monitored for hypertension.
2. Control group: Periapical radiographs of a total of 22 teeth of 22 patients (41.68 ± 12.13 years old, 16 females, 6 males) without systemic disease were included.

Re-RCT procedure

Before starting the treatment, all patients were given a detailed verbal explanation about the treatment and informed consent forms were obtained from the patients. All cases were created from teeth treated by the same endodontist (TDÇ) and with the same protocol listed below. After anesthesia (Ultracain DS Ampoule; Sanofi Aventis, Istanbul, Turkey) was applied to the relevant teeth of the patients, rubber dam isolation was performed. The access cavity was prepared by removing the existing decay and filling material from the teeth. Root canal fillings were removed using retreatment rotary files (ProTaper Retreatment, Dentsply Sirona, Ballaigues, Switzerland) with an endodontic motor (WDV Gold, VDW, Munich, Germany). The working length was determined using a #15 K-type hand file (Dentsply) and an electronic apex locator (Woodpecker DTE III; Guangxi, China). Root canal preparation was completed using ProTaper Next files (Dentsply Sirona, Ballaigues, Switzerland). The final preparation size was determined specifically for each root canal based on the initial canal size. The canals were irrigated with 2 mL of 2.5% NaOCl (Mikrovem, Istanbul, Türkiye) at each file change. The final irrigation was performed using 5 mL 17% EDTA (Imicryl, Konya, Turkey), 5 mL distilled water and 5 mL 2.5% NaOCl (Microvem), respectively. A 30-G side-venting needle (NaviTip; Ultradent, South Jordan, UT, USA) was used in all irrigation procedures. The root canals were dried using sterile paper points. The root canals were filled with gutta-percha cones (Dentsply Maillefer) and epoxy resin-based root canal sealer (AH Plus; Dentsply, Konstanz, Germany) using the cold lateral compaction technique. At the same visit, coronal restoration was completed using a one-stage self-etch adhesive, G-Premio Bond (GC Corporation, Tokyo, Japan), and composite (3 M ESPE, Seefeld, Germany).

Outcome assessments

Healing was defined exclusively by radiographic Periapical Index (PAI) scores; clinical symptoms (pain, tenderness, and swelling) were not analyzed. The periapical conditions of the patients who were followed for at least 6 months before and after Re-RCT were scored using the PAI, a 5-step scoring system, based on periapical radiographs of the relevant teeth[19]. When the radiographs were examined, written instructions and reference radiographs were available. PAI scoring was performed by two independent endodontist observers (MIA and TDÇ) for each group. In cases where there was a difference between the scores of two observers, a compromise was reached by calculating the correlation coefficients for inter-observer and intra-observer reliability (0.854 and 0.802, respectively).

The results at Re-RCT and follow-up examination were defined as follows:

Healthy periapical tissues (PAI score 1–2).

Healing: Apical radiolucency is significantly smaller on the follow-up radiograph than on the pre-Re-RCT periapical radiograph.

No improvement: Cases in which the periapical radiolucency is the same (PAI score 3–5), due to endodontic reasons (ongoing apical infection, fistula) or in cases where the periapical radiolucency has not completely disappeared after 4 years.

Worsened: The periapical radiolucency has widened, or a new periapical radiolucency has appeared (PAI score 3–5).

Treatment results were classified as healed/successful (PAI < 3) or nonhealing/failed (PAI ≥ 3) according to periapical radiographic criteria. The success rate was defined as the percentage of cases with successful outcomes.

In addition to the categorical PAI assessment, quantitative measurements of periapical lesion dimensions were performed on digital periapical radiographs taken preoperatively and at follow-up visits. Lesion size was measured in millimeters as the largest linear radiolucent diameter on digital images using the calibrated ImageJ software (National Institutes of Health, Bethesda, MD, USA) with a precision of 0.01 mm. For each lesion, three independent linear measurements were obtained at different orientations (vertical, horizontal, and oblique axes) across the widest radiolucent area, and the mean of these three measurements was calculated to represent the final lesion dimension.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics v23 (IBM Corp., Armonk, NY, USA) software. First, the Shapiro-Wilk normality test was conducted for continuous data. Data with normal distributions are reported as means ± standard deviation (means ± SD), and the Student's t-test was used to compare differences between the two groups. Data with a non-normal distribution are reported as median and interquartile range, and the Mann-Whitney U test was applied to compare differences between the two groups. The effect size for the Wilcoxon signed-rank test to assess preoperative lesion size, postoperative lesion size, and change in lesion size over time was calculated. The association between two categorical variables was assessed using Pearson's chi-squared test or Fisher's exact test. Logistic regression analysis was performed to detect the risk factors of radiographic evaluation results (healed or not healed). Receiver operating characteristic (ROC) curves were plotted and statistical indexes, such as area under the curve (AUC), sensitivity and specificity, were calculated. The percentage of healed patients was estimated using the Kaplan-Meier method, and the log-rank statistic was used for comparison. $P < 0.05$ was considered to be statistically significant.

Results

An examination of the data obtained in the current study revealed that the HT group (Median: 40.00) was older than the control group (Median: 50.50) ($p < 0.001$). The gender distribution of the study groups was similar ($p = 0.066$). There was no difference between the control and HT groups in terms of the follow-up period ($p = 0.282$). The preoperative lesion size, postoperative lesion size, and the magnitude of lesion size reduction were similar between the groups (preoperative lesion size: $t = 0.67$, $p = 0.504$; postoperative lesion size: $Z = 0.18$, $p = 0.860$; change in lesion size: $t = 0.27$, $p = 0.790$) (Fig. 2). In the control and HT groups, lesion size decreased significantly over time (Wilcoxon signed-rank test; control group: Z=-3.496, $p < 0.001$, $r = 0.75$; HT group: Z=-3.825, $p < 0.001$, $r = 0.82$). A significant decrease in the apical lesion size of the teeth included in the study was observed at all follow-up time points. These findings confirm that both HT patients and systemically healthy individuals demonstrated significant radiographic reductions in periapical lesion dimensions over time, with no intergroup differences observed. The relevant analyses are presented in Table 1.

The preoperative PAI values (3, 4, and 5) were distributed at similar rates in the control and HT groups ($p = 0.330$). Similarly, postoperative PAI values (1, 2, 3, and 4) were also at similar rates in both groups ($p = 0.880$, Table 2).

The number of patients without improvement in PAI values after single visit Re-RCT was determined as 3 (13.64%) in the control group and 2 (9.09%) in the HT group. There was no significant difference in recovery rates between male and female patients in either group (control group: $p = 1.000$; HT group: $p = 0.195$; Table 3).

As a result of the logistic regression analysis conducted to identify factors affecting the outcome of radiological evaluation, it was found that preoperative lesion size had a significant effect, and that as the size increased, the risk of non-healing in patients also increased ($p = 0.025$). It was determined that the variables of age, gender, follow-up period, and HT examined had no significant effect on patients' radiological evaluation outcomes ($p > 0.05$, Table 4).

It was observed that, in distinguishing between patients who recovered and those who did not after single visit Re-RCT, lesion size yielded a highly successful result with an AUC of 0.908 (95% CI: 0.817–0.998) ($p = 0.003$). According to the determined cutoff value of 5.325 for lesion size, sensitivity was calculated as 1.000 and specificity as 0.872 (Fig. 3). In the Kaplan-Meier analysis, the probability of recovery after surgery was found to be significantly higher in patients with a lesion size < 5.325 after the 12th month (Log-Rank: $p < 0.001$, Fig. 3).

Discussion

Primary/secondary root canal treatment is the first choice in AP treatment[20]. In the healing process of root canal treated teeth, the systemic health status of the patient is also an important factor, as well as many factors such as control of infectious processes of the pulp and unforeseen situations related to the periapical tissue. There is a significant relationship between endodontic pathology and cardiovascular diseases and their risk factors, especially HT[7]. Considering the high prevalence of HT, root canal treatment is quite common in these patients[20]. In cases where Re-RCT is not indicated, surgical endodontic treatment can also be applied in the treatment of AP. However, it has been reported that blood calcium levels increase in HT patients and bone mineral density in the body decreases accordingly[6]. AP is mainly associated with inflammatory processes caused by microorganisms and existing pathologies can be exacerbated by a systemic condition such as HT, which may contribute to delayed bone healing[21]. Therefore, Re-RCT was preferred as the first treatment option in this study. In the current literature, no study has been found comparing PAI results after a single visit of Re-RCT in HT patients with systemically healthy individuals. In this study, it was determined that there was no difference between the healing status of periapical tissues and treatment success after Re-RCT applied in a single visit between HT patients and systemically healthy individuals, and the null hypothesis was accepted.

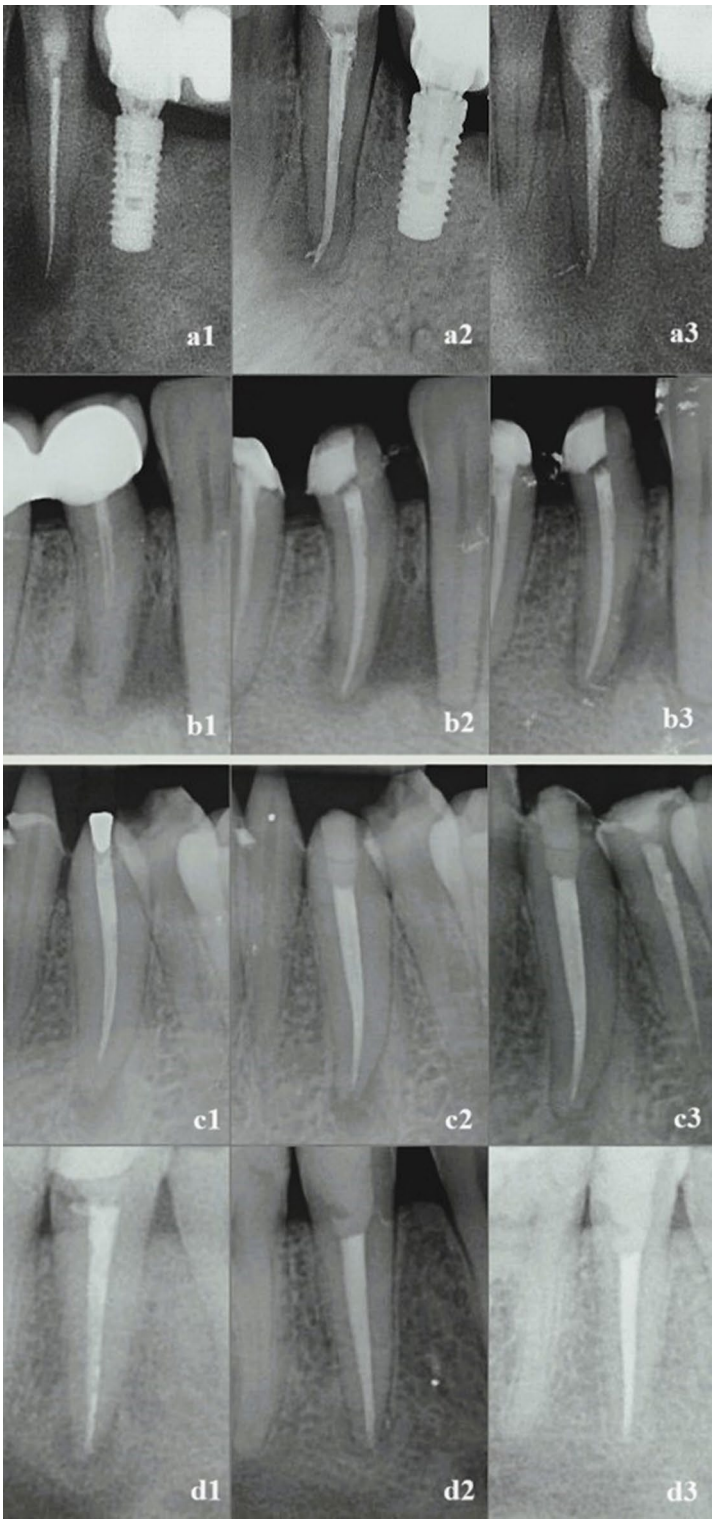

Fig. 2. (**a,b**) Radiographic follow-up of periapical status before and after Re-RCT in HT patients; (**a1**) preoperative, (**a2**) postoperative, (**a3**) 12 months follow-up after Re-RCT, (**b1**) preoperative, (**b2**) postoperative, b3). 7 months follow-up after Re-RCT. (**c,d**) Radiographic follow-up of periapical status before and after Re-RCT in healthy individuals (**c,d**) (**c1**) preoperative, (**c2**) postoperative, (**c3**) 12 months follow-up after Re-RCT, (**d1**) preoperative, (**d2**) postoperative, (**d3**) 18 months follow-up after Re-RCT.

	Control (*n*=22)	HT (*n*=22)	Test statistic	*P* Value
Age (years)			Z=3.49	<0.001
Mean±SD	41.68±12.14	53.32±9.23		
Med (IQR)	40.00 (34.50-50.25)	50.50 (45.00-63.25)		
Gender, n (%)			X^2=3.39	0.066
Female	16 (72.73)	10 (45.45)		
Male	6 (27.27)	12 (54.55)		
Follow-up period (months)			Z=1.07	0.282
Mean±SD	21.59±13.33	17.45±8.08		
Med (IQR)	15 (12-36)	14 (12-24)		
Preoperative lesion size			t=0.67	0.504
Mean±SD	4.64±0.7	4.47±0.96		
Med (IQR)	4.81 (3.98-5.25)	4.38 (3.86-5.33)		
Postoperative lesion size			Z=0.18	0.860
Mean±SD	1.07±1.6	0.98±1.03		
Med (IQR)	0.62 (0.47-1.05)	0.61 (0.43-1.1)		
Change of lesion size			t=0.27	0.790
Mean±SD	3.57±1.02	3.49±0.91		
Med (IQR)	3.78 (3.07-4.27)	3.62 (2.84-4)		

Table 1. It shows the distribution of the general characteristics of the patients included in the study according to groups. Z: Mann-Whitney U test, t: Student's t-test, X^2: Pearson's Chi-squared test, SD: standard deviation, n: number of cases, %: percentage data.

	Control	HT	X^2	*P* Value
Preoperative PAI			2.43	0.330
PAI - 3	4 (18.18)	5 (22.73)		
PAI - 4	5 (22.73)	9 (40.91)		
PAI - 5	13 (59.09)	8 (36.36)		
Postoperative PAI			1.60	0.880
PAI - 1	16 (72.3)	15 (68.18)		
PAI - 2	3 (13.64)	5 (22.73)		
PAI - 3	1 (4.55)	0 (0)		
PAI - 4	2 (9.09)	2 (9.09)		

Table 2. It shows the preoperative and postoperative PAI values according to the control and HT groups. Fisher's exact test.

			Gender		
Groups	Radiographic evaluation	n (%)	Female	Male	P Value
Control	Healed	19 (86.36)	14 (87.5)	5 (83.33)	1.000
	Not healed	3 (13.64)	2 (12.5)	1 (16.67)	
HT	Healed	20 (90.91)	8 (80)	12 (100)	0.195
	Not healed	2 (9.09)	2 (20)	0 (0)	

Table 3. It shows the change in PAI values over time according to gender in control and HT groups. Fisher's exact test, %: percentage data.

Information regarding the connection between HT and AP in the literature is limited and contradictory. A systematic review and meta-analysis study reported no difference in the prevalence of AP between HT patients and systemically healthy individuals, but hypertensive patients had an increased likelihood of losing root canal-treated teeth[20]. Additionally, Wang et al.[9] reported that the frequency of root canal-treated teeth remaining in the mouth in HT patients decreased 2 years after root canal treatment. These studies cannot be directly compared to the current study because they focused solely on the survival of root canal-treated teeth, ignoring periapical healing. However, high blood pressure has been associated with AP severity. It was reported that the bone resorption areas in experimentally created AP in hypertensive rats were larger radiographically than in the

	OR	95% CI	*P* value
Age	0.92	0.84 – 1.01	0.070
Gender - Male	0.32	0.03 – 3.17	0.332
Follow-up period (month)	0.91	0.77 – 1.06	0.225
Preoperative lesion size	32.73	1.55 – 693.03	0.025
Groups - HT	0.63	0.09 – 4.22	0.637

Table 4. It shows the logistic regression analysis for radiographic evaluation results. OR: odds ratios. CI: confidence interval. Gender: female, Groups: control was chosen as the reference group.

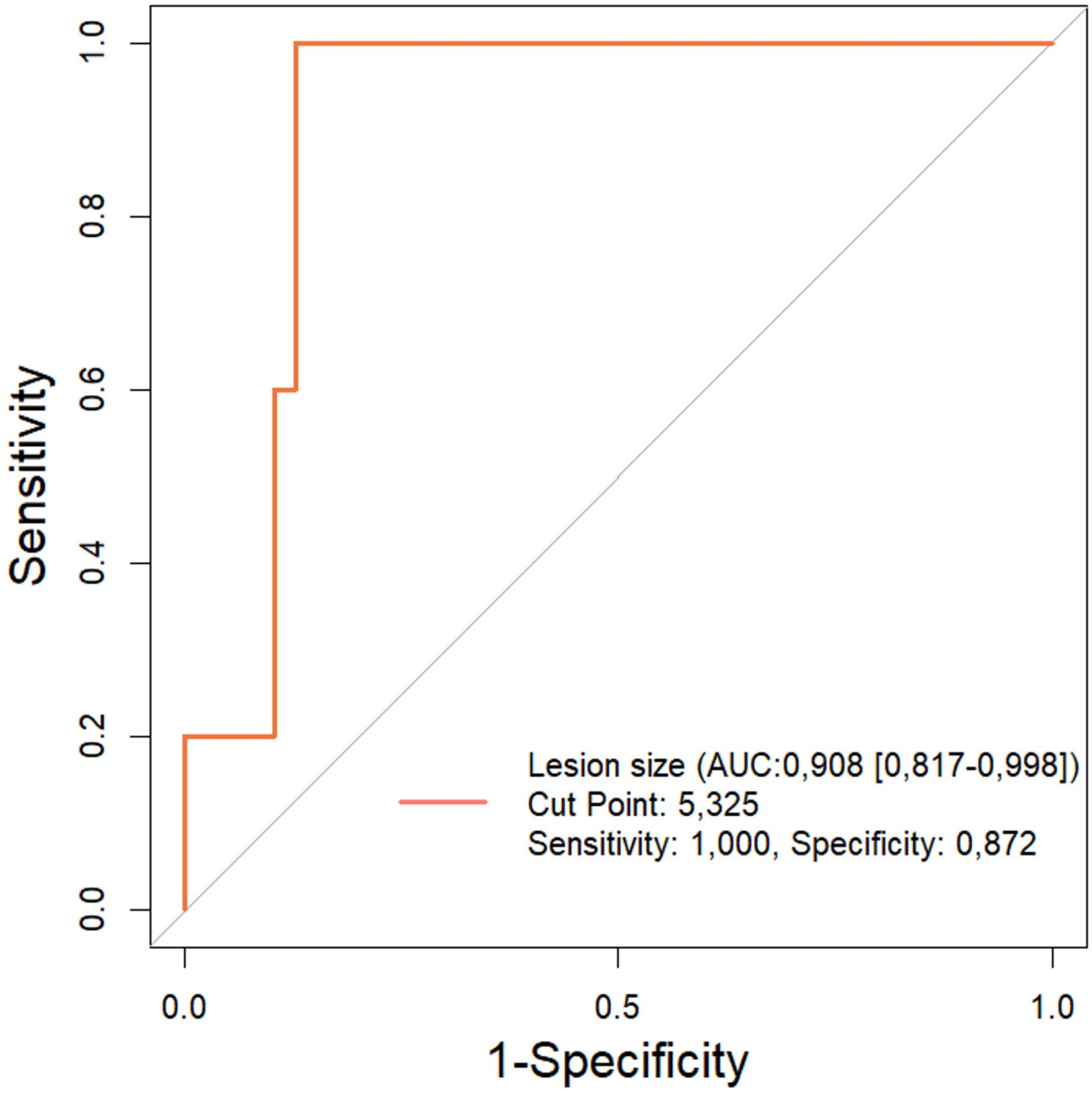

Fig. 3. ROC curve for lesion size.

control group. Although most published studies find a positive correlation between AP and HT, the quality of available evidence is low and the causal relationship has not been conclusively established[22].

When the long-term results of endodontic treatment are evaluated, the relevant tooth type and complex root canal anatomy affect the study results. It is reported in the literature that the complex root canal anatomy of multi-rooted teeth reduces the success of treatment[20]. Therefore, single-rooted and single-canal mandibular teeth were included in our study to prevent the study results from being affected by the tooth type.

In the past, endodontic treatment was completed in a single visit owing to the use of NiTi rotary files, routine use of rubber dam isolation, and effective intracanal disinfection with irrigation activation techniques[23]. Hargreaves[24] reported that endodontic treatment completed in a single visit is more effective than multiple visits. It has been reported in the literature that endodontic treatment can be completed in a single visit by effectively irrigating the root canals and then filling them in a three-dimensional sealed obturation[25]. Therefore, in our study, endodontic treatment of single-rooted and single-canal mandibular teeth with AP was completed in a single visit.

According to the results of our study, there was no difference in the distribution of PAI values before and after the procedure in the control and HT groups. Studies evaluating the outcomes of endodontic treatment have determined that the presence of preoperative radiolucency and the size of the periapical lesion are important factors affecting the success of endodontic treatment[23]. This finding is consistent with the results of our study. The logistic regression analysis performed to identify the factors influencing the radiological assessment in the current study revealed that the size of the preoperative lesion had a significant effect, and as the lesion size increased, the risk of non-healing in patients also increased. Therefore, attention was paid to ensuring that the preoperative lesion sizes of the patients included in the study were similar.

Periapical lesions are routinely monitored using intraoral periapical radiographs. In order for the bone healing to be visible radiographically in the periapical lesion after root canal treatment, a minimum of 6 months must pass after the treatment[26]. Therefore, teeth with a minimum 6-month follow-up periapical radiographs were included in the current study. However, the use of periapical radiography to evaluate periapical status in this study is a limitation. Periapical and panoramic radiographs have limitations, such as anatomical and geometric distortion, which may prevent the accurate detection of periapical lesions within the cancellous bone, especially when the buccal cortical bone is thick[27]. Additionally, bone resorption may not be observed in the early period, which may affect the study results. To overcome these drawbacks, future studies should use advanced radiographic techniques, such as cone-beam computed tomography or micro-computed tomography, which we believe will provide greater accuracy in diagnosing AP and measuring lesionvolume.

In studies evaluating the endodontic treatment outcomes of patients who have undergone Re-RCT, it has been reported that demographic data such as age and gender of the included patients may affect the study results[28]. Therefore, only patients between the ages of 18 and 65 were included in the present study, and no differences were found between the groups in terms of gender distribution. However, analyses revealed that the hypertension patient group was older than the control group. Nevertheless, it was determined that the examined variables of age, gender, follow-up period, and hypertension did not have a significant effect on the patients' radiological evaluation results. Similarly, in a recent study by Barakat et al.[29], multivariate logistic regression analysis showed that the most important factors affecting success were the preoperative PAI score, obturation, and quality of coronal restoration, whereas patient-related variables such as age, systemic condition, and oral hygiene were not significant. The inconsistencies reported among studies are likely due to differences in the demographic and systemic characteristics of the patient populations studied, variations in clinical treatment protocols and follow-up periods, and differences in the prognostic variables assessed and the methodological/statistical approaches used.

In this study, postoperative PAI values decreased compared to the beginning after Re-RCT performed in a single visit in both the control and HT groups. This result shows that there was an improvement in periapical lesions in both groups. Since no study in the literature has evaluated the condition of periapical tissues after Re-RCT performed in a single visit in HT patients and healthy individuals, the results could not be directly compared with another study. Contrary to our study findings, Wang et al.[9] has been reported that the survival rate of involved teeth decreases after endodontic treatment in HT patients. As a result of our study, Re-RCT success rate was observed as 86.3% in the control group, 90.9% in the HT group and 88.3% success rates in total in all follow-up periods. We believe that the initial success rates obtained in both the HT and control groups are due to the standardization of the chemomechanical preparation technique, application of rubber dam isolation, ensuring adequate intracanal disinfection with an effective irrigation protocol, and ensuring coronal and apical sealing, which play a role in the success of endodontic treatment.

In addition to the categorical PAI assessment, periapical lesion dimensions were quantitatively evaluated using serial radiographs obtained before Re-RCT and during follow-up. The significant reduction in lesion size in both groups ($p < 0.001$) indicated radiographic evidence of bone regeneration. Garrido et al.[30] similarly reported that apical lesion size and PAI scores decreased significantly after root canal treatment, concomitant with reductions in systemic inflammatory biomarkers, such as high-sensitivity C-reactive protein and its monomeric isoforms. This finding supports the concept that local periapical healing reflects systemic inflammatory modulation.

Segura-Egea et al.[1] emphasized that systemic disorders, including HT, diabetes mellitus, and osteoporosis, can modulate bone turnover and delay periapical repair. Similarly, Aydın et al.[31] observed that while PAI scores improved significantly in both diabetic and healthy patients, lesion shrinkage occurred more slowly in patients with diabetes, underscoring the influence of systemic metabolic control. In our study, however, both hypertensive and normotensive individuals showed comparable reductions in lesion dimensions ($p > 0.05$). This finding suggests that well-controlled HT does not negatively affect the rate or extent of periapical bone repair when optimal chemomechanical debridement and three-dimensional obturation are achieved. We found

that the mean lesion size decreased significantly in both groups from baseline to follow-up, with no intergroup difference, supporting the radiographic and biological equivalence of healing.

In the current study, there was no difference in Re-RCT success rate between groups. Since no study in the literature has evaluated the condition of periapical tissues after Re-RCT performed in a single visit in HT patients and healthy individuals, the results could not be directly compared with another study. In parallel with our study, Segura-Egea et al.[32] reported that the prevalence of AP and the outcome of root canal treatment in HT patients were not different when compared to the control group of healthy individuals. In contrast, Vidal et al.[33] reported that in a population of severely hypertensive patients, the presence of chronic AP was associated with higher levels of C-reactive protein, interleukin 6, and fibrinogen. These biological markers have been associated with bone resorption. Since the research results may be affected by demographic changes, it is thought that different results will be obtained[1]. These differences in study results may be due to factors such as age, gender, length of follow-up, and population. The findings obtained in this study may have occurred due to the similar decrease in the microorganism load in the root canals in both groups and the three-dimensional sealed root canal filling. We believe that the host immune response associated with the regulation of blood pressure in HT patients causes healing of periapical lesions, as in healthy individuals.

In this study, no differences were found in the healing of periapical lesions in men and women at all follow-up periods within and between groups. Similar to the findings of our study, Ng et al.[34] reported that there was no difference between men and women in terms of endodontic treatment success. Contrary to these findings Smith et al.[35] as a result of their retrospective study with five-year follow-up, they found that the success rate after endodontic treatment was higher in men. Differences in study results may occur depending on variables such as age, population, follow-up period, tooth type included in the study, preoperative lesion size, and treatment method applied.

The results of the multivariate logistic regression analysis conducted with the data from our study determined that age, gender, follow-up period, and the presence of HT had no significant effect on radiographic healing after single-visit Re-RCT. This finding is consistent with previous studies reporting that age and gender are not consistent prognostic factors for endodontic treatment success[29,36,37] and with reviews emphasizing that evidence regarding the effect of systemic diseases on endodontic treatment outcomes is limited and conflicting[32,38].

Similar inflammatory mediators are involved in both cardiovascular diseases and AP, and AP may contribute to systemic inflammatory burden. Clinical studies have reported that individuals with AP are 5.3 times more likely to develop cardiovascular disease than those without AP[39]. Similarly, in a cohort study[40] has been reported that individuals with incomplete root canal treatment have a higher risk of being hospitalized due to cardiovascular diseases. This indicates a bidirectional relationship between endodontic infection and HT and proves that systemic diseases can affect the pathogenesis of AP and that AP can also cause systemic consequences. More longitudinal studies are needed to evaluate the impact of primary root canal therapy and Re-RCT on systemic diseases and the impact of systemic diseases on periapical healing.

There are several points to consider when interpreting the findings of this study. First, the radiographic assessment was based on two-dimensional periapical radiographs rather than three-dimensional imaging techniques, such as cone-beam computed tomography. While this approach reflects routine clinical practice and a standardized exposure geometry was used, volumetric changes in lesion size due to variations in trabecular bone thickness may have been overlooked. Second, the study had a retrospective, single-center design and included only single-rooted mandibular premolars, which led to a relatively homogeneous but limited sample size. This may restrict the generalizability of the results to other tooth types and clinical settings of the study. Nevertheless, strict inclusion and exclusion criteria, the use of a standardized single-visit Re-RCT protocol, and a minimum follow-up period of 6 months for all cases strengthened the internal validity of the study. Finally, detailed information on systemic and host-related factors, such as long-term blood pressure control, inflammatory biomarkers, and broader cardiovascular risk profiles, was not available for all patients; therefore, these factors could not be fully included in the multivariate analyses. In addition, the cutoff point determined by ROC analysis is an exploratory finding specific to the lesion size and should be interpreted with caution due to the limited sample size and retrospective design; external validation in independent cohorts is required for clinicalgeneralizability. In the future, larger and more diverse populations, multicenter prospective studies, and the use of three-dimensional imaging techniques, along with comprehensive systemic data, will be necessary to validate and broaden these findings.

Conclusions

In this retrospective study, controlled HT did not adversely affect radiographic periapical healing following single-visit Re-RCT, with hypertensive and systemically healthy patients demonstrating similar healing rates and reductions in lesion size. Multivariate analysis indicated that HT and demographic variables were not associated with treatment outcomes, whereas larger preoperative lesions were associated with a greater likelihood of non-healing. Clinically, these findings suggest that predictable periapical repair can be achieved in patients with controlled HT when standardized chemomechanical preparation and high-quality obturation are performed, underscoring the importance of careful radiographic assessment of lesion size during treatment planning. Prospective studies with broader systemic evaluations and advanced imaging are needed to validate these observations.

Data availability

All data generated or analyzed during this study are included in this article.

Received: 1 October 2025; Accepted: 8 January 2026

Published online: 16 January 2026

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Author contributions

MIA & TDÇ: wrote the main manuscripts text, MIA: collected data and performed statistical analysis, prepared figures and tables, ZUA: designed the methodology and reviewed the main manuscripts text.

Declarations

Competing interests

The authors declare no competing interests.

Ethics statement

All patients provided verbal and written informed consent. The study was reviewed and approved by the Ethics Committee for Non-Interventional Studies of Bolu Abant İzzet Baysal University, in accordance with the principles of the Declaration of Helsinki and the International Ethical Guidelines for Health-Related Research Involving Human Subjects (approval number: 2023-204).

Additional information

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