# Clinical outcomes of non-surgical multiple-visit root canal retreatment: a retrospective cohort study

Olcay, Keziban ; Eyüboglu, Tan Fırat ; Özcan, Mutlu

Abstract: This study aimed to investigate the effects of several clinical factors on the success and survival rates of multiple-visit non-surgical root canal (NSRC) retreatment. Failed endodontically treated 236 teeth in 161 patients (18-72 years, 48% males; and 52% females) were retreated between March 2014 and December 2015 and were enrolled in this study. Two calibrated examiners evaluated the preoperative, intraoperative, and postoperative outcomes using the periapical index (PAI) scores. The teeth were classified as healed (healthy apical tissues, PAI  2, no signs or symptoms), healing (no signs and symptoms, PAI > 2 but reduced from the initial PAI score), and not-healed (presence of apical periodontitis, signs and/or symptoms, PAI > 2). The teeth scored as healed and healing was considered to be successful, while the not-healed ones were considered as failures. Of the 236 teeth, 135 (57.3%) in 103 patients (63.9%) were lost to follow-up, yielding to follow-up of 101 teeth (42.7%) in 58 patients (36%). Three teeth were extracted yielding to an overall success rate of 85.1%, at a mean observation time of 33.8 months. The teeth with periapical lesions < 5 mm had an 88.6% success rate, while those  5 mm had an 80% success rate (P > 0.05). While, age, gender, preoperative, intraoperative, and postoperative factors did not significantly affect the outcomes (P > 0.05), tooth type significantly affected the success rate (P < 0.05). The most frequently failed teeth were the mandibular first molars (P < 0.05). Based on these results, the multiple-visit NSRC retreatment exhibited a favorable success rate and could be offered for the endodontically failed teeth.

DOI: https://doi.org/10.1007/s10266-019-00426-6

**Clinical Outcomes of Non-surgical Multiple-visit Root Canal Retreatment:**

**A Retrospective Cohort Study**

**Keziban Olcay ● Tan Fırat Eyüboglu ● Mutlu Özcan**

Keziban Olcay (✉)

Istanbul Medipol University, Faculty of Dentistry, Department of Endodontics, Istanbul, Turkey

e-mail: kolcay@medipol.edu.tr

Tan Fırat Eyuboglu

Istanbul Medipol University, Faculty of Dentistry, Department of Endodontics, Istanbul, Turkey

Mutlu Özcan

University of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zürich, Switzerland

***Short title:*** *Outcomes of nonsurgical endodontic retreatment*

***Corresponding to:***

Dr. Keziban Olcay

Istanbul Medipol University

Faculty of Dentistry
Department of Endodontics
Atatürk Bulvarı, No: 27
34083 Unkapanı, Fatih
Istanbul, Turkey
Tel: +90 212 453 4800-4958
e-mail: kolcay@medipol.edu.tr

**Abstract:** This study aimed to investigate the effects of several clinical factors on the success and survival rates of multiple-visit non-surgical root canal (NSRC) retreatment. Failed endodontically treated 236 teeth in 161 patients (18 to 72 years, 48% males; and 52% females) were retreated between March 2014 and December 2015 and were enrolled in this study. Two calibrated examiners evaluated the preoperative, intraoperative, and postoperative outcomes using the periapical index (PAI) scores. The teeth were classified as healed (healthy apical tissues, PAI≤2, no signs or symptoms), healing (no signs and symptoms, PAI>2 but reduced from the initial PAI score), and not-healed (presence of apical periodontitis, signs and/or symptoms, PAI>2). The teeth scored as healed and healing were considered to be successful, while not-healed ones was considered as failures. Of the 236 teeth, 135 (57.3%) in 103 patients (63.9%) were lost to follow-up, yielding to follow up of 101 teeth (42.7%) in 58 patients (36%). Three teeth were extracted yielding to an overall success rate of 85.1%, at a mean observation time of 33.8 months. The teeth with periapical lesions <5 mm had an 88.6% success rate, while those ≥5 mm had an 80% success rate ($P>0.05$). While, age, gender, preoperative, intraoperative, and postoperative factors did not significantly affect the outcomes ($P >0.05$), tooth type significantly affected the success rate ($p<0.05$). The most frequently failed teeth were the mandibular first molars ($P<0.05$). Based on these results, the multiple-visit NSRC retreatment exhibited a favorable success rate and could be offered for the endodontically failed teeth.

**Keywords** Clinical trial ● Multiple-visit endodontic treatment ● Non-surgical retreatment ● Root canal therapy ● Success rate ● Survival rate

## Introduction

The main objectives of root canal treatment are cleaning and shaping of the root canal system, and filling it hermetically in order to prevent reinfection [1,2]. Although the success rate of root canal treatment was reported to range between 85 and 98% [3-5], failures may occur after treatment.

When primary root canal treatment is unsuccessful, non-surgical root canal (NSRC) retreatment is the first treatment option to eliminate infection [6]. NSRC retreatment is frequently preferred as it is the least invasive approach with favorable results [7,8]. However, NSRC retreatment success rates are lower than those of primary root canal treatment [9-11]. In the literature, the reported success rates of the NSRC retreatment shows a wide range between 62 to 91% [9,10,12-14]. Typically, the number of root canals, presence of preoperative symptoms, apical extrusion of the root canal filling, absence/deficiency of coronal restoration, intraoperative complications, and increased radiographic size of the periapical lesion may decrease the treatment success rate [6,10,11,15,16]. Among all factors, the main reason for the failure of root canal treatment is considered as microorganisms in the apical triad of the root canal system. This apical part of the root canal surface has been reported to remain untouched during chemo-mechanical preparation, regardless of the technique and instrument used [17,18] which contain necrotic tissues. The remaining bacteria in such tissues may cause long-term infections [17].

Composition of the microbiota that causes infection in root canal treated teeth is significantly different from the primary infections in the untreated teeth [19,20]. Additionally, microorganisms living in the form of biofilm in the untouched regions cannot be removed through contemporary root canal preparation, disinfection or filling methods [17,21]. Hence, the use of intracanal dressings is suggested between sessions due to its antimicrobial effect in the root canal system [22,23].

Accordingly, the objective of the present cohort study was to analyze the clinical and radiographic success of failed endodontic teeth treated in multiple sessions using NSRC retreatment retrospectively and report on the associated tooth survival during up to follow-up period of 3 years.

## Materials and methods

The research protocol of this study was approved by the Istanbul Medipol University, Ethical Board of Clinical Trials and Non-interventional Research (Approval Number: 171). Informed consent was obtained from all participants included in the study. All enrolled patients signed the written informed consent forms.

### Patient population

Patients involved on the study were referrals to the Department of Endodontics, Faculty of Dentistry, Istanbul Medipol University in Turkey for root canal retreatment between March 2014 and December 2015. The inclusion criteria were as follows: endodontically failed teeth requiring retreatment in adult patients, 18 to 80 years of age. Patients having vertical root fractures, teeth shaped or obturated with techniques other than the ProTaper Rotary System (Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply DeTrey GmbH, Konstanz, Germany), single-visit treatments, teeth treated less than 2 years, and teeth treated with surgical endodontic treatment were excluded from this study.

One hundred and sixty one patients who met the inclusion criteria were included in the study. For each patient, a form was filled out including the following information: Demographic information of the patient (age, gender), tooth type and time since retreatment (in months), preoperative signs and symptoms (preoperative pain status, periapical radiolucency, preoperative periapical index (PAI) score, periodontal status, history of previous endodontic surgery), intraoperative signs and symptoms (root canal filling length, root canal filling voids, complications, sealer extrusion), postoperative signs and symptoms (percussion/palpation discomfort, periapical radiolucency, postoperative PAI score, vertical root fracture, and presence/absence of fiber post), root canal filling density, coronal restoration quality, coronal restoration type.

### Retreatment protocol

Failed endodontically treated teeth (N=236) in 161 patients were retreated by one endodontist (K.O.) with 10 years of experience using a standardized treatment protocol. Panoramic films (Kodak 9000; Carestream

Health, Inc., Rochester, NY, USA) and periapical radiographs (Kodak RVG 5100; Carestream Health, Inc.) were used for the diagnosis of the endodontically failed teeth, using a parallel technique (RINN XCP-ORA, Dentsply Sirona, Konstanz, Germany) with an exposure time of 0.16 s and exposure dose of 1.22 mGy.

The standard procedure included infiltrative anesthesia for all of the teeth at the first appointment. The entire dose of anesthesia was administered using a 27 gauge, 2-inch dental needle (Set Inject; Set Medical Instruments, Istanbul, Turkey) with 1 ml of articaine and 0.012 mg/ml of epinephrine (Ultracaine D-S Forte; Aventis, Bridgewater, NJ, USA). All treatments were conducted under x2.5 magnification (EyeMag Smart, Carl Zeiss, Germany). The crowns, caries, and defective restorations were removed initially and a dental dam was placed according to standard practice. Then an access cavity was made to perform straight-line access. The posts were removed primarily using an ultrasonic device (UDS-N2; Woodpecker, Guangxi, China).

The previous obturation materials and root canal fillings were completely removed using the combination of hand files (Mani, Inc., Utsunomiya, Tochigi, Japan) and the retreatment kit (ProTaper Retreatment Kit; (Dentsply Maillefer). No solvents were used to degrade the root canal filling or sealer. The working length was determined using an electronic apex locator (Root ZX mini; J. Morita Mfg. Corp., Kyoto, Japan). Both the removal of previous root canal filling and the working length determination were confirmed with digital radiographs.

The canals were cleaned and shaped employing a crown-down technique (ProTaper Universal Rotary System; Dentsply Maillefer) in accordance with the manufacturer's instructions. A master apical preparation was made in the mesial canals of the mandibular molars, while the mesiobuccal and distobuccal canals of the maxillary molars were prepared to an apical size of F4 (ProTaper Universal Rotary System; Dentsply Maillefer). In the distal canals of the mandibular molars and the palatal canals of the maxillary molars, the apical preparation was completed with an F5 (ProTaper Universal Rotary System) to ISO #70 K-type file (Mani Inc., Tochigi, Japan), depending on the root canal size and anatomy. Sodium hypochlorite (NaOCl) of

2 ml was used to rinse the canals after each instrument using a disposable irrigation syringe (KerrHawe SA, Bioggio, Switzerland). At the end of the preparation of the root canals, 1 ml of 17% ethylenediaminetetraacetic acid (EDTA) was applied for 2 minutes in order to remove the smear layer. Finally, the root canals were dried with paper points and treated with a mixture of calcium hydroxide ($Ca(OH)_2$) powder (Vision, Istanbul, Turkey) and distilled water using K-type files (Mani Inc.). The access cavities were sealed with a minimum of 3-mm thick temporary restorative filling material (Coltosol F; Coltene/Whaledent Inc., Altstatten, Switzerland).

After two weeks, the $Ca(OH)_2$ paste was removed from the root canal mechanically using hand files combined with copious irrigation using a minimum of 10 ml of 5.25% NaOCl for 10 minutes and 2 ml of 17% EDTA for 2 minutes. The root canals were subsequently dried with paper points and obturated with a gutta-percha cone of the same size as the master apical file (ProTaper Universal; Dentsply Maillefer) and root canal sealer (AH Plus; Dentsply DeTrey GmbH). The lateral compaction method was ermployed with size #20 gutta-percha cones (Dentsply Maillefer) using size #25 nickel-titanium finger spreaders (Dentsply Maillefer). After cutting the gutta-percha and cleaning the remnants from the cavity, an all-in-one adhesive resin (Clearfil S3 Bond; Kuraray Noritake Dental Inc., Okayama, Japan) was used according to the manufacturer's instructions, prior to the coronal restoration. Afterwards, the coronal restoration was completed using resin composite (Filtek Z250; 3M ESPE, St. Paul, MN, USA) and a fiber post, if needed (Cytec blanco HT-Glasfiber; E. Hahnenkratt GmbH, Königsbach-Stein, Germany).

**Assessment of outcome measures**

The patients were recalled 2 to 3 years after the treatment. All patients were communicated by phone call. Each patient was called up until the phone was turned on or refused to come to the follow-up appointment. Patients who could not be contacted due to phone number change or non-registry were tried to be reached through the number of the patient's companion registered in the system of the hospital. All phone numbers were dialed at least 20 times on different days and times until the end of the study. At the end of this entire

process, patients included in the study were classified as showed up to follow up/was not reached/ refused to come. All calls were performed by the staff members working in the department.

At the follow-up appointment, the presence of any palpation/percussion pain or discomfort, the presence of any sinus tract swelling, a fistula or sign of infection in the gingival tissue, marginal integrity of the coronal restoration, diameter of periapical lesions and the quality of the root canal filling (length and density of the root canal filling) were recorded using an imaging software (KODAK program, Kodak Dental Imaging Software 6.3, Carestream Health Inc.). Digital periapical radiographs were obtained and all the preoperative and postoperative radiographs were evaluated by 2 calibrated observers in order to determine the periapical status using the PAI scores described as follows:

PAI 1 – normal periapical structure

PAI 2 – small changes in the structure of the bone not pathognomonic for apical periodontitis

PAI 3 – changes in the bone structure with mineral loss characteristic for apical periodontitis

PAI 4 – well defined apical radiolucency characteristic for apical periodontitis

PAI 5 – severe periodontitis with exacerbating features and bone expansion

"Not-healed" teeth were classified as "failure," and "success" included the teeth classified as "healed" and "healing". The treatment outcomes were classified into 3 categories according to the following definitions:

1. Healed: The absence of any clinical signs or symptoms and normal periapical tissue with an intact periodontal ligament space and lamina dura or a slightly widened periodontal ligament around extruded material (PAI 1-2).

2. Healing: The absence of any clinical signs or symptoms with periapical radiolucency still present, but reduced in size (PAI 3-5).

3. Not-healed: The presence of signs or symptoms and/or the emergence of new periapical radiolucency, or unchanged or enlarged periapical radiolucency (PAI 3-5).

**Observer calibration**

All the PAI scores were obtained from periapical radiographs made using parallel technique. Two investigators were calibrated for recording the PAI scores with a calibration kit of 100 reference radiographs [24]. The PAI scores were dichotomized to reflect the absence (PAI≤2) or presence (PAI>2) of apical periodontitis. Those teeth with multiple root canals were scored according to the root canal with the highest PAI score. If the evaluators chose different scores, the worst score was recorded.

**Statistical analysis**

The data obtained from the preoperative, intraoperative, and postoperative parameters and their associations with the outcomes were statistically analyzed using the software programs (Number Cruncher Statistical System (NCSS), 2007 LLC., Kaysville, Utah, USA and Power Analysis and Sample Size (PASS) 2008). Cohen's kappa scores were calculated for the inter- and intra-examiner agreement twice with a 2-month interval. In addition to the descriptive statistical methods (mean, standard deviation, median, frequency, and ratio), the Mann Whitney U test was used for effect of age on the success rate. In addition, Pearson's chi-squared test, Fisher's exact test, and Fisher-Freeman-Halton tests were used to compare the qualitative variables. The multivariate analyses were made using the "Enter" logistic regression analysis method. P value of 0.05 was accepted as the level of significance in all tests.

**Results**

Of the 236 teeth, 135 (57.3%) in 103 patients (63.9%) were lost to follow-up, yielding to follow up of 101 teeth (42.7%) in 58 patients (36%). The reasons for not attending the recall appointments were recorded. Of those 103 patients, 53 (51.4%, 75 teeth) refused to come to the follow-up appointment, and 50 patients (48.5%, 60 teeth) could not be contacted. Three teeth had been extracted, of which 1 was for restorative reasons, 1 due to vertical root fracture, and 1 for periodontal reasons.

The mean follow-up period of the NSRC retreatment was 33.8 months. Thee age of the patients ranged between 18 and 72 years with a mean age of 44.3±14.1 years old. The mean age of the healed group was

45.3±14.3 years old, and that of the not-healed group was 38.6±11.6 years old, with no significant difference (P=0.135). Of all the patients, 28 (48.3%) were males and 30 (51.7%) were females, showing no significant difference on the outcome measures (P>0.05).

The success rates were 81.8% (n=82) for healed, 3.9% (n=4) for healing, and 14.9% (n=15) for not-healed groups (Table 1). The teeth categorized as healed and healing were considered to be successfully treated, while those that were not-healed were considered to be failures. Thus, the overall success rate was 85.1%.

The most common reasons for endodontic failures observed in this study were insufficient restoration and/or root canal filling, missing coronal restoration for a long time, and other prosthetic needs. There were no correlations between the preoperative (radiolucency, pain, perforations, periodontal defects, root canal filling density and length), intraoperative (sealer extrusion and presence of root canal filling voids), and postoperative (root canal filling quality, coronal restoration type, and presence of post) factors, and they did not significantly affect the outcomes (P>0.05) (Table 2). The preoperative periradicular lesions with diameters of less than 5 mm presented better outcomes than the larger lesions, but there was no statistically significant difference (P>0.05).

The failure rate in the mandibular molar teeth was significantly higher than in the mandibular anterior, maxillary premolar and maxillary molar teeth (P<0.05). There was no significant difference between the maxillary anterior, mandibular premolar, and mandibular molar teeth (P>0.05).

The calibrated observers agreed on 94% of the observations. For the PAI scores, the kappa values for the inter- and intra-observer agreements were 0.936 and 0.964, respectively, showing very good agreement.

## Discussion

Several factors may influence endodontic treatment outcomes, such as the tooth type, preoperative periapical lesion size, presence of preoperative pain, operator experience, and number of visits [6-8,25].

Due to the complex anatomy of root canals, adequate cleaning and shaping of the root canals, particularly in the apical third, are beyond reach. Therefore, medication with an antibacterial agent, notably in cases with infected root canal fillings, is still a well-accepted method used for endodontic treatment [9]. Therefore, the aim of the present study was to assess the success rates and clinical outcomes of NSRC retreatment cases undergoing multiple-visit treatments performed by a specialist for 2-3 years follow-up time.

Of the 161 patients treated between March 2014 and December 2015, 58 patients agreed to come to back for a review. Fifty-three patients refused to come to the recall appointment due to, among other reasons, relocation, family reasons, being treated at other institutions, and distance. In addition, some patients reported that their teeth had no problems, and they were not willing to come back for a control. Fifty patients could not be reached because their phone numbers were not in use or someone else answered the phone. As a result, 58 patients were involved in this study. It has to be noted that whether for a study or not, controls are free of charge at the university where this study took place. If patients were paid for recalls, drop-out rate could have decreased.

There is a number of studies reporting on the NSRC retreatment outcomes in the literature [7-13,15,16,19,25,28,30-32]. Some of these studies were prospective [11,15,16,19,25], one was a systematic review [10], and others were retrospective [9,26,27,30-33]. In these retrospective studies, the success rate of the multiple-visit NSRC retreatment ranged between 62 and 95% [9,26,27,30-32]. In a recent systematic review [10], the multiple-visit retreatment success rate was reported as 79.5%. In the current retrospective cohort study, the success rate was 85.1%. Moreover, 94.2% of the teeth were found to be asymptomatic and fully functional. In some of the mentioned studies, the treatments were performed by dental students [9,27,30,31] and similar to this study, in others one single operator performed the treatments [28,32]. The reason why the success rates in other studies were lower than in this study may be related to the fact that the treatments in the other studies were performed by different clinicians and/or the treatments in this study

were performed by an experienced specialist. The experience of the clinician can significantly influence the success rate of the treatment.

The periapical lesion size has been reported to have a significant effect on the success rate in previous studies [8,9,30-32]. In one systematic review, the success rate for small lesions (<5 mm) was reported to be 25% higher than that for large lesions (≥5 mm) [10]. The results reported by Çalışkan [30] (68.3% and 58.8%, respectively) and Sjogren et al. [9] (65% and 38%, respectively) also support these findings. Contrarily, in the present study, no statistical significant difference was found between the periapical lesion sizes (<5 mm or ≥5 mm, 88.6% and 80%, respectively), in accordance with the results of the Sjogren et al. [9]. In addition, three out of the four teeth in the “healing” group had >5 mm periapical lesions at the beginning of the NSRC retreatment. Bergenholtz et al. [28] reported a 78% success rate in cases with periapical lesions. This rate was 80% in a study by de Chevigny et al. [32]. In the present study, all of the cases had periapical lesions, and the success rate of the teeth with periapical lesions was 85%. A possible explanation of this effect could be associated with improvements in technology, as well as the new systems and materials that are being used in endodontic therapy in recent years. In other studies, the cases were not treated by a specialist, and the experience of the operator may have influenced the success rate as well [34].

The tooth type had a significant effect on the NSRC retreatment success rate, particularly in the mandibular molar teeth [6,33]. In the present study, a significant effect of tooth type was evident on the success rate and the mandibular molar teeth were found to be the most failed tooth type. Contrary to the results of this study, one study reported that the success rates for the mandibular molar teeth were the highest, followed by those for the mandibular premolar teeth, the maxillary premolars and molars, and finally, the incisors/canines [10]. One possible explanation for this result could be that the anatomy of the molar teeth presented a greater challenge for the elimination of root canal infections, especially in the apical

part of the mesial root canals [29]. For this reason, in order to achieve optimal mechanical shaping and disinfection, F4 Protaper file was used [29].

The age, gender, presence of a post, and periodontal defects had no effects on the outcome measures, which is similar to other studies [9,30]. Among the various factors analyzed, neither the root canal filling density nor the root filing length had any effect on the success rate in the current study. However, the root canal filling length and density were found to be the most important outcome predictors in previous studies [9,10,30,31]. For example, Sjogren et al. [9] reported that the roots with root canal fillings at the apex or within 2 mm of the apex showed 94% success rate, while the roots filled beyond the apex presented 76% success rate, and the roots that were filled more than 2 mm short of the root apex had 68% success. In the present study, one case was filled more than 2 mm short of the root apex and two cases were filled to excess. The remaining 98 teeth were filled adequately. In the treated teeth, the access cavities were sealed with a minimum of 3-mm thick temporary restorative filling material which could be considered too thin but no washout of the temporary material was observed.

The average follow-up period of the treated teeth in this study was about 34 months, which was adequate for a radiographic assessment of healing after the endodontic treatment. In the presence of lesions, especially those greater than 5 mm diameter, a long recall period (2-5 years) is needed to evaluate the success of the treatment [8,9,28,32]. The healing rate in the teeth with preoperative perforations was 37.3% lower than in the teeth without perforations (absent=87.3%, present=50%). All 6 teeth with perforations were treated with mineral trioxide aggregate where 3 of them healed but the other 3 failed.

The PAI system introduced by Ørstavik et al. [24] was used in the current study in order to create more reliable criteria for the status of the periapical tissues. In previous studies it has also been reported that this system is successful, preferable, and easy to perform in the observation of periapical changes and in the comparison of conventional endodontic retreatment results [8,30]. In recent studies repeated radiological evaluations using full-scale PAI reveal a significant prognostic value in periapical disease follow-up over the

long term [35,36]. In addition, although teeth with necrotic pulps were expected to be more likely to have periodontal ligament (PDL) expansion, the PDL area of healthy tooth showed significant variations from periapical radiography when examined in CBCT [37]. For all these reasons, periapical radiography and PAI scoring were preferred in the follow-up of endodontic treatment.

Although the tooth type seems to be the only predictor of the success rate according to the results of this study, a longer follow-up duration and increased number of patients may provide other possible predictors of the outcomes and success rates of NSRC retreatment therapy.

## Conclusions

Non-surgical multiple-visit root canal retreatment of 101 endodontically treated teeth healed with 85.1%, while 94.2% remained asymptomatic and fully functional after a mean observation time of 33.8 months. The tooth type was found to be the only predictor affecting the treatment outcome since mandibular first molar teeth; especially the mesial root canals with periapical lesions failed the most. The preoperative periapical lesion size did not affect the treatment success rate.

## Compliance with ethical standards

**Conflict of interest**: The authors declare that they have no conflict of interest.

**Funding:** This study was not supported by any funding source.

**Ethical approval**: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

**Informed consent:** Informed consent was obtained from all participants included in the study.

**References**

1. Schilder H. Filling root canals in three dimensions. Dent Clin North Am. 1967:723-44.

2. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am. 1974;18:269-96.

3. Dammaschke T, Steven D, Kaup M, et al. Long-term survival of root-canal-treated teeth: a retrospective study over 10 years. J Endod. 2003 29: 638-43.

4. Alley BS, Kitchens GG, Alley LW, et al. A comparison of survival of teeth following endodontic treatment performed by general dentists or by specialists. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;98:115-8.

5. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. J Endod. 2004;30:846-50.

6. Olcay K, Ataoglu H, Belli S. Evaluation of related factors in the failure of endodontically treated teeth: A cross-sectional study. J Endod. 2018;44:38-45.

7. Ashraf H, Milani AS, Shakeri Asadi S. Evaluation of the success rate of nonsurgical single visit retreatment. Iran Endod. 2007 2: 9-72.

8. Eyuboglu TF, Olcay K, Özcan M. A clinical study on single-visit root canal retreatments on consecutive 173 patients: frequency of periapical complications and clinical success rate. Clin Oral Investig. 2017;21:1761-68.

9. Sjogren U, Hagglund B, Sundqvist G, et al. Factors affecting the long-term results of endodontic treatment. J Endod. 1990;16:498-504.

10. Ng YL, Mann V, Gulabivala K. Outcome of secondary root canal treatment: a systematic review of the literature. Int Endod J. 2008;41:1026-46.

11. He J, White RK, White CA, Schweitzer JL, Woodmansey KF. Clinical and patient-centered outcomes of nonsurgical root canal retreatment in first molars using contemporary techniques. J Endod. 2017;43:231-7.

12. Torabinejad M, Corr R, Handysides R, et al. Outcomes of nonsurgical retreatment and endodontic surgery: a systematic review. J Endod. 2009;35:930-7.

13. Salehrabi R, Rotstein I. Epidemiologic evaluation of the outcomes of orthograde endodontic retreatment. J Endod. 2010;36:790-2.

14. Moazami F, Sahebi S, Sobhnamayan F, et al. Success rate of nonsurgical endodontic treatment of nonvital teeth with variable periradicular lesions. Iran Endod J. 2011;6:119-24.

15. Friedman S, Lost C, Zarrabian M, et al. Evaluation of success and failure after endodontic therapy using glass ionomer cement sealer. J Endod. 1995;21:384-90.

16. Ricucci D, Russo J, Rutberg M, et al. A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112:825-42.

17. Siqueira JF Jr, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. J Endod. 2008;34:1291–1301.

18. Ricucci D, Siqueira JF Jr. Fate of the tissue in lateral canals and apical ramifications in response to pathologic conditions and treatment procedures. J Endod. 2010;36:1-15.

19. Sundqvist G, Figdor D, Persson S, et al. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998;85:86-93.

20. Siqueira JF Jr, Rôças IN. Exploiting molecular methods to explore endodontic infec-tions: part 2-redefining the endodontic microbiota. J Endod. 2005;31:488-98.

21. Siqueira JF Jr. Aetiology of root canal treatment failure: why well-treated teeth can fail. Int Endod J. 2001;34:1-10.

22. Sjögren U, Figdor D, Spångberg L, et al. The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. Int Endod J. 1991;24:119-25.

23. Paiva SS, Siqueira JF Jr, Rôças IN, et al. Clinical antimicrobial efficacy of NiTi rotary instrumentation with NaOCl irrigation, final rinse with chlorhexidine and interappointment medication: a molecular study. Int Endod J. 2013;46:225-33.

24. Orstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol. 1986;2:20-34.

25. Nesković J, Zivković S, Medojević M, et al. Outcome of orthograde endodontic retreatment--A two-year follow-up. Srp Arh Celok Lek. 2016;144:174-80.

26. Allen RK, Newton CW, Brown C. A statistical analysis of surgical and nonsurgical endodontic retreatment cases. J Endod. 1989;15:261-6.

27. Fristad I, Molven O, Halse A. Nonsurgically retreated root filled teeth--radiographic findings after 20-27 years. Int Endod J. 2004;37:12-8.

28. Bergenholtz G, Lekholm U, Milthon R, et al. Retreatment of endodontic fillings. Scand J Dent Res. 1979;87:217-24.

29. Aminoshariae A, Kulild J. Master apical file size - smaller or larger: a systematic review of microbial reduction. Int Endod J. 2015;48:1007-22.

30. Caliskan MK. Nonsurgical retreatment of teeth with periapical lesions previously managed by either endodontic or surgical intervention. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;100:242-8.

31. Imura N, Pinheiro ET, Gomes BP, et al. The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist. J Endod. 2007;33:1278-82.

32. de Chevigny C, Dao TT, Basrani BR, et al. Treatment outcome in endodontics: the Toronto study-phases 3 and 4: orthograde retreatment. J Endod. 2008;34:131-7.

33. Zadik Y, Sandler V, Bechor R, et al. Analysis of factors related to extraction of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106:e31-5.

34. Burry JC, Stover S, Eichmiller F, et al. Outcomes of primary endodontic therapy provided by endodontic specialists compared with other providers. J Endod. 2016;42:702-5.

35. Kirkevang LL, Ørstavik D, Wenzel A, et al. Prognostic value of the full-scale Periapical Index. Int Endod J. 2015;48:1051-8.

36. Kirkevang LL, Ørstavik D, Bahrami G, et al. Prediction of periapical status and tooth extraction. Int Endod J. 2017;50:5-14.

37. Pope O, Sathorn C, Parashos P. A comparative investigation of cone-beam computed tomography and periapical radiography in the diagnosis of a healthy periapex. J Endod. 2014;40:360-5.

**Captions to legends:**

**Tables**

**Table 1** Presentation of the prognostic factors, inception cohort, study sample and distribution of their associations with the heaed and not-healed teeth.*p < 0.05, **p < 0.01; PAI: periapical index; [a]Fisher's exact test, [b]Fisher-Freeman-Halton test, [c]Pearson's chi-squared test

**Table 2** Presentation of preoperative, intraoperative and postoperative factors and their distributions in the healed and not-healed groups, p values, and post hoc power values. *p < 0.05; PAI: periapical index; [a]Fisher's exact test; [b]Fisher-Freeman-Halton test, [c]Pearson's chi-squared test

## Tables:

| Prognostic factors | Inception cohort n (%) | Study sample n (%) | Healed n (%) | Not-healed n (%) | *P* |
|---|---|---|---|---|---|
| **Preoperative factors** | | | | | |
| **Age** | | | | | |
| ≥45 | 108 (45.8) | 46 (45.5) | 42 (91.3) | 4 (8.7) | [c]0.112 |
| <45 | 128 (54.2) | 55 (54.5) | 44 (80.0) | 11 (20.0) | |
| **Gender** | | | | | |
| Male | 89 (37.7) | 41 (40.6) | 34 (82.9) | 7 (17.1) | [c]0.999 |
| Female | 147 (62.3) | 60 (59.4) | 52 (86.6) | 8 (13.3) | |
| **Preoperative pain** | | | | | |
| Absent | 104 (44.1) | 40 (39.6) | 35 (87.5) | 5 (12.5) | [c]0.590 |
| Present | 132 (55.9) | 61 (60.4) | 51 (83.6) | 10 (16.4) | |
| **Tooth type** | | | | | |
| Maxillary anterior | 64 (27.1) | 20 (19.8) | 17 (85.0) | 3 (15.0) | [b]0.021 |
| Mandibular anterior | 14 (5.9) | 7 (6.9) | 7 (100) | 0 (0) | |
| Maxillary premolar | 61 (25.8) | 31 (30.7) | 29 (93.5) | 2 (6.5) | |
| Mandibular premolar | 32 (13.5) | 16 (15.8) | 13 (81.3) | 3 (18.7) | |
| Maxillary molar | 29 (12.2) | 10 (9.9) | 10 (100) | 0 (0) | |
| Mandibular molar | 36 (15.2) | 17 (16.8) | 10 (58.8) | 7 (51.2) | |
| **Radiolucency** | | | | | |
| <2 mm | 68 (28.8) | 24 (23.8) | 21 (87.5) | 3 (12.5) | [b]0.568 |
| 2–5 mm | 109 (46.2) | 47 (46.5) | 41 (87.2) | 6 (12.8) | |
| >5 mm | 59 (25.0) | 30 (29.7) | 24 (80.0) | 6 (20.0) | |
| **Preoperative PAI score** | | | | | |
| 1 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | [b]0.091 |
| 2 | 19 (8.1) | 2 (1.9) | 1 (50.0) | 1 (50.0) | |
| 3 | 146 (61.9) | 66 (65.4) | 59 (89.4) | 7 (10.6) | |
| 4 | 48 (20.3) | 22 (21.8) | 18 (81.8) | 4 (18.2) | |
| 5 | 23 (9.7) | 11 (10.9) | 8 (72.7) | 3 (27.3) | |
| **Periodontal defects** | | | | | |
| Absent | 121 (51.3) | 52 (51.5) | 42 (80.8) | 10 (19.2) | [c]0.082 |
| Present | 115 (48.7) | 49 (48.5) | 44 (89.8) | 5 (10.2) | |
| **Root canal filling density** | | | | | |
| Good | 20 (8.5) | 18 (17.8) | 15 (83.3) | 3 (16.6) | [b]0.915 |
| Poor | 189 (80.1) | 71 (70.3) | 60 (84.5) | 11 (15.5) | |
| Unfilled canal | 27 (11.4) | 12 (11.9) | 11 (9.2) | 1 (8.3) | |
| **Root canal filling material** | | | | | |
| Gutta-percha | 212 (89.8) | 91 (90.1) | 78 (85.7) | 13 (14.3) | [a]0.641 |
| Silver point | 0 (0) | 0 (0) | 0 (0) | 0 (0) | |
| Paste | 24 (10.2) | 10 (9.9) | 8 (80.0) | 2 (20.0) | |
| **Length of root canal filling** | | | | | |
| Adequate (0-2 mm) | 80 (33.9) | 34 (33.7) | 27 (79.4) | 7 (20.6) | [b]0.668 |
| Short (>2 mm) | 153 (64.8) | 65 (64.4) | 57 (87.7) | 8 (12.3) | |
| Extensive overfill | 3 (1.3) | 2 (1.9) | 2 (100) | 0 (0) | |
| **Perforation** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Absent | 228 (96.6) | 95 (94.1) | 83 (87.4) | 12 (12.6) | [a]0.041* |
| Present | 8 (3.4) | 6 (5.9) | 3 (50.0) | 3 (50.0) | |
| **Time since initial treatment** | | | | | |
| >4 years | 0 (0) | 0 (0) | 0 (0) | 0 (0) | [c]0.035* |
| >3 years | 109 (46.2) | 38 (37.6) | 36 (94.7) | 2 (5.3) | |
| ≤3 years | 127 (53.8) | 63 (62.4) | 50 (79.4) | 13 (20.6) | |
| <2 years | 0 (0) | 0 (0) | 0 (0) | 0 (0) | |
| **Previous apical surgery** | | | | | |
| No | 236 (100) | 101 (100) | 86 (85.1) | 15 (14.9) | - |
| Yes | 0 (0) | 0 (0) | 0 (0) | 0 (0) | |
| **Intraoperative factors** | | | | | |
| **Root canal filling length** | | | | | |
| Adequate | 229 (97.0) | 98 (97.0) | 84 (85.7) | 14 (14.3) | - |
| Short | 3 (1.3) | 1 (0.9) | 0 (0) | 1 (0.9) | |
| Long | 4 (1.7) | 2 (1.9) | 2 (100) | 0 (0) | |
| **Root canal filling voids** | | | | | |
| Absent | 232 (98.3) | 100 (99) | 15 (15) | 85 (85) | - |
| Present | 4 (1.7) | 1 (0.9) | 0 (0) | 1 (100) | |
| **Complications** | | | | | |
| No | 236 (100) | 101 (100) | 86 (85.1) | 15 (14.9) | - |
| Yes | 0 (0) | 0 (0) | 0 (0) | 0 (0) | |
| **Sealer extrusion** | | | | | |
| No | 201 (85.2) | 87 (86.1) | 73 (84.8) | 14 (16.1) | [a]0.685 |
| Yes | 35 (14.8) | 14 (13.9) | 13 (92.8) | 1 (7.1) | |
| **Seal material** | | | | | |
| Temporary | 0 (0) | 0 (0) | 0 (0) | 0 (0) | - |
| Definitive | 236 (100) | 101 (100) | 86 (85.1) | 15 (14.9) | |
| **Number of roots** | | | | | |
| Single-rooted | 137 (58) | 52 (51.5) | 45 (86.5) | 7 (13.5) | [c]0,686 |
| Multi-rooted | 99 ( 42) | 49 (48.5) | 41 (83.7) | 8 (16.3) | |
| **Number of remaining cavity walls** | | | | | |
| None | 37 (15.6) | 14 (13.9) | 10 (71.4) | 4 (28.6) | [b]0.582 |
| 1 | 62 (26.3) | 28 (27.7) | 24 (85.7) | 4 (14.3) | |
| 2 | 88 (37.3) | 44 (43.6) | 39 (88.6) | 5 (11.4) | |
| 3 | 45 (19.1) | 12 (11.8) | 10 (83.3) | 2 (16.7) | |
| 4 | 4 (1.7) | 3 (3) | 3 (100) | 0 (0) | |
| **Postoperative factors** | | | | | |
| **Density of root canal filling** | | | | | |
| Dense and tapered | | 100 (99) | 85 (85.0) | 15 (15.0) | - |

| | | | | |
|---|---|---|---|---|
| Voids present | 0 (0) | 0 (0) | 0 (0) | |
| Poorly condensed | 1 (0.9) | 1 (100) | 0 (0) | |
| **Quality of coronal restoration** | | | | |
| Adequate | 98 (97.0) | 83 (84.7) | 15 (15.3) | - |
| Marginal deficiency present | 3 (3.0) | 3 (100) | 0 (0) | |
| **Postoperative signs and symptoms** | | | | |
| Absent | 97 (96.0) | 84 (86.5) | 13 (13.4) | - |
| Present | 4 (4.0) | 2 (50.0) | 2 (50.0) | |
| **Radiolucency** | | | | |
| Absent | 82 (81.2) | 82 (100) | 0 (0) | - |
| Present | 19 (18.8) | 4 (21.0) | 15 (78.9) | |
| **Postoperative PAI score** | | | | |
| 1 | 58 (57.4) | 58 (100) | 0 (0) | [b]0.001** |
| 2 | 24 (23.8) | 24 (100) | 0 (0) | |
| 3 | 10 (9.9) | 3 (30.0) | 7 (70.0) | |
| 4 | 8 (7.9) | 1 (12.5) | 7 (87.59 | |
| 5 | 1 (0.9) | 0 (0) | 1 (100) | |
| **Fracture** | | | | |
| Absent | 101 (100) | 86 (85.1) | 15 (14.9) | - |
| Present | 0 (0) | 0 (0) | 0 (0) | |
| **Restoration at follow-up** | | | | |
| Definitive filling | 36 (35.6) | 30 (83.3) | 6 (16.7) | [a]1.000 |
| Crown | 65 (64.4) | 56 (86.2) | 9 (13.8) | |
| **Post** | | | | |
| Absent | 57 (56.4) | 51 (89.5) | 6 (10.5) | [a]0.054 |
| Present | 44 (43.6) | 35 (79.5) | 9 (20.5) | |

**Table 1** Presentation of the prognostic factors, inception cohort, study sample and distribution of their associations with the heaed and not-healed teeth.*p < 0.05, **p < 0.01; PAI: periapical index; [a]Fisher's exact test, [b]Fisher-Freeman-Halton test, [c]Pearson's chi-squared test

| | Number of teeth | Healed (n=86) n (%) | Not-healed (n=15) n (%) | *p* | Post-hoc power |
|---|---|---|---|---|---|
| **Preoperative factors** | | | | | |
| **Preoperative pain** | | | | | |
| Absent | 40 | 35 (87.5) | 5 (12.5) | [c]0.590 | 0.091 |
| Present | 61 | 51 (83.6) | 10 (16.4) | | |
| **Preoperative radiolucency** | | | | | |
| <2 mm | 24 | 21 (87.5) | 3 (12.5) | [b]0.568 | 0.107 |
| 2–5 mm | 47 | 41 (87.2) | 6 (12.8) | | |
| >5 mm | 30 | 24 (80.0) | 6 (20.0) | | |
| **Preoperative PAI scores** | | | | | |
| 1 | 0 | 0 (0) | 0 (0) | [b]0.091 | 0.206 |
| 2 | 2 | 1 (50.0) | 1 (50.0) | | |
| 3 | 66 | 59 (89.4) | 7 (10.6) | | |
| 4 | 22 | 18 (81.8) | 4 (18.2) | | |
| 5 | 11 | 8 (72.7) | 3 (27.3) | | |
| Minimum-maximum (median) | | 2–5 (3) | 2–5 (3.5) | | |
| Mean±standard deviation | | 3.38±0.67 | 3.64±0.93 | | |
| **Periodontal defects** | | | | | |
| Absent | 52 | 42 (80.8) | 10 (19.2) | [c]0.082 | 0.249 |
| Present | 49 | 44 (89.8) | 5 (10.2) | | |
| **Root canal filling density** | | | | | |
| Good | 18 | 15 (83.3) | 3 (16.6) | [b]0.914 | 0.120 |
| Poor | 71 | 60 (84.5) | 11 (15.5) | | |
| Unfilled canal | 12 | 11 (9.2) | 1 (8.3) | | |
| **Length of root canal filling** | | | | | |
| Adequate (0–2 mm) | 34 | 27 (79.4) | 7 (20.6) | [b]0.668 | 0.159 |
| Short (>2 mm) | 65 | 57 (87.7) | 8 (12.3) | | |
| Extensive overfill | 2 | 2 (100) | 0 (0) | | |
| **Intraoperative factors** | | | | | |
| **Sealer extrusion** | | | | | |
| No | 87 | 73 (84.8) | 14 (16.1) | [a]0.685 | 0.266 |
| Yes | 14 | 13 (92.8) | 1 (7.1) | | |
| **Postoperative factors** | | | | | |
| **Restoration at follow-up** | | | | | |
| Definitive filling | 36 | 30 (83.3) | 6 (16.7) | [a]1.000 | 0.061 |
| Crown | 65 | 56 (86.2) | 9 (13.8) | | |
| **Post** | | | | | |
| Absent | 57 | 51 (89.5) | 6 (10.5) | [a]0.054 | 0.263 |
| Present | 44 | 35 (79.5) | 9 (20.5) | | |

**Table 2** Presentation of preoperative, intraoperative and postoperative factors and their distributions in the healed and not-healed groups, p values, and post hoc power values. *p < 0.05; PAI: periapical index; [a]Fisher's exact test; [b]Fisher-Freeman-Halton test, [c]Pearson's chi-squared test.