

# A clinical study on single-visit root canal retreatments on consecutive 173 patients: frequency of periapical complications and clinical success rate

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Received: 17 November 2015 / Accepted: 5 September 2016 / Published online: 22 September 2016  
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## Abstract

**Objectives** This study assessed the outcome measures of single-visit root canal retreatments and frequency of periapical complications considering preoperative, intraoperative and postoperative factors.

**Materials and methods** Between November 2011 and December 2012, in 173 patients, a total of 234 endodontically treated teeth were retreated in a single appointment by one experienced endodontist. Five teeth were extracted and 119 teeth were lost to follow-up yielding to 110 teeth (47 %) to be examined by two calibrated examiners for the outcome of healing (periapical index score-PAI  $\leq 2$ ; no signs or symptoms) or non-healing (presence of apical periodontitis-PAI  $> 2$ ; signs or symptoms). Preoperative, intraoperative and postoperative factors were evaluated for their association with the outcome. Data were analysed using Fisher's exact and Fisher-Freeman Halton tests for bivariate analysis to identify potential outcome predictors. Logistic regression models were used for multivariate analysis to determine significant outcome predictors.

**Results** Mean observation time was 29 months. Follow-up assessment revealed 100 teeth (90.9 %) as healed and 10 teeth

(9.1 %) non-healed. Age, gender, tooth type and preoperative (pain, periodontal defects, root filling density and length), intraoperative (sealer extrusion) and postoperative (type of coronal restorations) factors did not significantly affect the outcome ( $p > 0.05$ ). Preoperative periradicular lesions with diameters less than 5 mm presented significantly better outcome than larger lesions ( $p < 0.05$ ; odds ratio (OD) 6; 95 % CI 1.45–24.85). Logistic regression model showed an increased risk of non-healing for the parameter of preoperative periradicular lesions with diameters larger than 5 mm (OD 6.42; 95 % CI 1.51–27.27).

**Conclusions** Single-appointment root canal retreatments presented a favourable success rate. Only preoperative lesion size had a significant effect on the outcome where the lesions smaller than 5 mm performed significantly better healing.

**Clinical relevance** Single-appointment root canal retreatments could be considered as a viable treatment option for orthograde retreatment cases with periradicular lesion size smaller than 5 mm.

**Keywords** PAI scores · Periapical complications · Periapical lesion · Root canal retreatment · Single-appointment endodontic therapy

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## Introduction

The primary goal of endodontic treatment is to prevent or heal apical periodontitis (AP) [17], but it has been reported in cross-sectional studies from different countries that more than 30 % of all endodontically treated teeth in the studied populations are associated with AP or “post treatment disease” [2, 5, 10].

Post treatment diseases could be treated by two options including orthograde retreatment and apical surgery [10]. In

a previous study, orthograde retreatments presented a success rate of 81 % classified as “healed” and 93 % as “no symptoms and fully functional” [7]. In a systematic review, it has also been concluded that endodontic surgery offers more favourable initial success but orthograde retreatment yields to a better long-term outcome [27]. Although early results of single-visit treatments are contradictory [11, 29, 30], due to novel techniques and equipment available today [33] and patient requests, a considerable amount of increased interest and effort were accumulated on single-visit treatments. Completing the treatment in a single appointment reduces the treatment time and cost, decreases microleakage risk and avoids recontamination of root canals between appointments in multiple-visit treatments [8, 32, 34]. In fact, no significant differences were observed in healing of periapical radiolucency between teeth treated in one visit (without) and those treated in two visits using calcium hydroxide for 4 weeks and that the presence of a positive bacterial culture at the time of filling did not influence the outcome of treatment [18]. Similarly, Ashraf et al. reported single-appointment retreatments with a success rate of 84.9 % and recommended single-appointment retreatments for symptomless teeth [1].

Due to excessive request from patients as a result of limited time for dental visits during working hours and long travelling time required to visit dental offices, single-appointment treatments [8, 18, 32] and retreatments [1] for root canal treatments could bring economical advantages.

The objective of this study therefore was to assess the frequency of periapical complications and success rate of single-appointment non-surgical root canal retreatments retrospectively considering preoperative, intraoperative and postoperative factors.

## Materials and methods

### Inclusion and exclusion criteria

This retrospective study included patients who were in need of orthograde retreatment and treated in a single appointment accordingly at the Istanbul Medipol University between November 2011 and December 2012. The ethics committee of the same university approved the study and all enrolled subjects signed a written informed consent. All retreatments were assigned due to persisting periapical lesions, preoperative signs and symptoms and coronal and/or apical leakage of root canals. In total, in 173 patients, 234 teeth were retreated by one endodontist (T.F.E.) who had an experience of 12 years. The diagnoses of the relevant teeth were made with a panoramic (KODAK 9000, Carestream Health, Rochester, NY, USA) and periapical radiograph (KODAK RVG 5100, Carestream Health) using a parallel technique with an exposure time of 0.16 s and exposure dose of 1.22 mGy. The teeth

diagnosed with excessive periodontal disease, vertical root fractures or those that received surgical endodontic treatment were excluded.

### Retreatment procedure

The treatments were carried out in a single appointment. All restorations (single crowns and fixed dental prosthesis) were removed initially to gain direct access to the relevant tooth. Root posts were primarily removed using an ultrasonic device (UDS-N2, Woodpecker, Guangxi, People’s Republic of China) and if required with a portegue.

After having access to the previously obturated root canals, #1, #2 ve #3 Gates Glidden (GG) burs (Mani Inc., Tochigi, Japan) and #15 Kerr files (Mani Inc.) were used to remove the root canal filling completely. No chemical solvent was used to remove the gutta-percha or the sealer. Cleaning and shaping of the canal were performed employing a crown-down technique using nickel-titanium rotary instruments (Revo-S Micro-Méga, Besançon, France). After measuring the root lengths with an apex locator (Apex Pointer, Micro-Méga), each tooth was prepared up to AS 40 file, 0.5 mm short of the apex. The canals were irrigated after the use of each instrument with 1 ml of 2.5 % sodium hypochlorite (NaOCl). The last irrigation was accomplished using 2.5 ml 5 % ethylene diamine tetraacetic acid (EDTA), 2.5 ml of 2.5 % NaOCl and 5 ml of distilled water, respectively. A single-cone technique was then used to fill the root canals with either AS35 or AS40 gutta-percha cones (Revo-S, Micro-Méga). Root canal filling paste (AH Plus, Dentsply, DeTrey, Konstanz, Germany) was introduced into the root canal using master cones with a brushing motion and accessory gutta-percha cones (SU 25, Revo-s, Micro-Méga) were used when needed using non-compaction method.

A total-etch bond (Single bond 2, 3M ESPE, St. Paul, MN, USA) technique was used according to the manufacturer’s instructions prior to coronal restoration. Flowable resin composite (Filtek Ultimate Flowable, 3M ESPE, St. Paul, MN, USA) was used as base material in order to seal the canal orifices. Thereafter, the coronal restoration was made with resin composite (Filtek Ultimate, 3M ESPE) or a fibre post (Cytec Blanco, HT-Glasfiber, E. Hahnenkratt GmbH, Königsbach-Stein, Germany) and composite core (RelyX U200, 3M ESPE) prior to a fixed prosthetic restoration depending on the prosthetic plan.

### Radiographic evaluation

A periapical radiograph of the relevant tooth was made immediately after the retreatment with paralleling technique using the same digital radiograph with the same parameters used prior to treatment as described above. The preoperative and intraoperative data were recorded at the database.

## Follow-up evaluation

During the follow-up, clinical signs and symptoms of the relevant tooth were recorded and radiographs were made to record periapical indices (PAI). The principal investigator (T.F.E.) and the coexaminer (K.O.) examined all preoperative and postoperative radiographs. The PAI scores of periapical healing and non-healing were recorded for each endodontically retreated tooth during the follow-up after the retreatment.

The endodontically retreated teeth were clinically examined, and patient response was recorded upon pain in percussion, palpation and chewing (present or absent), any swelling, fistula or sign of infection at the gingival tissue (present or absent), quality of the coronal restoration, occlusal marginal defects (present or absent) and the quality of the root canal filling (length and density of the root filling) (Table 1).

## Calibration of the observers

All PAI scores were obtained from periapical radiographs with a paralleling technique. Two investigators were calibrated for recording PAI with a calibration kit of 100 reference radiographs [11]. The PAI scores were dichotomized to reflect absence (PAI  $\leq 2$ ) or presence (PAI  $> 2$ ) of apical periodontitis. Teeth with multiple root canals were scored for the root canal with the highest PAI score.

## Statistical analysis

Data obtained from preoperative, intraoperative and postoperative factors and their association with the outcome were statistically analysed using a software programme (Number Cruncher Statistical System, NCSS 2007 and Power Analysis and Sample Size, PASS 2008 Statistical Software, UT, USA). Fisher's exact and Fisher-Freeman Halton tests were used for bivariate analysis to identify potential outcome predictors, and logistic regression models were used for multivariate analysis to assess significant outcome predictors. Inter-examiner and intraexaminer Cohen's kappa scores were calculated twice within 2 months interval. Post hoc power analyses were made for the parameters studied.

**Results** Post hoc power analyses indicated preoperative PAI score, preoperative radiolucency less than 80 % and length of root filling with high odds ratio more than 80 %.

Of all patients treated ( $N = 234$  teeth), 119 (50.8 %) teeth, 98 of 173 patients (56.6 %) were lost until the final follow-up, 5 teeth were extracted of which 4 were for restorative and 1 for periodontal reasons. Out of 98 patients (119 teeth), 1 patient was deceased (1 tooth), 28 patients declined recalls (34 teeth), and 69 patients did not respond (84 teeth). One hundred ten teeth (47 %) were examined by two calibrated examiners for the following outcomes: "healed" (periapical index score PAI

$\leq 2$ ; no signs or symptoms) or "non-healed" (presence of apical periodontitis: PAI  $> 2$ , signs or symptoms) (Table 1). Inter-examiner and intraexaminer Kappa scores ranged between 0.936 and 0.964, showing a very good agreement (Table 2). There was statistically no significant difference among the factors between inception cohort and study group ( $p > 0.05$ ) (Table 1).

Until the final follow-up, 100 teeth (90.9 %) were categorized as "healed" and 10 teeth (9.1 %) as "non-healed". The mean age of the study group was  $43.5 \pm 14.4$ . Whilst 45 (60.8 %) of the patients were female, 29 (39.2 %) of them were male. The mean age of the "healed" group was  $43 \pm 13.7$  whilst the "non-healed" group was  $38 \pm 15.2$  with no significant difference ( $p = 0.745$ ;  $p > 0.05$ ). Tooth type or tooth location also had no significant effect on the outcome. Among all 10 "non-healed" teeth that had PAI scores  $> 2$  (6 teeth PAI = 3, 3 teeth PAI = 4, 1 tooth PAI = 5), only 1 was clinically symptomatic (PAI = 4). One of them had a persistent and growing lesion at the bifurcation area diagnosed with a strip perforation and extracted during the follow-up (PAI = 3). Six teeth presented smaller lesions compared to baseline situation, including the symptomatic tooth and the perforated tooth; lesions did not change in 3 teeth and became larger in 1 tooth.

There was no correlation between preoperative pain and outcome measures of the study ( $p > 0.05$ ) (Table 3). Preoperative PAI scores had a significant effect on the outcome ( $p = 0.014$ ). Preoperative periradicular lesion with a diameter smaller than 5 mm demonstrated significantly better outcome than the larger lesions ( $p = 0.025$ ; odds ratio (OD) 6; 95 % CI 1.45–24.85) (Table 3). Preoperative PAI score 5 had a significantly increased failure ratio (OD 6.8; 95 % CI 1.75–26.73) (Table 3).

Preoperative periodontal defects, preoperative root filling material, density and length, intraoperative root filling length, root filling voids, sealer extrusion, postoperative quality, type of coronal restorations and post applications had no significant effect on the outcome ( $p > 0.05$ ). Although the length of root filling had no effect on the outcome, OD for adequate root canal filling length was calculated to be 3.13 (95 % CI 0.51–19.35) with a greater difference compared to other root canal filling lengths according to the logistic regression models (Table 4).

## Discussion

With the increased success rate and newly developed materials, single-appointment root canal treatment procedure has become a viable treatment protocol for both primary root canal treatments and retreatments [1, 9, 19, 33, 34]. Yet, preoperative factors affecting the treatment outcome are essential for decision-making in endodontic treatment [4, 5, 7, 10].

**Table 1** Distribution of prognostic factors, inception cohort, study sample and their association with healing and non-healing and *p* values (univariate analysis)

Prognostic factors	Inception cohort ( <i>n</i> (%))	Study sample ( <i>n</i> (%))	Non-healed ( <i>n</i> (%))	Healed ( <i>n</i> (%))	<i>p</i>
Preoperative factors					
Age					
≥45	132 (56.4)	64 (58.2)	7 (10.9)	57 (89.1)	0.757
<45	102 (43.6)	46 (41.8)	3 (6.5)	43 (93.5)	
Gender					
Male	106 (45.3)	48 (43.6)	5 (10.4)	43 (89.6)	0.772
Female	128 (54.7)	62 (56.4)	5 (8.1)	57 (91.9)	
Preoperative pain					
Present	125 (53.4)	59 (53.6)	7 (11.9)	52 (88.1)	0.970
Absent	109 (46.6)	51 (46.4)	3 (5.9)	48 (94.1)	
Tooth					
Maxillary anterior	67 (28.6)	28 (25.5)	1 (3.6)	27 (96.4)	0.964
Mandibular anterior	18 (7.7)	7 (6.4)	1 (14.3)	6 (85.7)	
Maxillary premolar	46 (19.7)	23 (20.9)	4 (17.4)	19 (82.6)	
Mandibular premolar	38 (16.2)	20 (18.2)	1 (5)	19 (95)	
Maxillary molar	27 (11.5)	15 (13.6)	1 (6.7)	14 (93.3)	
Mandibular molar	38 (16.2)	17 (15.5)	2 (11.8)	15 (88.2)	
Radiolucency					
Absent	2 (0.9)	1 (0.9)	0 (0)	1 (100)	0.216
<2 mm	67 (28.6)	21 (19.1)	0 (0)	21 (100)	
2–5 mm	93 (39.7)	53 (48.2)	3 (5.7)	50 (94.3)	
>5 mm	72 (30.8)	35 (31.8)	7 (20)	28 (80)	
Preoperative PAI score					
1	0 (0)	0 (0)	0 (0)	0 (0)	0.431
2	4 (1.7)	2 (1.8)	0 (0)	2 (100)	
3	124 (53)	48 (43.6)	2 (4.2)	46 (95.8)	
4	63 (26.9)	36 (32.7)	2 (5.6)	34 (94.4)	
5	43 (18.4)	24 (21.8)	6 (25)	18 (75)	
Periodontal defects					
Absent	195 (83.3)	96 (87.3)	8 (8.3)	88 (91.7)	0.345
Present	39 (16.7)	14 (12.7)	2 (14.3)	12 (85.7)	
Root filling density					
Good	6 (2.6)	2 (1.8)	0 (0)	2 (100)	0.408
Poor	212 (90.6)	96 (87.3)	9 (9.4)	87 (90.6)	
Unfilled canal	16 (6.8)	12 (10.9)	1 (8.3)	11 (91.7)	
Root filling material					
Gutta-percha	220 (94)	100 (90.9)	9 (9)	91 (91)	0.448
Silver point	0 (0)	0 (0)	0 (0)	0 (0)	
Paste	16 (6.8)	10 (9.1)	2 (20)	8 (80)	
Length of root filling					
Adequate (0–2 mm)	28 (12)	9 (8.2)	1 (11.1)	8 (88.9)	0.751
Short (>2 mm)	195 (83.3)	95 (86.4)	7 (7.4)	88 (92.6)	
Beyond apex	6 (2.6)	3 (2.7)	0 (0)	3 (100)	
Extensive overfill	5 (2.1)	3 (2.7)	2 (66.7)	1 (33.3)	
Perforation					
Absent	234 (100)	110 (100)	10 (9.1)	100 (90.9)	–
Present	0 (0)	0 (0)	0 (0)	0 (0)	
Time since initial treatment					
≥1	234 (100)	110 (100)	10 (9.1)	100 (90.9)	–
<1	0 (0)	0 (0)	0 (0)	0 (0)	
Previous apical surgery					
No	234 (100)	110 (100)	10 (9.1)	100 (90.9)	–
Yes	0 (0)	0 (0)	0 (0)	0 (0)	
Intraoperative factors					
Root filling length					
Adequate	234	109	9	100	
Short	0	1	1	0	
Long	0	0	0	0	
Root filling voids					
Absent	234 (100)	110 (100)	10 (9.1)	100 (90.9)	–
Present	0 (0)	0 (0)	0 (0)	0 (0)	
Complications					
No	234 (100)	110 (100)	10 (9.1)	100 (90.9)	–
Yes	0 (0)	0 (0)	0 (0)	0 (0)	
Sealer extrusion					
No	152 (65)	60 (54.5)	4 (6.7)	56 (93.3)	0.064
Yes	82 (35)	50 (45.5)	6 (12)	44 (88)	
Temporary seal material					

**Table 1** (continued)

Prognostic factors	Inception cohort (n (%))	Study sample (n (%))	Non-healed (n (%))	Healed (n (%))	<i>p</i>
Temporary	0 (0)	0 (0)	0 (0)	0 (0)	–
Definitive	234 (100)	110 (100)	10 (9.1)	100 (90.9)	
Postoperative factors					
Density of root filling					
Dense and tapered		110 (100)	10 (9.1)	100 (90.9)	
Voids present		0 (0)	0 (0)	0 (0)	
Poorly condensed		0 (0)	0 (0)	0 (0)	
Quality of coronal restoration					
Adequate		108 (98.2)	10 (9.3)	98 (90.7)	
Marginal deficiency present		2 (1.8)	0 (0)	2 (100)	
Postoperative signs and symptoms					
Absent		109 (99.1)	9 (8.3)	100 (91.7)	
Present		1 (0.9)	1 (100)	0 (0)	
Radiolucency					
Absent		101 (91.8)	1 (1)	100 (99)	
Present		9 (8.2)	9 (100)	0 (0)	
Postoperative PAI score					
1		75 (68.2)	0 (0)	75 (100)	
2		25 (22.7)	0 (0)	25 (100)	
3		5 (4.5)	5 (100)	0 (0)	
4		4 (3.6)	4 (100)	0 (0)	
5		1 (0.9)	1 (100)	0 (0)	
Fracture					
Absent		110 (100)	10 (9.1)	100 (90.9)	
Present		0 (0)	0 (0)	0 (0)	
Restoration at follow-up					
Definitive filling		36 (32.7)	3 (8.3)	33 (91.7)	
Crown		75 (68.2)	7 (9.3)	68 (90.7)	
Post					
Absent	165 (70.5)	76 (69.1)	8 (10.5)	68 (89.5)	0.788
Present	69 (29.5)	34 (30.9)	2 (5.9)	32 (94.1)	

This study solely focused on the outcomes of single-visit retreatment considering possible preoperative, intraoperative and postoperative factors affecting the results.

This retrospective study presented 90.9 % success rate as 98.2 % of the teeth were asymptomatic and fully functional after a mean observation time of 29 months. Age, gender, tooth type and periodontal defects had no effect on the outcome measures similar to other studies [4, 7]. All patients with asymptomatic non-healed teeth were informed about the situation. It is critical to communicate with the patients for

retaining their teeth whether with successful outcome or being asymptomatic with a notification of routine follow-ups of the involved teeth. Patients in this group and those in the study group were all in agreement for retaining their teeth and were willing to attend further follow-ups.

Root canal retreatment without apical periodontitis was reported to have a high healing rate (93–98 %) in previous studies [4, 7, 22, 23] but due to high incidence of lesions in the teeth involved in the study group, only one tooth was free of apical periodontitis. Therefore, in this study, no conclusions

**Table 2** Intraexaminer (T versus K) and inter-examiner Cohen’s kappa values based on PAI scores that were recorded from the same radiographs within 2 months interval (1 versus 2)

PAI	Intra-examiner		Inter-examiner	
	T 1–T 2 <i>n</i> (%)	K 1–K 2 <i>n</i> (%)	T 1–K 1 <i>n</i> (%)	T 2–K 2 <i>n</i> (%)
1	33 (23.7)	31 (22.3)	32 (23)	29 (20.9)
2	35 (25.2)	35 (25.2)	34 (24.5)	37 (26.6)
3	23 (16.5)	25 (18)	25 (18)	24 (17.3)
4	29 (20.9)	29 (20.9)	29 (20.9)	30 (21.6)
5	19 (13.7)	19 (13.7)	19 (13.7)	19 (13.7)
Cohen’s kappa	0.936 (very good)	0.955 (very good)	0.964 (very good)	0.964 (very good)
<i>p</i>	<0.001**	<0.001**	<0.001**	<0.001**

\*\**p* < 0.01

**Table 3** Distribution of investigated preoperative, intraoperative and postoperative variables and their significance in “healed” and “non-healed” groups

		Number	Healed (n = 100) (n (%))	Non-healed (n = 10) (n (%))	p	Post hoc power
Preoperative factors						
Preoperative pain	Absent	51	48 (94.1)	3 (5.9)	0.334 <sup>a</sup>	0.304
	Present	59	52 (88.1)	7 (11.9)		
Preoperative radiolucency	<2 mm	21	21 (100)	0	0.025 <sup>a,b</sup>	0.715
	2–5 mm	54	51 (94.4)	3 (5.6)		
	>5 mm	35	28 (80)	7 (20)		
Preoperative PAI scores	3	50	48 (96)	2 (4)	0.014 <sup>a,b</sup>	0.792
	4	36	34 (94.4)	2 (5.6)		
	5	24	18 (75)	6 (25)		
	Min-max (median)		3–5 (4)	3–5 (5)		
Periodontal defects	Mean ± SD		3.7 ± 0.76	4.4 ± 0.84	0.613 <sup>a</sup>	0.142
	Absent	96	88 (91.7)	8 (8.3)		
Root filling density	Present	14	12 (85.7)	2 (14.3)	1.000 <sup>b</sup>	0.067
	Good	2	2 (100)	0		
Length of root-fill	Poor	96	87 (90.6)	9 (9.4)	0.072 <sup>b</sup>	0.831
	Unfilled	12	11 (91.7)	1 (8.3)		
	Adequate	11	9 (81.8)	2 (18.2)		
	Short (>2 mm)	95	88 (92.6)	7 (7.4)		
	Beyond apex	3	3 (100)	0		
Extensive overfill	Extensive	1	0	1 (100)		
	overfill					
Intraoperative factors						
Sealer extrusion	Yes	50	44 (88)	6 (12)	1.000 <sup>a</sup>	0.157
	No	60	56 (93.3)	4 (6.7)		
Postoperative factors						
Restoration at follow-up	Definitive	36	33 (91.7)	3 (8.3)	1.000 <sup>a</sup>	0.042
	Crown	74	67 (90.5)	7 (9.5)		
Post	Absent	76	68 (89.5)	8 (10.5)	0.721 <sup>a</sup>	0.089
	Present	34	32 (94.1)	2 (5.9)		

\*p < 0.05

<sup>a</sup> Fisher’s exact test

<sup>b</sup> Fisher-Freeman Halton test

could be drawn regarding the success rate of retreatments in apical periodontitis-free teeth. Yet, the presence of apical periodontitis, in this study, is an indispensable factor for the success rate of both root canal treatments and retreatments which was frequently reported in previous studies with a success rate in the range of 64–87 % [6, 7, 9, 15, 16, 23, 25]. Contrary to previous studies, in the presence of apical periodontitis with a reasoning of stronger predictive ability of other prognostic factors (presence of perforation, root filling quality, postoperative restoration) that were unique to retreatment [7], in this study, none of the prognostic factors that were reported to be primary predictors statistically affected the results. The size of the apical periodontitis was critical for the outcome of retreatments that was consistent with other studies [3, 25].

Both in primary root canal treatments [16] and root canal retreatments [15], the size of the lesion has not been reported to be a significant predictor, providing that larger lesions need a longer observation time. Considering the observation time of this study, the impact of lesion size on the outcome may decrease over time, which needs to be verified in long-term follow-up.

Preoperative perforation and root filling quality were previously reported to be primary predictors [7], but in this study, no evidence was found supporting this statement. The reason for this might be the study group involved in this study that consisted of patients who applied to the university clinics for compromised root canal treatments they had received previously that were poorly done as a consequence of insufficient

**Table 4** Effect of preoperative radiolucency and length of root filling on the outcomes of single-appointment orthograde retreatment and odds ratio according to logistic regression model

	p	Odds ratio	% 95 CI	
			Lower	Upper
Preoperative radiolucency (>5 mm)	0.012*	6.415	1.509	27.266
Length of root filling (adequate)	0.220	3.129	0.506	19.354

\* p < 0.05

instrumentation, root canal filling or compromised coronal restoration. Therefore, the number of preoperative perforation cases in the archives was scarce and none were good enough for the indication of orthograde retreatment. Only one postoperative perforation case could not be treated and therefore extracted suggesting a deleterious effect of perforation on the outcomes of orthograde retreatments.

The quality of previous root filling (root filling length and density) has been reported to be the most important outcome predictor [4, 7]. The teeth with adequate previous root canal filling might be more resistant to orthograde retreatment [25, 26] due to possible extraradicular biofilm [21, 24, 28], apical cysts [14, 20], foreign-body reactions [12, 13] or undiagnosed root cracks. On the other hand, teeth with inadequate previous root canal filling are more susceptible to routine orthograde retreatment [1, 26]. Although adequate root canal filling length showed an OD of 3.13 (95 % CI 0.51–19.35), no statistical significance was found between the quality of previous root canal filling and outcome of retreatments. This might be due to the approach of the previous dentist to root canal treatment causing many failed or failing cases to be involved of insufficiently shaped and filled root canals with only one or two 0.02 taper gutta-percha cones, ending around the middle third of the root canal. Hence, this could have affected any statistical difference consisting adequate previous root canal treatment cases.

The archive consisted of patients with inadequate previous root canal treatments in terms of both root canal filling length and density. There were only nine teeth with adequate length that lacked the ideal density, whilst only two teeth had adequate density, yet both were overfilled. Although apical lesion size seemed to be the only predictor according to the results of this study, prolonged follow-up time and increased number of patients in the study group may reveal other predictors regarding the outcome and success rate of single-appointment orthograde root canal treatment.

Endodontic treatment requires multi-step procedures including root canal disinfection and a final functioning, aesthetic coronal restoration. The importance of coronal restorations was reported in previous studies as primary predictors regarding the outcome of endodontic treatments [16, 19, 31]. Since all treatments were carried out in single appointment, the negative effect of temporary restorations was not an issue in this study [7]. The type of the definitive restoration was also found to be ineffective on the outcome of orthograde retreatments that was also in agreement with previous studies [4, 7]. The single-appointment approach might also be the reason for high success rate of orthograde retreatments in this study regarding the previous studies [1, 5, 8, 9, 19, 33, 35]. Patients are being followed up for long-term observations on the outcome measures reported in this study.

## Conclusions

After 29 months of mean observation time, of the single-appointment orthograde retreatments of 110 endodontically treated teeth, 90.9 % of the teeth were healed, whereas 98.2 % remained asymptomatic and functional. The primary and only predictor seems to be the size of apical periodontitis (>5 mm).

## Compliance with ethical standards

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

**Funding** The work was not supported by any fund 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.

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

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