Original Article

pISSN, eISSN 0125-5614
M Dent J 2025; 45 (2) : 93-108

Effect of restorative factors on the periapical status of well-obturated endodontically treated teeth: A retrospective cohort study

Nattheera Poomchart[1], Danuchit Banomyong[2], Sittichoke Osiri[2], **Kallaya Yanpiset**[2]

[1] *Residency Training Program in Endodontics, Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

[2] *Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

Objectives: This retrospective cohort study evaluated the effect of restorative factors on the periapical status of well-obturated endodontically treated teeth.

Materials and Methods: The clinical/radiographic data of restorative factors were gathered from patients receiving non-surgical root canal treatment at the Faculty of Dentistry/Mahidol University, Thailand, from October 2017 to December 2020; only well-obturated endodontically treated teeth were included. Coronal restoration quality, type of restoration, definitive restoration status, defective restorations during follow-up, waiting period for the definitive restoration, post placement, and other factors associated with post-retained restorations were collected. From the clinical/radiographic assessments, endodontic outcomes were evaluated as success (healed) or failure (healing/disease) rate. Multivariable modified Poisson regression analyses were conducted to identify significant risk factors to the outcome.

Results: The study analyzed 405 well-obturated endodontically treated teeth from 319 patients, 9-83 years old. At the 29.9 ± 13.9-month recall, the overall success rate (healed) was 84.4%. The restorative factors that significantly decreased the success rate were (1) inadequate/unsealed coronal restoration, (2) temporary (e.g. Cavit or IRM) restoration, (3) absence of a definitive restoration, and (4) >6-month waiting period for definitive indirect restoration. For teeth with post-retained restorations, <4-mm remaining root filling and misdirected post-space preparation significantly reduced the success rate.

Conclusions: The success rate of well-obturated endodontic treatment was 84.4%. The adequate/sealed, definitive coronal restoration and placing an indirect restoration within 6 months improved the success rate. Moreover, ≥4-mm remaining root filling and appropriate post-space preparation significantly increased the success rate.

Keywords: coronal restoration, endodontic outcomes, endodontically treated teeth, restorative factors, retrospective cohort study.

How to cite: Poomchart N, Banomyong D, Osiri S, **Yanpiset K**. Effect of restorative factors on the periapical status of well-obturated endodontically treated teeth: A retrospective cohort study. M Dent J 2025;45(2): 93-108.

Introduction

Achieving the highest endodontically treated teeth (ETT) success rate relies on the quality of the root canal treatment (RCT) and the coronal restoration [1-3]. An ETT is restored to protect the remaining tooth structure against fracture and, provide a coronal seal to prevent root canal reinfection. Thus, a good coronal restoration improves RCT long-term success [4, 5].

Most studies on the effect of restorations on endodontic success included teeth with both good- and poor-quality RCT [1-3, 6-9], in which the significant factors were analyzed from a combination of the teeth regardless of the quality

Corresponding author: Kallaya Yanpiset
Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Mahidol University,
No. 6, Yothi Road, Ratchathewi District, Bangkok 10400, Thailand
Tel: + 66 2200 7825 ext.7827 Email: kallaya.yan@mahidol.ac.th
Received: 7 March 2025 **Revised:** 27 April 2025 **Accepted:** 29 April 2025

of RCT [2, 3, 6-8]. Thus, the effect of the coronal restoration on periapical status tended to be partly affected by the poor RCT. The effects of restorative factors (RFs) on endodontic outcome could be more noticeable in a cohort study focusing on well-obturated ETT with an appropriate recall-period. Moreover, assessing endodontic outcomes by evaluating dynamic changes of periapical status over a period provides a more effective measure of treatment success.

Many RFs affect the RCT outcome. A definitive restoration should be immediately placed to decrease the coronal leakage and tooth fracture risk, potentially resulting in periapical disease [10]. However, definitive restoration (indirect type, such as overlay or crown) placement may be delayed in teeth with a questionable prognosis, or due to a waiting list for restorative treatment. The appropriate waiting period for the definitive restoration is still unresolved [11, 12]. The potential effects of different tooth/restoration parameters and waiting periods for a definitive restoration on the periapical health should be identified, particularly in well-obturated ETT.

Teeth with a substantial loss of coronal structure may require a post to provide retention for a coronal restoration [4, 13]. The post-space preparation may reduce the apical seal of the root canal filling, which may influence treatment outcome [3, 14]. Laboratory studies have found that the apical seal of a root canal filling should be ≥4-5 mm [15]. However, the acceptable remaining length of the root canal filling was reported to be 3-4 mm in clinical studies combining both good- and poor-quality RCT [3, 14]. Other RFs related to the teeth with post-retained restorations, e.g., a misdirected post preparation or a gap between the post tip and root canal filling that may be detrimental to the outcome, have not been comprehensively evaluated. Thus, the effects of the RFs in post-retained restorations on the endodontic outcome should be investigated in well-obturated ETT.

No cohort studies in the impact of RFs, particularly on the periapical status of well-obturated ETT have been published. Good-quality RCTs can be assumed from well-obturated root canal fillings on radiographs [16]. Therefore, the objective of this retrospective cohort study was to evaluate the effects of RFs on the periapical status of well-obturated ETT.

Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki. This retrospective cohort study was approved by the Institutional Review Board of the Faculty of Dentistry and Faculty of Pharmacy, Mahidol University, Bangkok, Thailand (MU-DT/PY-IRB 2021/097.0212).

Sample size calculation

The sample size was determined using Stata/MP software version 16.1 (Stata Corp., College Station, TX, USA) with a statistical power=80% and a significance level=0.05, based on a clinical study [3]. The data of the teeth with good-quality RCT revealed a 90.1% success rate for the teeth with adequate coronal restorations and a 61.2% success rate for those with inadequate restorations. The calculated sample size was ≥95 teeth: 77 teeth with adequate restorations, and 18 teeth with inadequate restorations.

Data acquisition from the clinical and radiographic records

The clinical/radiographic data were collected from the dental records and periapical radiographs of the patients who received

non-surgical RCT (NSRCT) at the Endodontic Clinic, Faculty of Dentistry/Mahidol University, Bangkok, Thailand, from October 2017 to December 2020.

Inclusion criteria

The inclusion criteria were well-obturated, endodontically treated permanent teeth with mature root formation in patients with an American Society of Anesthesiologists (ASA) physical status I or II, and had a minimum follow-up period of 12 months. The dental records/radiographs were adequate for evaluating root canal obturation quality, periapical status, and RFs. The root canal filling quality was evaluated as previously described [16], where good root canal obturation met the following criteia: (a) root canal filling within 0−2 mm from the radiographic apex, and (b) homogenous root canal filling density. After complete RCT, interim or definitive coronal restorations were performed according to the restorative plan with different waiting periods.

Exclusion criteria

The exclusion criteria were teeth with a history of traumatic injury, root resorption, advanced periodontal disease, crack, root fracture, or root perforation.

The data from the clinical records/ radiographs comprised age, sex (male/female), tooth type (anterior/premolar/molar), tooth location (maxilla/mandible), RCT type (primary/ retreatment), preoperative periapical lesion (absent/present), lesion size (no lesion/≤5 mm/ >5 mm, based on the longest distance) [17], and tooth structure loss (surfaces). Moreover, the restorative and timing factors were defined as follows:

- *Quality of the coronal restoration at the last recall* was assessed based on dental records of clinical and radiographic evaluations of restoration integrity [3, 9, 16, 18] at follow-up examination, according to the following criteria:
  - *Adequate seal*: Restorations with radiographically intact margins and no evidence of fractures, cracks, recurrent caries, or marginal discoloration as noted in the clinical records.
  - *Inadequate seal*: Restorations with detectable signs of overhangs, fractures, cracks, poor marginal fit, open margins, recurrent caries, or absence of a coronal restoration.
- *Type of restoration at the last recall* was categorized as indirect restoration (cuspal coverage-overlays or crowns), direct resin composite, or temporary restoration (temporary filling with Cavit/IRM/glass-ionomer cement, or temporary crown/bridge).
- *Status of the definitive restoration* according to the pre-operative plan (absent/present).
- *Defective restorations during the follow-up period* (no/yes) including caries, fractures, dislodgement, and restoration repair.
- *Waiting period* from root canal obturation to definitive restoration (≤6 months/>6 months). For teeth that had not received a definitive restoration, the waiting period was determined until the last recall.
- *Post placement* (absent/present).

For teeth with post placement, additional information was collected:

- Post type (metallic/non-metallic post).
- Remaining root canal filling length (<4 mm or ≥4 mm).
- Extension of the post in relation to the root length: coronal third, middle third, or apical third [19, 20].
- Post width at the apical end of the post [21] as a ratio of the root width and categorized as ≤ $^1/_3$ or > $^1/_3$ of the root width [20, 22]. For a tooth with two root canals in a single root, the post width was not determined.

- Gap between the post and gutta-percha (absent/present).
- Misdirection of the post (absent/present).

Outcome assessment

The radiographic images were imported into the ImageJ software (National Institute of Health, Bethesda, MD, USA) and adjusted for brightness/contrast/angulation. One examiner (N.P.) performed all radiographic interpretations after calibration twice with a set of 30 periapical radiographs within a two-week interval. Cohen's Kappa coefficient was used to assess the intra-examiner reliability until achieving almost perfect agreement (k=0.81-0.99) [23]. In the present study, the intra-examiner reliability score was 0.917.

The outcomes were evaluated based on the patients' clinical/radiographic information using Friedman and Mor's criteria [24] and categorized as: 'healed' (normal clinical/radiographic appearance), 'healing' (reduced periapical radiolucency size and no clinical signs/symptoms), and 'disease' (persistent or new periapical radiolucency, with or without clinical signs/symptoms). The outcome was grouped into two categories: success (healed) or failure (healing/disease) following Strindberg's criteria [25]. For multi-rooted teeth, the overall outcome was evaluated from the root with the worst periapical status. Additionally, the functional rate was assessed, indicating the teeth with a normal clinical presentation, regardless of their radiographic appearance.

Statistical analysis

Stata/MP software version 16.1 (Stata Corp.) and SPSS software version 26.0 (IBM, New York, NY, USA) were utilized for data analysis. The treatment outcome distributions were reported as frequency and percentage. Modified Poisson regression analyses, using univariable and multivariable models, identified the potential risk factors to the outcome and risk ratios with a significance level at 5% ($p<0.05$). The effect of the waiting period for the definitive restoration on the outcome based on restoration types was also investigated.

Results

Among 3,538 teeth with NSRCT, 825 teeth had follow-up data. Based on the criteria, 517 teeth (62.7%) were initially included, of which 112 teeth were excluded. Finally, 405 teeth with a well-obturated root canal filling, comprising 116 anterior teeth, 145 premolars, and 144 molars (219 maxillary and 186 mandibular teeth), from 319 patients remained for periapical status outcome determination (Figure 1).

Approximately two-thirds of the patients were females (208/319 patients). The patients had a median age of 54 years (interquartile range 43–63 years). The patients were divided into two groups (<60 years and ≥60 years) in the age effect analysis.

With a mean recall period of 29.9 ± 13.9 months (12.1–64.5 months), 342/405 teeth (84.4%) with a well-obturated root canal filling were success (healed) while 63/405 teeth (15.6%) were failure (healing and disease). In the failure group, 18 teeth (4.5%) were in the healing stage with a reduced periapical radiolucency size, and 45 teeth (11.1%) were diseased with a persistent, enlarged, or newly emerged periapical radiolucency.

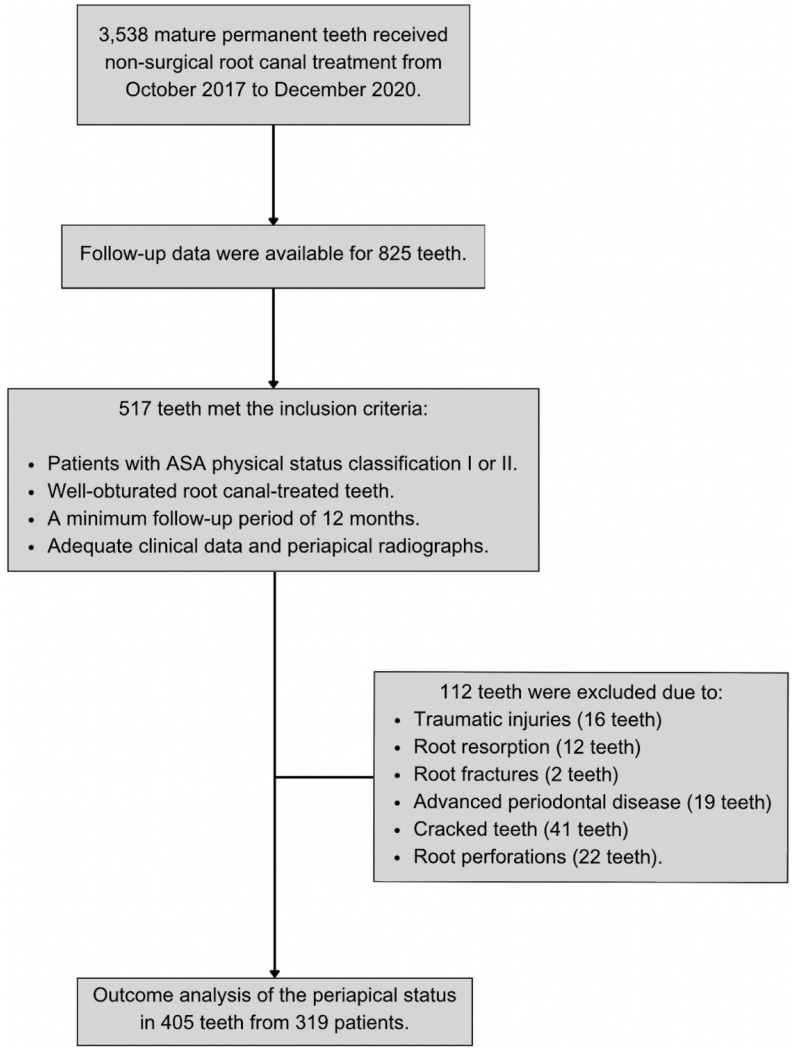


Figure 1 Flow chart illustrating the recruitment process of the teeth that received non-surgical endodontic treatment and different coronal restorations based on the inclusion and exclusion criteria.

The restoration types at the last recall were indirect restorations (194 teeth, 47.9%), direct resin composite (186 teeth, 45.9%), and temporary restorations (25 teeth, 6.2%). Moreover, 69.1% (280 teeth) were restored with definitive restorations following the treatment plan, either indirect restorations or resin composite. Additionally, 91.6% (371 teeth) had adequate-seal coronal restorations, and 47.2% (191 teeth) received definitive restorations within 6 months. During the follow-up period, 44 teeth (10.9%) required repair/replacement of the defective restorations. There were 172 teeth (42.5%) with post-retained restorations (Table 1).

The univariable analysis (Table 1) showed no significant difference in treatment outcomes between the sex and age groups. The significant preoperative factors to the treatment outcome were the type of RCT (p=0.021), preoperative periapical lesion (p<0.001), and lesion size (p<0.001). The significant RFs were the quality and type of restoration at the last recall (p<0.001), presence of a definitive restoration (p=0.047), restorative defect during the follow-up period (p=0.001), and waiting period for a definitive restoration (p=0.001). However, post placement did not significantly affect the treatment outcome.

Table 1 The characteristics and distributions of the demographic data, preoperative, restorative, and timing factors with univariable analysis of treatment outcome in 405 teeth.

Factors	Success (Healed)	Failure (Healing + Disease)	Crude Risk Ratio	95%CI of Risk Ratio	*p*-value
	n (%)	n (%)			
Sex					
Male (n=154)	129 (83.8)	25 (16.2)	1.07	0.73–1.58	0.722
Female (n=251)	213 (84.9)	38 (15.1)	1		
Age					
< 60 years (n=253)	217 (85.8)	36 (14.2)	1		
≥ 60 years (n=152)	125 (82.2)	27 (17.8)	1.25	0.85–1.83	0.253
Type of RCT*					
Primary treatment (n=352)	302 (85.8)	50 (14.2)	1		
Retreatment (n=53)	40 (75.5)	13 (24.5)	1.73	1.09–2.74	0.021*
Preoperative periapical lesion*					
Absent (n=118)	110 (93.2)	8 (6.8)	1		
Present (n=287)	232 (80.8)	55 (19.2)	2.83	1.62–4.92	<0.001*
Periapical lesion size*					
No lesion (n=118)	110 (93.2)	8 (6.8)	1		
≤ 5 mm (n=148)	129 (87.2)	19 (12.8)	1.89	1.03–3.48	0.040*
> 5 mm (n=139)	103 (74.1)	36 (25.9)	3.82	2.17–6.72	<0.001*
Restored surfaces†					
1 surface (n=51)	45 (88.2)	6 (11.8)	1		
2 surfaces (n=144)	123 (85.4)	21 (14.6)	1.24	0.64–2.42	0.529
> 2 surfaces (n=148)	129 (87.2)	19 (12.8)	1.09	0.55–2.15	0.800
Quality of coronal restoration at the last recall*					
Adequate seal (n=371)	329 (88.7)	42 (11.3)	1		
Inadequate seal (n=34)	13 (38.2)	21 (61.8)	5.46	3.76–7.91	<0.001*
Restoration type at the last recall*					
Indirect restoration (n=194)	167 (86.1)	27 (13.9)	1		
Direct composite (n=186)	160 (86.0)	26 (14.0)	1.01	0.67–1.51	0.983
Temporary (n=25)	15 (60.0)	10 (40.0)	2.87	1.67–4.96	<0.001*
Definitive restoration status*					
Absent (n=125)	100 (80.0)	25 (20.0)	1.47	1.00–2.16	0.047*
Present (n=280)	242 (86.4)	38 (13.6)	1		

Table 1 The characteristics and distributions of the demographic data, preoperative, restorative, and timing factors with univariable analysis of treatment outcome in 405 teeth. (continued)

Factors	Success (Healed)	Failure (Healing + Disease)	Crude Risk Ratio	95%CI of Risk Ratio	*p*-value
	n (%)	n (%)			
Restoration defect during the follow-up period*					
No (n=361)	311 (86.1)	50 (13.9)	1		
Yes (n=44)	31 (70.4)	13 (29.6)	2.13	1.35–3.38	0.001*
Waiting period for the definitive restoration*					
≤ 6 months (n=191)	171 (89.5)	20 (10.5)	1		
> 6 months (n=214)	171 (79.9)	43 (20.1)	1.92	1.29–2.86	0.001*
Post placement					
Absent (n=233)	195 (83.7)	38 (16.3)	1.12	0.76–1.65	0.557
Present (n=172)	147 (85.5)	25 (14.5)	1		

*Statistically significant factors determined by univariable analysis.

†Missing data was observed for this factor in 62 teeth due to a lack of information in the clinical records.

Most direct resin composite and indirect restorations exhibited an adequate seal at 90.3% and 95.9% respectively, while 32% of the temporary restorations had an inadequate seal. The teeth with adequate restorations had an 88.7% healed rate, while those with inadequate restorations had a much lower healed rate (38.2%). In the sub-analysis, the healed rates of the indirect restorations, direct resin composite, and temporary restorations with an inadequate seal markedly decreased to 62.5%, 33.3%, and 25%, respectively, compared with adequately sealed restorations (Table 2).

Table 2 The types and the quality of the coronal restorations on treatment outcomes.

Restoration type	Quality of coronal restoration			
	Adequate seal		Inadequate seal	
	Success (Healed)	Failure (Healing + Disease)	Success (Healed)	Failure (Healing + Disease)
	n (%)	n (%)	n (%)	n (%)
Indirect restoration (n=194)	162 (87.1)	24 (12.9)	5 (62.5)	3 (37.5)
Direct resin composite† (n=186)	154 (91.7)	14 (8.3)	6 (33.3)	12 (66.7)
Temporary restoration†† (n=25)	13 (76.5)	4 (23.5)	2 (25.0)	6 (75.0)
Total (n=405)	329 (88.7)	42 (11.3)	13 (38.2)	21 (61.8)

†The combination of direct resin composite restorations for both interim and definitive restorations.

††The combination of temporary filling and temporary crown/bridge.

The factors with $p<0.25$ in the univariable analysis were analyzed using the multivariable analysis of the outcome in 405 teeth (Table 3). Two factors, having a periapical lesion and lesion size were associated; therefore, only the periapical lesion size was included in the multivariable model. From the multivariable analysis, the quality/type of coronal restoration at the last recall, definitive restoration status, waiting period for definitive restoration, periapical lesion size, and RCT type significantly influenced the outcome.

In the multivariable analysis, the teeth with endodontic retreatment demonstrated a significantly lower healed rate compared with those with primary RCT ($p=0.008$). Periapical lesions size >5 mm was associated with a significantly lower healed rate compared with those with no lesion or lesions ≤5 mm ($p<0.001$ and 0.013 respectively). The healed rate was

Table 3 The multivariable analysis of the factors with *p*-value <0.25 in the univariate analysis (n=405 teeth).

Factors	Adjusted Risk Ratio	95%CI of Risk Ratio	*p*-value
Type of RCT**			
Primary treatment	1		
Retreatment	1.76	1.16–2.66	0.008**
Periapical lesion size**			
No lesion	1		
≤ 5 mm	2.02	1.16–3.52	0.013**
> 5 mm	4.38	2.61–7.35	<0.001**
Quality of the coronal restoration at the last recall**			
Adequate seal	1		
Inadequate seal	5.38	3.56–8.13	<0.001**
Restoration type at the last recall**			
Indirect restoration	1		
Direct resin composite restoration	1.19	0.69–2.05	0.529
Temporary restoration	2.77	1.29–5.95	0.009**
Definitive restoration status**			
Absent	2.20	1.07–4.49	0.031**
Present	1		
Restoration defect during the follow-up period			
No	1		
Yes	1.08	0.69–1.68	0.740
Waiting period for the definitive restoration**			
≤ 6 months	1		
> 6 months	1.78	1.07–2.94	0.026**

**Statistically significant factors determined by multivariable analysis.

significantly lower in the teeth with inadequate-seal restorations than in those with adequate-seal restorations (p<0.001, risk ratio=5.38). Teeth with temporary restorations had significantly lower healed rates than those with direct resin composite and indirect restorations (p=0.002 and 0.009; risk ratio=2.32 and 2.77, respectively). The absence of a definitive restoration significantly decreased the healed rate compared with its presence (p=0.031, risk ratio=2.20). The waiting period for a definitive restoration longer than 6 months significantly decreased the healed rate compared with those completed within 6 months (p=0.026, risk ratio=1.78).

In the subgroup analysis (Figure 2) on the waiting period for a definitive restoration in the direct composite groups (86 teeth), 69.8% (60 teeth) were completed within 1 month. In the direct composite subgroups, no significant difference in the treatment outcomes was observed between the teeth with waiting periods within and longer than one month (p=0.547). Of the 319 teeth planned for indirect definitive restorations, 60.8% (194 teeth) received indirect restorations at the last recall. The subgroup analysis revealed that the teeth that received a definitive restoration after 6 months had a significantly lower healed rate compared with those completed within 6 months (p=0.011, risk ratio=1.93).

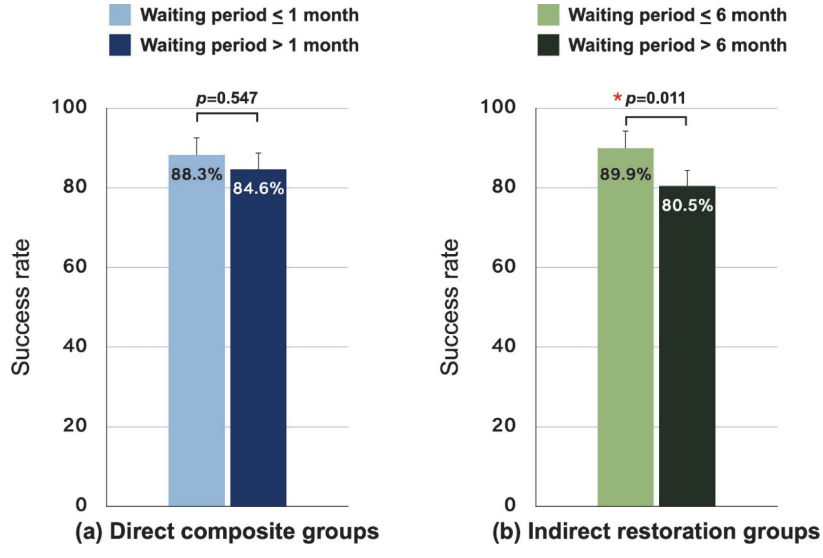


Figure 2 The success rate in the subgroup analysis on the waiting period for the definitive restorations in the (a) direct resin composite groups and (b) indirect restoration groups (*: p<0.05-significant).

The presence of restorative defects during the follow-up period did not significantly affect the treatment outcome (p=0.74). During the follow-up period, 44 teeth had restoration defects, the defective restorations in 40 teeth (90.9%) were repaired immediately after detection. At the last recall, 31 teeth with adequate-seal restorations showed an 87.1% healed rate that was markedly higher than those (13 teeth) with inadequate-seal restorations (30.8%) (Figure 3).

In the 172 teeth with the post-retained restorations, no root perforation was found after post-space preparation. The overall healed rate of the well-obturated ETT with post-retained restorations was 85.5%. For the remainder, 2.3% (4 teeth) were healing, and 12.2% (21 teeth) exhibited disease. For the risk factors analysis, the RFs with p<0.25 in the univariable analysis were included into a multivariable model of 172 teeth with post-retained restorations (Table 4). The multivariate analysis identified two significant factors to the outcomes: <4-mm remaining root canal filling and post misdirection. Teeth with <4-mm remaining root canal filling or with post misdirection had significantly lower healed rates compared with the teeth with a root canal filling ≥4 mm (p=0.001, risk ratio=3.79) or without post-misdirection (p=0.006, risk ratio=2.74).

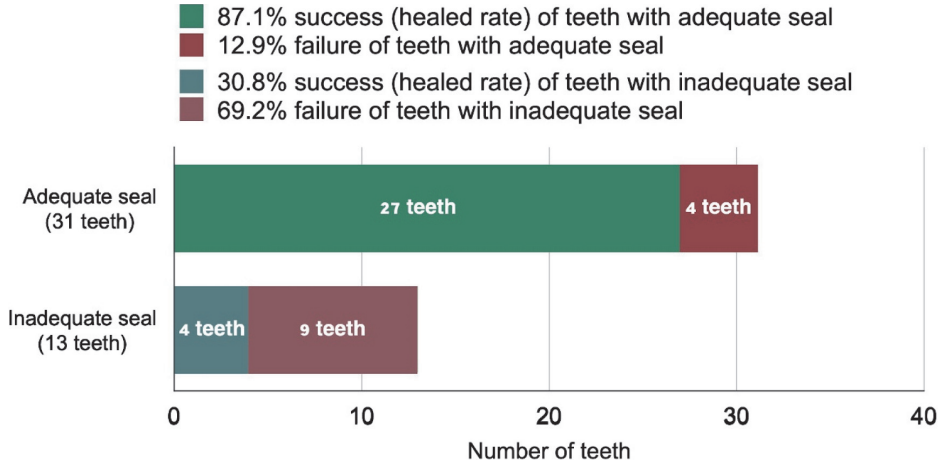


Figure 3 The treatment outcome of 44 teeth that presented with defective restorations during the follow-up period (requiring repair or replacement) based on the quality of the coronal restoration at the last recall.

Table 4 The characteristics and distributions of the restorative factors after univariable and multivariable analysis of the endodontic outcomes in 172 teeth with post-retained restorations.

Factors	Success (Healed) (n=147)	Failure (Healing + Disease) (n=25)	Risk Ratio		Univariable analysis		Multivariable analysis	
	n (%)	n (%)	Crude	Adjusted	95%CI of Risk Ratio	*p*-value	95%CI of Risk Ratio	*p*-value
Type of post								
Metallic post (n=28)	24 (85.7)	4 (14.3)	1					
Non-metallic post (n=144)	123 (85.4)	21 (14.6)	1.02	-	0.46–2.28	0.960	-	-
Post length								
Coronal third (n=7)	6 (85.7)	1 (14.3)	1.09	1.95	0.24–4.92	0.911	0.35 – 10.85	0.444
Middle third (n=145)	126 (86.9)	19 (13.1)	1	1.45			0.57 – 3.67	0.436
Apical third (n=20)	15 (75.0)	5 (25.0)	1.91	1	0.91–3.99	0.086		
Post width (n=115) †								
≤ 1/3 root width (n=105)	88 (83.8)	17 (16.2)	1					
> 1/3 root width (n=10)	8 (80.0)	2 (20.0)	1.24	-	0.39–3.86	0.716	-	-
Remaining root filling**								
< 4 mm (n=23)	15 (65.2)	8 (34.8)	3.05	3.79	1.65–5.63	<0.001	1.71 – 8.41	0.001**
≥ 4 mm (n=149)	132 (88.6)	17 (11.4)	1	1				
Gap between the post and root filling								
Absent (n=124)	108 (87.1)	16 (12.9)	1	1				
Present (n=48)	39 (81.3)	9 (18.7)	1.45	1.46	0.79–2.68	0.232	0.80 – 2.66	0.212
Misdirected of post**								
Absent (n=158)	138 (87.3)	20 (12.7)	1	1				
Present (n=14)	9 (64.3)	5 (35.7)	2.82	2.74	1.37–5.82	0.005	1.34 – 5.57	0.006**

†Missing data in 57 teeth because the post width could not be determined.

**Statistically significant factors determined by multivariable analysis.

Discussion

This retrospective cohort study is the first to identify the effect of RFs on endodontic outcomes in ETT showing good root canal obturation on periapical radiographs. Most previous studies had a cross-sectional design that investigated the RFs to the outcome in the teeth with both good and poor RCT [1-3, 6-9, 11, 12, 16, 26-30]. However, our present study was designed by including only teeth with well-obturated root canals and excluding teeth with poor root canal obturation. This study design enabled a more accurate assessment of the actual effect of RFs on treatment outcomes. In addition, this retrospective study

evaluated the outcomes over a recall period of more than 12 months to monitor the dynamic changes in periapical status, which provided a more effective outcome assessment than the evaluation at a single time point.

This study studied on the RFs affecting the outcome, but limitedly focused on well-obturated ETT, reflecting the controlled quality of endodontic treatment. All endodontic procedures were performed under aseptic conditions with proper root canal disinfection before the obturation. The procedures included rubber dam isolation, root canal disinfection through mechanical preparation; intracanal irrigation with sodium hypochlorite; and antimicrobial intracanal medication with calcium hydroxide, which significantly reduced the bacterial load within the root canals [31-33]. After the disinfection, root canal obturation was well performed to achieve apical seal to prevent reinfection. It could not be denied that not only the quality of coronal restoration but also the quality root canal treatment strongly affected the periapical status of ETT [2, 3, 6, 7, 34, 35].

In the cross-sectional studies, 74-91% success rates were reported for the teeth with well-obturated root canals [1-3, 6-9, 16, 30]. Our retrospective study found an 84.4% success (healed) rate at the 30-month recall, similar to previous results. However, 4.5% of the teeth (n=18) in the failure group were in the healing stage. Of these teeth, 14 teeth had large preoperative periapical lesions. An extended follow-up of 3-4 years or longer may be required for the complete healing of large lesions [36, 37], which would likely increase the healed rate. In our study with an overall functional rate of 88.9%, none of the healing teeth had clinical signs/symptoms. These healing teeth might heal completely when evaluated using a longer recall period.

This study identified four significant RFs on the outcome of well-obturated ETT. The most impactful factor was the quality of the coronal restoration with the highest risk ratio (5.38), indicating inadequate restorations led to more RCT failures, consistent with previous studies [1-3, 6, 27-29, 38, 39]. Good coronal restorations provide a seal to prevent bacterial leakage [4, 5, 37, 40, 41], enhancing the highest treatment success in combination with good RCT [2, 3].

The restoration types were categorized in our study into direct resin composite, indirect restorations, and temporary restorations. Most temporary restorations used Cavit and IRM. Laboratory studies [42, 43] showed that these temporary fillings should be used in sufficient thickness, avoid excessive occlusal force, and for a short period to prevent dislodgement or coronal leakage. The temporary restorations in our study were unintentionally used for over 12 months due to the patients not attending the restorative appointment. Consequently, the temporary restoration group had a significantly lower healed rate than the other restoration groups, indicating that prolonged use of the temporary restoration negatively impacted the outcome. Additionally, the inadequate-seal temporary restorations subgroup had higher failure rates than the adequate-seal subgroup.

Having a definitive restoration significantly improved the treatment outcomes in our study. ETT require appropriate definitive restorations, either direct or indirect restorations, to provide a better coronal seal and tooth protection compared with interim or temporary restorations [44]. In our study, teeth with direct (resin composite) and indirect (overlay/crown) definitive restorations showed very high healed rates (97.7% and 95.9%, respectively). For teeth waiting for definitive restorations, any problems with the interim restorations tended to negatively affect the outcome.

The waiting period for definitive restorations significantly influenced the treatment outcomes. The teeth restored ≤6 months had a higher healed rate than those restored >6 months. The delay in definitive restorations placement increased the risk of coronal leakage, tooth fracture, and other failures, thus overall success decreased.

In the present study, the waiting period for a definitive indirect restoration was generally longer than that for a direct resin composite restoration. The teeth definitively restored with direct resin composites were usually completed ≤1 month after root canal obturation. Teeth restored with direct resin composite >1 month later had a reduced healed rate; however, the difference was not significant. Hence, teeth should be definitively restored with direct composite as planned within one month after RCT to prevent the risk of failure.

For the teeth planned for indirect definitive restorations, a waiting period >6 months significantly lowered the healed rate compared with those restored ≤6 months. Among the diseased teeth, 76% (34 teeth) had received the definitive restoration >6 months, and 44.4% (20 teeth) had unrestorable tooth fractures requiring tooth extraction. Therefore, unnecessarily delayed definitive indirect restorations placement increased the risk of coronal leakage and tooth fracture, adversely affecting the periapical status of the teeth.

The defective interim restorations did not significantly affect the treatment outcomes. This was because regular follow-ups were conducted to monitor and correct small interim restoration defects before they enlarged, causing significant coronal leakage or fracture. Thus, interim restoration defects did not increase the risk of treatment failure if they were repaired immediately after detection [10].

The presence of a post did not significantly impact the treatment outcome in well-obturated ETT. However, the post-space preparation may compromise the apical seal of a root canal filling. In this study, inadequate remaining gutta-percha and post misdirection had a significant adverse effect on the outcome. Remaining gutta-percha <4 mm negatively impacts endodontic outcomes by compromising the apical seal, as shown clinically by Thampibul et al. [3] and supported by laboratory findings, in which ≥4-5 mm of gutta-percha should remain to ensure an adequate apical seal [15, 22]. In our study, half of the failed teeth with misdirected posts had <4-mm remaining root canal filling, which might explain the impact of a misdirected post-space preparation on the outcomes. In contrast, all successful misdirected-post teeth had ≥4 mm of apical seal.

For ETT with post-retained restorations, studies demonstrated the negative impact of detecting a gap between the post and root canal filling on the treatment outcomes [45, 46]. However, our study did not find this effect on the endodontic outcome. This may be because most of the gap-detected teeth had a gap <1 mm and still had an adequate length of remaining root canal filling >4 mm without other post placement defects. Therefore, the combination of an apical seal from adequate remaining gutta-percha and coronal seal from the intra-radicular restoration led to successful outcomes.

Conclusion

Well-obturated ETT demonstrated a high success (healed) rate (84.4%) and functional rate (88.9%). However, the success could be compromised by an inadequate-seal coronal

restoration, absence of a definitive restoration, long-term temporary restoration, and delayed placement of a definitive indirect restorations for over 6 months. For the teeth with post-retained restorations, high success (85.5%) and functional (87.8%) rates were found. The success was adversely affected by <4 mm of remaining gutta-percha and post misdirection.

Highlights

- This retrospective cohort study in endodontically well-treated teeth reported the restorative factors affecting endodontic success.
- A definitive coronal restoration, either direct or indirect type, should be placed as soon as possible after RCT.
- If indirect restoration (crown) is planned but has to be delayed, the waiting period should not exceed 6 months.
- In teeth with post-retained restorations, the post-space must be carefully prepared to ensure a minimum of 4-mm remaining root canal filling and not deviate from the root canal path.
- Maintaining regular follow-up of ETT with direct restorations is essential to ensure the integrity and coronal seal.

Acknowledgements

The authors express our sincere gratitude to Asst. Prof. Dr. Chulaluk Komoltri for her support and guidance in statistical analysis.

References

1. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. ***Int Endod J***. 1995 Jan;28(1):12-18. doi: 10.1111/j.1365-2591.1995.tb00150.x.
2. Song M, Park M, Lee CY, Kim E. Periapical status related to the quality of coronal restorations and root fillings in a Korean population. ***J Endod***. 2014 Feb;40(2):182-186. doi: 10.1016/j.joen.2013.10.017.
3. Thampibul P, Jantarat J, Arayasantiparb R. Post-treatment apical periodontitis related to the technical quality of root fillings and restorations in Thai population. ***Aust Endod J***. 2019 Aug;45(2):163-170. doi: 10.1111/aej.12302.
4. Ree M, Schwartz RS. The endo-restorative interface: current concepts. ***Dent Clin North Am***. 2010 Apr;54(2):345-374. doi: 10.1016/j.cden.2009.12.005.
5. Polesel A. Restoration of the endodontically treated posterior tooth. ***G Ital Endod***. 2014 Jun;28(1):2-16. doi: 10.1016/j.gien.2014.05.007.
6. Hommez GMG, Coppens CRM, De Moor RJG. Periapical health related to the quality of coronal restorations and root fillings. ***Int Endod J***. 2002 Aug;35(8):680-689. doi: 10.1046/j.1365-2591.2002.00546.x.
7. Tavares PBL, Bonte E, Boukpessi T, Siqueira JF Jr,Lasfargues JJ. Prevalence of apical periodontitis in root canal-treated teeth from an urban French population: influence of the quality of root canal fillings and coronal restorations. ***J Endod***. 2009 Jun;35(6):810-813. doi: 10.1016/j.joen.2009.03.048.
8. Kalender A, Orhan K, Aksoy U, Basmaci F, Er F, Alankus A. Influence of the quality of endodontic treatment and coronal restorations on the prevalence of apical periodontitis in a Turkish Cypriot population. ***Med Princ Pract***. 2013;22(2):173-177. doi: 10.1159/000341753.
9. Craveiro MA, Fontana CE, de Martin AS, Bueno CE. Influence of coronal restoration and root canal filling quality on periapical status: clinical and radiographic evaluation. ***J Endod***. 2015 Jun;41(6):836-840. doi: 10.1016/j.joen.2015.02.017.
10. AAE COLLEAGUES ONLINE. Coronal leakage: clinical and biological implications in endodontic success [Internet]. ***Endodontics: Colleagues for Excellence*** Fall-Winter. 2002. Available from: https://www.aae.org/specialty/wp-content/uploads/sites/2/2017/07/fw02ecfe.pdf.

11. Chugal NM, Clive JM, Spångberg LSW. Endodontic treatment outcome: effect of the permanent restoration. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod***. 2007 Oct;104(4):576-582. doi: 10.1016/j.tripleo.2007.04.011.
12. Stenhagen S, Skeie H, Bårdsen A, Laegreid T. Influence of the coronal restoration on the outcome of endodontically treated teeth. ***Acta Odontol Scand***. 2020 Mar;78(2):81-86. doi: 10.1080/00016357.2019.1640390.
13. Baba NZ, Goodacre CJ. Restoration of endodontically treated teeth: contemporary concepts and future perspectives. ***Endod Topics***. 2014 Nov;31(1):68-83. doi: 10.1111/etp.12066.
14. Kvist T, Rydin E, Reit C. The relative frequency of periapical lesions in teeth with root canal-retained posts. ***J Endod***. 1989 Dec;15(12):578-580. doi: 10.1016/s0099-2399(89)80153-0.
15. Mattison GD, Delivanis PD, Thacker RW Jr, Hassell KJ. Effect of post preparation on the apical seal. ***J Prosthet Dent***. 1984 Jun;51(6):785-789. doi: 10.1016/0022-3913(84)90377-9.
16. Tronstad L, Asbjørnsen K, Døving L, Pedersen I, Eriksen HM. Influence of coronal restorations on the periapical health of endodontically treated teeth. ***Endod Dent Traumatol***. 2000 Oct;16(5):218-221. doi: 10.1034/j.1600-9657.2000.016005218.x.
17. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. ***J Endod***. 1990 Oct;16(10):498-504. doi: 10.1016/s0099-2399(07)80180-4.
18. Maslamani M, Khalaf M, Mitra AK. Association of quality of coronal filling with the outcome of endodontic treatment: A follow-up study. ***Dent J (Basel)***. 2017 Jan 11;5(1):5. doi: 10.3390/dj5010005.
19. Liu M-C. Restoration of endodontically treated premolars and molars: A review of rationales and techniques. ***J Prosthodont Implantol***. 2014;3(1):2-16. doi: 10.6926/JPI.201408_3(1).0001.
20. Stockton LW. Factors affecting retention of post systems: a literature review. ***J Prosthet Dent***. 1999 Apr;81(4):380-385. doi: 10.1016/s0022-3913(99)80002-x.
21. Fayad MI, Ashkenaz PJ, Johnson BR. Different representations of vertical root fractures detected by cone-beam volumetric tomography: a case series report. ***J Endod***. 2012 Oct;38(10):1435-1442. doi: 10.1016/j.joen.2012.05.015.
22. Goodacre CJ, Spolnik KJ. The prosthodontic management of endodontically treated teeth: a literature review. Part III. Tooth preparation considerations. ***J Prosthodont***. 1995 Jun;4(2):122-128. doi: 10.1111/j.1532-849x.1995.tb00327.x.
23. Landis JR, Koch GG. The measurement of observer agreement for categorical data. ***Biometrics***. 1977 Mar;33(1):159-174. doi: 10.2307/2529310.
24. Friedman S, Mor C. The success of endodontic therapy--healing and functionality. ***J Calif Dent Assoc***. 2004 Jun;32(6):493-503. doi: 10.1080/19424396.2004.12223997.
25. Strindberg LZ. The dependence of the results of pulp therapy on certain factors: an analytic study based on radiographic and clinical follow-up examinations. ***Acta Odontol Scand***. 1956;14:1-175.
26. Imura N, Pinheiro ET, Gomes BP, Zaia AA, Ferraz CC, Souza-Filho FJ. The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist. ***J Endod***. 2007 Nov;33(11):1278-1282. doi: 10.1016/j.joen.2007.07.018.
27. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. ***Int Endod J***. 2011 Jul;44(7):583-609. doi: 10.1111/j.1365-2591.2011.01872.x.
28. Llena C, Nicolescu T, Perez S, Gonzalez de Pereda S, Gonzalez A, Alarcon I, *et al*. Outcome of root canal treatments provided by endodontic postgraduate students. a retrospective study. ***J Clin Med***. 2020 Jun;9(6):1-14. doi: 10.3390/jcm9061994.
29. Pontoriero DIK, Grandini S, Spagnuolo G, Discepoli N, Benedicenti S, Maccagnola V, *et al*. Clinical outcomes of endodontic treatments and restorations with and without posts up to 18 years. ***J Clin Med***. 2021 Feb;10(5):1-12. doi: 10.3390/jcm10050908.
30. Bukmir RP, Paljevic E, Vidas J, Glazar I, Pezelj-Ribaric S, Prso IB. Is coronal restoration a predictor of posttreatment apical periodontitis?. ***Eur J Dent***. 2022 May;16(2):386-395. doi: 10.1055/s-0041-1735909.
31. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. ***Scand J Dent Res***. 1981 Aug;89(4):321-328. doi: 10.1111/j.1600-0722.1981.tb01689.x.

32. Byström A, Sundqvist G. Bacteriologic evaluation of the effect of 0.5 percent sodium hypochlorite in endodontic therapy. ***Oral Surg Oral Med Oral Pathol***. 1983 Mar;55(3):307-312. doi: 10.1016/0030-4220(83)90333-x.
33. Shuping GB, Orstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. ***J Endod***. 2000 Dec;26(12):751-755. doi: 10.1097/00004770-200012000-00022.
34. Siqueira JF Jr, Rôças IN, Alves FR, Campos LC. Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod***. 2005 Sep;100(3):369-374. doi: 10.1016/j.tripleo.2005.03.029.
35. Gillen BM, Looney SW, Gu LS, Loushine BA, Weller RN, Loushine RJ*, et al.* Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. ***J Endod***. 2011Jul;37(7):895-902. doi: 10.1016/j.joen.2011.04.002.
36. Orstavik D. Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. ***Int Endod J***. 1996 May;29(3):150-155. doi: 10.1111/j.1365-2591.1996.tb01361.x.
37. Gulabivala K, Ng YL. Factors that affect the outcomes of root canal treatment and retreatment—A reframing of the principles. ***Int Endod J***. 2023 Mar;56 Suppl 2:82-115. doi: 10.1111/iej.13897.
38. Juric R, Vidmar G, Blagus R, Jan J. Factors associated with the outcome of root canal treatment-A cohort study conducted in a private practice. ***Int Endod J***. 2024 Apr;57(4):377-393. doi: 10.1111/iej.14022.
39. Pietrzycka K, Radwanski M, Matinlinna JP, Lukomska-Szymanska M. The prevalence of root canal treatment, periapical status, and coronal restorations in elderly patients in the Polish population. ***Heliyon***. 2024 Aug 21;10(17):e35584. doi: 10.1016/j.heliyon.2024.e35584.
40. Vieira AR, Pacheco-Yanes J, Gazzaneo ID, Neves MAS, Siqueira JF, Jr., Goncalves LS. Factors influencing the outcome of nonsurgical root canal treatment and retreatment: A retrospective study. ***Aust Endod J***. 2024 Aug;50(2):245-259. doi: 10.1111/aej.12828.
41. Park DM, Seok WH, Yoon JY. Factors influencing non-surgical root canal treatment outcomes in mandibular second molars: A retrospective cone-beam computed tomography analysis. ***J Clin Med***. 2024 May 16;13(10). doi: 10.3390/jcm13102931.
42. Ciftçi A, Vardarli DA, Sönmez IS. Coronal microleakage of four endodontic temporary restorative materials: an in vitro study. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod***. 2009 Oct;108(4):e67-70. doi: 10.1016/j.tripleo.2009.05.015.
43. Jirathanyanatt T, Srisatjaluk R, Choenklang P. Bacterial leakage through double seal intermediate restorative materials. ***M Dent J***. 2015;35(3):291-298.
44. Safavi KE, Dowden WE, Langeland K. Influence of delayed coronal permanent restoration on endodontic prognosis. ***Endod Dent Traumatol***. 1987 Aug;3(4):187-191. doi: 10.1111/j.1600-9657.1987.tb00622.x.
45. Moshonov J, Slutzky-Goldberg I, Gottlieb A, Peretz B. The effect of the distance between post and residual gutta-percha on the clinical outcome of endodontic treatment. ***J Endod***. 2005 Mar;31(3):177-179. doi: 10.1097/01.don.0000137646.07662.8e.
46. Ozkurt Z, Kayahan MB, Sunay H, Kazazoglu E, Bayirli G. The effect of the gap between the post restoration and the remaining root canal filling on the periradicular status in a Turkish subpopulation. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod***. 2010 Jul;110(1):131-135. doi: 10.1016/j.tripleo.2010.02.036.