

# Influence of technical quality and coronal restoration on periapical health of root canal treatment performed by Malaysian undergraduate students

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## Abstract

**Introduction:** Root canal treatment (RCT) and its coronal restoration should be regularly assessed to ensure a successful treatment outcome. The aim of the current study is to evaluate the relationship between the obturation technical quality and coronal restoration in the clinical and radiographic outcome of RCT provided by Malaysian undergraduate students.

**Materials and Methods:** A total of 143 root-treated teeth from 136 patients were evaluated through clinical examinations and periapical radiographs with a mean follow-up period of 2.4 (standard deviation = 1.59) years. The quality of the coronal restoration was classified according to modified United States Public Health Service criteria and the technical quality of the obturation was assessed based on two variables: length and density. Periapical status was evaluated according to periapical index scores.

**Results:** About 64% of the teeth were classified as healthy with a significant reduction of apical periodontitis from 70.3% preoperatively to 36% at reassessment ( $P < 0.001$ ). About 92.1% of obturation was of acceptable length, whereas 5% underfilled and 2.9% overfilled. Teeth with acceptable obturation length were five times less likely associated with apical periodontitis than the inadequately filled ones. 90% of canals had adequate obturation density with no significant association to apical periodontitis. Teeth restored with intracoronal restorations had 50% more chance of developing apical periodontitis. Inadequately restored teeth and teeth with poor obturation quality were associated with three times more likely apical periodontitis occurrence. The quality of endodontic treatment and the coronal restoration significantly influenced the periapical status ( $P < 0.001$ ).

**Conclusion:** The radiographic obturation quality and coronal restorations of the RCTs performed by the undergraduate students in a Malaysian public dental school were acceptable in 63.8% of cases with a 64% favorable outcome.

**Keywords:** Apical periodontitis, coronal restoration, endodontic outcome, radiographic technical quality, root canal treatment

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## INTRODUCTION

Root canal treatment (RCT) is conducted to reduce the intracanal and periapical bacterial load as well as eradicate the necrotic pulp and dentin debris. Adequately disinfected and sealed root canal will promote healing of the periapical tissue.<sup>[1]</sup> Reinfection of root-treated teeth may pursue if the integrity of the coronal restoration and root canal obturation is compromised. Recolonization of a previously treated root canal may complicate subsequent treatment with reduced treatment outcome.<sup>[2]</sup> Hence, to ensure a successful treatment outcome and prolong tooth retention, the RCT procedure must be performed effectively and of a high technical standard. Root canal that is thoroughly prepared using the endodontic instruments with characteristics that correctly preserve the dental anatomy facilitates three-dimensional obturation, which results in healing of the periapical pathosis.<sup>[3]</sup>

As such, radiographs during RCT are an essential treatment records for pretreatment assessment, intraoperative treatment procedure evaluation, and postoperative monitoring of treatment outcome. Numerous studies have used radiographs to assess the technical quality of RCTs done by undergraduate dental students with these studies producing mixed results.<sup>[4,5]</sup> Apart from root canal filling, the quality of a coronal restoration is another outcome predictor of a RCT. The significance of the coronal seal over the apical seal on the periapical health has been emphasized by Ray and Trope<sup>[6]</sup> and Kirkevang.<sup>[7]</sup> On the contrary, Tronstad *et al.*<sup>[8]</sup> found less significant importance on the coronal restoration over the quality of the root filling. Regardless, the attainment of sufficient coronal seal in root-treated teeth as another important outcome predictor of an RCT should be emphasized.

To ensure that the quality and competence of Malaysian dental undergraduates are consistent with the international standards, the Malaysian Dean's Council has outlined the minimum clinical experience (MCE) and expected clinical experience (ECE) guidelines (Deans Council/MCE/V3/2018), made compulsory to all Malaysian undergraduate dental students. The MCE and ECE guidelines<sup>[9]</sup> cover the quantitative and qualitative clinical competencies-based assessment encompassing all the dental disciplines including endodontic treatment which are to be adhered to. The endodontic requirement listed in the document is in line with the European Society of Endodontology guidelines.<sup>[10]</sup>

Regular monitoring of undergraduate students' work through audit research is essential to ensure the delivery

of adequate treatment standard.<sup>[11]</sup> A previous audit was conducted in 2017 to evaluate the immediate outcome of RCT performed by Universiti Sains Islam Malaysia (USIM)'s undergraduate students. About 66.5% of the root-treated teeth showed evidence of periapical healing on obturation, while 30.4% still presented periapical lesion with no active infection during obturation.<sup>[12]</sup> In ensuring a successful treatment outcome, regular review or follow-up is advocated after 1 year for all root-treated teeth to assess the periapical healing, as well as to evaluate the integrity of the restorative margin.<sup>[10]</sup> At present, there is a limited report on the outcome of RCT conducted by Malaysian undergraduate dental students. Therefore, the present study was conducted to evaluate the technical quality of root canal fillings, coronal restoration, and the outcome predictors of the RCT provided by Malaysian undergraduate dental students evaluated through radiographic and clinical examination.

## MATERIALS AND METHODS

This retrospective study includes patients who attended the 3<sup>rd</sup>-, 4<sup>th</sup>- and 5<sup>th</sup>-year undergraduate Dental School Polyclinic of USIM from the year 2010 to 2016 for RCT. A total of 143 root-treated teeth from 136 patients were evaluated clinically and radiographically at baseline and follow-up. The cases were selected based on the following criteria: nonsurgical cases of single and multi-rooted permanent teeth with mature root apex treated by 4<sup>th</sup>- and 5<sup>th</sup>-year undergraduate students; obturation was done more than 1 year and full details of case history notes with a full set of periapical radiographs is available. Cases that did not fulfill the previous requirements were excluded.

The ethical approval by the USIM ethics committee (Reference USIM/FPg-MEC/2013/23) was obtained before start of the study. The clinical examination, diagnosis, and RCT protocol were conducted under the supervision of an endodontic and restorative specialist. Periapical radiograph was taken preoperatively for diagnostic purposes before endodontic treatment. In cases where multiple caries management of vital and nonvital teeth was involved, initial RCT was conducted on the tooth indicated for RCT. The initial RCT procedure consisted of caries free, initial canal disinfection with sodium hypochlorite (3%), placement of intracanal medicament, and tooth built up with preendo restoration. All the RCTs were conducted in multiple visits.

### Root canal treatment protocol

Local anesthesia was administered, and rubber dam isolation was applied in all cases. Access cavity with straight-line access and coronal flaring were obtained before working

length determination with Raypex 5 apex locators (VDW Endodontic Synergy, Munich Germany) and periapical radiograph. The periapical radiographs for multirrooted teeth were taken using the parallax technique with intraoral phosphor plate X-ray. The radiographic technique performed by students was supervised by a radiographer to ensure the correct radiographic angulation. The canal instrumentation in single-rooted teeth was performed using the modified double-flared technique with K-files, while the multirrooted teeth were performed using the crown down technique with the Hand ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland). In addition, 3% sodium hypochlorite (CanalPro™, Coltene®) was the routine canal disinfection used, delivered via syringe and side port needle 28G or 30G, depending on the canal sizes. The nonsetting calcium hydroxide was used as an intracanal medicament. The apical length of the master cone gutta-percha was verified with a periapical radiograph before obturation. The canal was then later filled with standardized gutta-percha points in anterior and premolar teeth or ProTaper gutta-percha points (Dentsply Maillefer, Ballaigues, Switzerland), in molar teeth and AH plus sealer (Dentsply Sirona). Here, the cold lateral compaction method was the obturation technique employed. Postobturation periapical radiographs were taken routinely to assess the density and length of the obturation and the temporary restoration. The teeth were temporarily and permanently restored during the 1-week review, followed by permanent restoration at subsequent visits.

### Clinical and radiographic examination

The undergraduate dental students conducted primary RCT s in 274 teeth during the study period and 260 teeth met the inclusion criteria. However, only 136 patients agreed to attend the review recall and were included as study participants. A data collection form was generated by adapting several indices and criteria from previous literatures.<sup>[13-15]</sup> The form was divided into two parts, which were the assessment of the coronal seal and the evaluation of the obturation quality. After obtaining patients' informed consent and collecting of all the patients' information, the examiners then performed clinical and radiographic evaluations. The clinical examination was performed by three independent trained restorative specialists. The following information was recorded in the data collection form:

- i. Presence and absence of signs and symptoms (pain, tenderness to percussion and/or palpation, pain on biting, presence of swelling or periodontal pocket)
- ii. Pulpal and apical diagnosis
- iii. Canal preparation technique

- iv. Condition of tooth
- v. Types of coronal restorations
- vi. Time interval from obturation to the placement of permanent restoration.

### Evaluation of the technical quality of root canal obturation

During the review appointment, a periapical radiograph of the root-treated teeth was taken and processed using Planmeca™ intraoral X-ray unit Planmeca Romexis® software. The technical standard of the RCT was evaluated based on the obturation density and obturation level, following the guidelines of the European Society of Endodontology.<sup>[10]</sup> The obturation density and level were evaluated according to the index adapted from Zhong et al.,<sup>[13]</sup> by assessing from the end of obturation to the radiographic apex. The descriptions of the indices are shown in Table 1.

### Clinical and radiographic examination of postendodontic restoration

Three independent trained dentists were calibrated for the clinical examination using the Modified United States Public Health Service (USPHS) Ryge's criteria<sup>[16]</sup> in three cycles until 100% agreement was achieved. The coronal restoration was evaluated as adequate if it was fully present during the evaluation with acceptable enamel and dentine margin and there was no marginal gap identified from the radiographic images.

### Evaluation of periapical status

The examiners went through a radiographic calibration exercise by assessing ten sets of periapical radiographs in three sessions. The Cohen kappa coefficient was used to rate the interexaminer reliability for Periapical Index (PAI) with the inter-examiner agreement at 0.8.

**Table 1: The radiographic criteria and index of obturation level and obturation density**

Parameters	Criteria	Codes and definition
Obturation density	Adequate	1=No voids or inhomogeneous zones visible, no space discernable between filling material and canal wall (ideal) 2=No voids or inhomogeneous zones visible in apical third, no space discernible between filling material and canal wall in apical third (acceptable)
	Inadequate	3=Voids or inhomogeneous zones visible in apical third, or space discernible between filling material and canal wall in apical third (defective)
Obturation level	Underextended	1=Root filling ending >2 mm from the radiographic apex
	Well extended	2=Root filling ending 0-2 mm from the radiographic apex
	Overextended	3=Root filling beyond the radiographic apex

The periapical bone status was evaluated using PAI adopted from Orstavik *et al.*,<sup>[14]</sup> ranging from PAI 1 (normal periapical bone structure) to PAI 5 (severe apical periodontitis with exacerbating feature). For each root-filled tooth, at least two periapical radiographs were examined. The preoperative radiograph was assessed as the baseline PAI and the review recall radiograph as the postoperative radiograph. In cases of multirrooted teeth, only the root canal presented with the worst PAI score was evaluated.

### Treatment outcome classification

The presence of apical radiolucency was assessed in all teeth. The periapical status was assessed using the PAI scoring system adopted from Orstavik *et al.*,<sup>[14]</sup> according to the following criteria:

1. Normal periapical structures
2. Slight changes in bone structure
3. Changes in the bone structure with little mineral loss
4. Periodontitis with well-defined radiolucent area
5. Severe periodontitis with exacerbating features.

The radiographic treatment outcome was evaluated by dichotomizing the PAI score into PAI 1 and 2 (“success”) versus PAI 3,4 and 5 (“failure” or “diseased”).<sup>[14]</sup> Overall, the radiographic and clinical criteria used to classify the outcomes were divided into two categories:

#### Success

- i. Healed: Absence of signs and symptoms and absence of radiographic signs of apical periodontitis (PAI score <3)
- ii. Incomplete healing: Absence of signs and symptoms and reduction of the size of the periapical lesion (reduction of preoperative PAI 3, 4 and 5 to follow-up PAI 1 and 2).

#### Failure

- i. Uncertain healing: Absence of signs and symptoms and no radiographic sign of reduction for the size of the periapical lesion (follow-up PAI score remained the same as the preoperative)
- ii. Unsatisfactory healing: Development of a new periapical lesion or increase in the size of the periapical lesion (increase of preoperative PAI score from PAI 1 and 2 to PAI 3, 4, and 5) and/or the presence of signs and symptoms, including extracted tooth or tooth indicated for extraction.

### Statistical analysis

Descriptive analysis was performed in the form of mean and standard deviation (SD), and frequency and percentage

to describe the characteristics of the root-treated teeth involved in this study. Analysis was performed using IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY, USA: IBM Corp. Pearson Chi-square with Fisher test was run to look for any association between the outcome of RCT with obturation and restoration quality. On top of that, additional report of odds ratio (effect size) was reported for significant findings of the Chi-square test. McNemar and Cochran Q tests were performed to determine the success rate of the RCT outcome done by the undergraduate students. The significant test was set at  $P < 0.05$ .

## RESULTS

### Sample characteristics

From a total of 143 teeth that were re-examined, 5 teeth were extracted resulting in a final sample of 138 teeth. The extracted teeth were excluded from the study sample as the mode of RCT failure could not be determined following the criteria of this study. The follow-up period ranged from 1 year to 6 years and the mean follow-up period was 2.4 (SD = 1.59) years. There was an almost equal distribution of root-treated teeth in the maxillary (57.3%) and mandibular (42.7%) dentition. Lower anterior teeth were the least endodontically treated teeth at 5.6%, while the upper and lower posterior teeth (37.1%) were the most treated teeth.

Pulp necrosis and apical periodontitis were the most common indication for RCT at 68.6% and 61%, respectively. Elective endodontics for prosthodontics purposes was carried out on 3.4% of the cases. The double-flared technique (65.3%) using stainless steel files was more frequently employed than crown down technique (43.7%) for the cleaning and shaping procedure. About 26.4% of postendodontic restorations were either absent or had margin failure, with only 73.7% of the restorative margin considered acceptable based on the evaluation done through the radiographs.

### Technical quality of root fillings

According to the radiographic evaluation criteria, 118 (84.9%) out of 138 teeth appeared to have adequate obturation density and well-extended obturation level. Of all teeth, 92.1% had root fillings that were well extended in within 0–2 mm from the radiographic apex, while 5% were underextended/short filled and 2.9% overextended/overfilled beyond the apex. The obturation density is acceptable in 90% of the cases, whereby there was no void found at the apical part of the root filling.

### Condition of postendodontic restoration

The most common final restoration done for root canal treated tooth was crown, followed by composite with 50.7% and 23.9%, respectively [Table 2]. About 72.5% of the

**Table 2: Distribution of sample characteristics**

Parameters	Criteria	n (%)
Gender	Female	53 (39.0)
	Male	83 (61.0)
Arch	Maxillary	82 (57.3)
	Mandibular	61 (42.7)
Root type	Anterior	52 (36.4)
	Premolar	46 (32.2)
	Molar	45 (31.5)
Pulp diagnosis	Vital	4 (3.4)
	Symptomatic irreversible pulpitis	25 (21.2)
	Asymptomatic irreversible pulpitis	7 (5.9)
Apical diagnosis	Necrotic pulp	81 (68.6)
	Normal apical tissue	35 (29.7)
	Apical periodontitis	72 (61.0)
Preparation technique	Apical abscess	11 (9.3)
	Double flare	77 (65.3)
	Crown down	41 (34.7)
Condition of tooth	Present	128 (96.2)
	Extracted	5 (3.8)
Types of coronal restoration	Crown	68 (50.7)
	Composite	32 (23.9)
	Amalgam	19 (14.2)
	Temporary	15 (11.2)
Time interval to permanent restoration (months)	<1	12 (9.4)
	1-3	8 (6.3)
	>3	107 (84.3)
Margin of restoration	Absent	5 (3.8)
	Inadequate	30 (22.6)
	Adequate	98 (73.7)

root-treated teeth examined were found adequately restored and presented with acceptable restoration quality. Based on the Modified USPHS Ryge criteria, it was found through the examination that the anatomical contour was continuous or slightly flattened or over contoured (89%) with no secondary caries (94.1%). The restoration was intact (93.4%) with no marginal discoloration (87.5%), no ledge or ditching (55.1%), and no mismatch color with adjacent tooth (54.1%) in all the restorations. Table 3 shows a comparison of the clinical presentations between intracoronal and extracoronal restorations. All the extracoronal restorations were intact and fully present with acceptable margins during the examination, while 14.8% of the intracoronal restorations were fractured or missing with an unacceptable margin of 16.4%. This may contribute to 11.5% of secondary caries among the intracoronal restorations, particularly composite and temporary restoration.

### Treatment outcome

Hundred and twenty-one periapical radiographs of RCT were observed at the baseline, during obturation and follow-up to determine the success rate. Cochran's Q test determined that there was a statistically significantly different in the proportion of successful PAI over time,  $\chi^2 (2) = 64.586, P < 0.001$ .

About 64% of the root-treated teeth were presented with a healthy periapical during the review. An exact

**Table 3: The characteristics of the intra and extra coronal of the endodontically treated teeth based on modified united states public health service Ryge's criteria<sup>[16]</sup>**

Characteristics	Intracoronal restoration			Total, n (%)	Extra coronal restoration, n (%)
	Amalgam, n (%)	Composite, n (%)	Temporary, n (%)		
Anatomical contour					
A	15 (78.9)	27 (87.1)	7 (63.6)	49 (80.3)	68 (100.0)
B	4 (21.1)	3 (9.7)	1 (9.1)	8 (13.1)	0
C	0	1 (3.2)	3 (27.3)	4 (6.6)	0
Secondary caries					
A	0	5 (16.1)	2 (18.2)	7 (11.5)	1 (1.5)
C	19 (100.0)	26 (83.9)	9 (81.8)	54 (88.5)	67 (98.5)
Retention/gross fracture					
A	16 (84.2)	28 (90.3)	8 (72.7)	52 (85.2)	68 (100.0)
B	3 (15.8)	2 (6.5)	1 (9.1)	6 (9.8)	0
C	0	1 (3.2)	2 (18.2)	3 (5.0)	0
Marginal discoloration					
A	19 (100.0)	22 (71.0)	7 (63.6)	48 (78.8)	65 (95.6)
B	0	5 (16.1)	1 (9.1)	6 (9.8)	2 (2.9)
C	0	4 (12.9)	2 (18.2)	6 (9.8)	0
H	0	0	1 (9.1)	1 (1.6)	1 (1.5)
Marginal integrity					
A	12 (63.2)	20 (64.5)	6 (54.5)	38 (62.3)	35 (48.5)
B	4 (21.1)	8 (25.8)	1 (9.1)	13 (21.3)	33 (51.5)
C	3 (15.8)	3 (9.7)	3 (27.3)	9 (14.8)	0
H	0	0	1 (9.1)	1 (1.6)	0
Colour match					
A	0	19 (61.3)	8 (72.7)	27 (54.3)	44 (65.7)
B	0	8 (25.8)	1 (9.1)	9 (14.8)	22 (32.8)
C	0	4 (12.9)	0	4 (6.6)	0
H	19 (100.0)	0	2 (18.2)	21 (34.4)	1 (1.5)

McNemar test determined that there was a statistically significant difference in the proportion of absence of apical periodontitis between pre- and post-RCT treatment,  $P < 0.001$ .

Further analysis was conducted to evaluate the association between the obturation and postendodontic restoration variables and the apical periodontitis [Table 4]. Overall, a significant association was found between the obturation quality (acceptable obturation density and well-extended obturation level) and RCT outcome ( $P < 0.05$ ). Of all the parameters assessed, only obturation density was found to not be significantly associated with apical periodontitis ( $P > 0.05$ ). Intracoronar restoration had two times the odds at presenting with apical periodontitis than extracoronar restoration. On the other hand, RCT with unacceptable obturation quality had three times the odds to present with apical periodontitis, whereas under/overextended obturation had five times higher the odds of presenting with apical periodontitis than well-extended obturation. In regard to restoration quality, restoration with unacceptable quality had three times higher the odds of presenting with apical periodontitis. The odds of both low-quality restoration and obturation to present with apical periodontitis were 3.5 times higher than good quality.

## DISCUSSION

USIM along with other dental schools have adopted and integrated the European society of Endodontology recommendation in the undergraduate endodontic

curriculum.<sup>[17]</sup> In USIM, the endodontic teaching is provided during the final 4 years of the 5-year Bachelor Dental Surgery course through didactic teaching, preclinical practical and clinical training. The preclinical training on resin block and three single-rooted teeth is conducted during the 2<sup>nd</sup> and 3<sup>rd</sup> years of study, while the preclinical training on resin block and two multi-rooted teeth is carried out in the 4<sup>th</sup> year. The clinical training commences in the final 3 years of study, in which the students are required to complete clinical RCT for three single-rooted teeth and at least one uncomplicated multi-rooted tooth before graduation, as per MCE and competency-based guidelines.<sup>[9]</sup> During the clinical training, the students' clinical performances and treatment records are closely observed by the dental specialist to ensure adherence to the set technical standard.

According to the radiographic criteria used based on the digital periapical radiographs, 84.9% of the root canal filling done in single and multirooted teeth by the undergraduate students were of acceptable quality, having both adequate filling length and homogeneous apical root filling. The teeth that were homogeneously filled along the canal length were able to prevent bacterial penetration to the apical area.<sup>[18]</sup> Conflicting results were also reported by other studies<sup>[19,20]</sup> and these variations were due to differences in the clinical teaching practices as well as different criteria used for the radiographic assessment.<sup>[21]</sup>

The apical length parameters in this study were fairly achieved with 92.1% of the canals filled to the acceptable length, in within 0–2 mm from the apex. The combination of radiograph and apex locator as used in this study ensures that the root canal is adequately cleaned and filled to the acceptable working length. The distance between the obturation terminus and radiographic apex significantly affected the outcome of the RCT, with 87%–94% healing rate, while teeth that were short filled had a lower healing rate of 68%–77.6%.<sup>[22]</sup> This was confirmed by the results of the present study, in which the well-extended root fillings were associated with healthy periapical tissues. On the contrary, underfilled and overfilled cases were significantly associated with apical periodontitis and a lower healing rate. The short-filled canal may indicate the presence of canal sclerosis or procedural errors such as ledge and zipping. The uninstrumented apical canal in underfilled cases can harbor bacteria and necrotic dentine debris, responsible for the persistence of periapical disease and risk failure of the RCT.<sup>[23,24]</sup> On the other hand, the obturation material that was overfilled at the periapical area could potentially elicit foreign body reaction resulting in sustenance or development of new periapical lesion.<sup>[25]</sup>

**Table 4: Quality of obturation and restoration and the relation to periapical health**

Variables	Apical periodontitis		P
	Absent (PAI 1 and 2), n (%)	Present (PAI 3, 4, and 5), n (%)	
Type of restoration			
Intracoronar	34 (54.0)	29 (46.0)	0.037
Extracoronar	46 (71.9)	18 (28.1)	
Obturation quality			
Unacceptable	7 (41.4)	10 (58.8)	0.032
Acceptable	78 (67.8)	37 (32.2)	
Obturation density			
Adequate	6 (46.2)	7 (53.8)	0.148
Inadequate	79 (53.8)	40 (33.6)	
Obturation level			
Under and over extended	2 (28.6)	5 (71.4)	0.042
Well-extended	83 (66.4)	42 (33.6)	
Restoration quality			
Inadequate	17 (47.2)	19 (52.8)	0.005
Adequate	67 (73.6)	24 (26.4)	
Restoration and obturation quality			
Inadequate	23 (48.9)	24 (51.1)	0.001
Adequate	61 (77.2)	18 (22.8)	

PAI: Periapical index

The quality of the obturation density in this study if compared to others had a 90% similarity with Vukadinov *et al.*,<sup>[26]</sup> but a slightly lower similarity to that of Unal *et al.*<sup>[27]</sup> at 92%. From this study, the teeth with acceptable obturation density were not significantly associated with apical periodontitis which is similar to the reports by Sjogren *et al.*<sup>[22]</sup> and Eriksen *et al.*<sup>[28]</sup> Several studies reported variable treatment outcomes with regard to tooth type.<sup>[27,29]</sup> The outcome was not measured in this study as the statistical assumption was not met.

The attainment of coronal seals in adequately filled root canals is considered an integral part of endodontic treatment in preventing reinfection of the root canal space.<sup>[6,7]</sup> About 27.5% of the root-treated teeth in this study were inadequately restored and were associated with a higher incidence of apical periodontitis. The result of adequately restored teeth in this study was superior to another study as reported by Morena *et al.*<sup>[30]</sup> and Saporiti *et al.*<sup>[31]</sup> at 40% and 52.3%, respectively. It is empirical to ensure that all the treated teeth in this study were permanently restored with a reliable restoration on completion of the RCT. The use of the gold standard full cuspal coverage, placed in 50.7% of the root-treated teeth in this study, able to provide a reliable and sustainable coronal seal of endodontically treated posterior teeth, with the reported survival rate six times greater than intracoronal restoration.<sup>[32]</sup> This is supported by the findings from the current study, whereby endodontically treated teeth restored with intracoronal restoration had likely twice the chance of developing apical periodontitis than teeth restored with extracoronal restoration. Nevertheless, dental crowns were not always recommended as the final restoration for root-treated teeth. The current evidence suggested that the survival rates against the fracture of endodontically treated posterior teeth restored with crowns or resin composites were not significantly different in the teeth with 1–3 surface loss.<sup>[33]</sup> Teeth with intact marginal ridges and conservative access cavity preparation can be restored permanently with bonded intracoronal restoration, as advocated for 23.9% of the root-treated teeth in this study. The advancement in adhesion technology and the improvement of composite resin mechanical properties offer the adoption of the conservative approach to restoring endodontically treated teeth as it provides the seal, reinforcement, and protection, while delaying the execution of a full crown.<sup>[34]</sup>

Five of the roots treated teeth (3.6%) were already extracted during the study; therefore, the root canal was considered a failure. The reason of this failure might be associated with the delay in the placement of permanent restoration that caused the fracture of the remaining susceptible tooth

structure. During the review recall, it was found that 12.8% of the root-treated teeth were still in amalgam intracoronal restoration and 6% in temporary restoration. The findings of this study concurred with the study reported by Lynch *et al.*, in which loss of endodontically treated teeth occurred more often when the teeth were restored with temporary restoration compared to other types of restorations.<sup>[35]</sup>

The failure of the composite restoration in this study was associated with poor color match and marginal discoloration, both at 12.9% as well as secondary caries (16.1%). Clinical evaluation of intracoronal and extracoronal marginal seal in this study found that 92.6% of the restoration had acceptable margins. However, when assessed radiographically, the marginal integrity was remarkably reduced to 73.7%. The acceptable radiographic score in this study was comparable to the findings by Hommez *et al.* 2002.<sup>[36]</sup> The break in the coronal marginal seal may predispose to bacterial leakage into the filled pulp space and subsequent reinfection of the periapical area, as seen in 52.8% of cases of inadequate restoration in this study. Hence, it is essential to complement radiographic information with clinical data in identifying the presence of marginal leakage of subgingival restoration as it is difficult to visualize the restorative margin clinically. Thus, the results of this study suggest conducting both clinical and radiographic assessments during review recalls. During the review recall, it was found that 12.8% of the root-treated teeth were still in amalgam intracoronal restoration and 6% in temporary restoration. The amalgam restoration placed in the root-treated teeth in this study was indicated as core built up before the crown construction and was not considered a final restoration. The success rate of endodontically treated teeth was reduced in teeth that only received core built up without cuspal coverage and permanent restoration at 71% and 58%, respectively.<sup>[37]</sup> In the present study, 15.8% of the amalgam restoration placed was partly fractured but not associated with secondary caries. This may be owed to the self-sealing ability of amalgam corrosion products at its restorative margin over time.<sup>[38]</sup> On the other hand, 27.3% of the temporary restorations performed were partially or completely dislodged, resulting in impaired marginal integrity predisposing to the highest incidence of caries development among all the restorations examined at 18.2%. The findings of this study concurred with the study reported by Lynch *et al.*, in which loss of endodontically treated teeth occurred more often when the endodontically was restored with temporary restoration compared to other types of restorations.<sup>[35]</sup>

It was found that only 15.7% of the root-treated teeth received final restoration in <4 months after obturation.

This posed grave concern as the success of root-treated teeth is evidently reduced when the permanent restorations are delayed.<sup>[39]</sup> The endodontically treated teeth that received a crown 4 months after RCTs were extracted at three times the rate of teeth that received the crown within 4 months. The reason that contributed to the delay in this study might be because the study was conducted in a dental school setting.<sup>[37]</sup> A few of the RCT cases were conducted by the final year students at the end of their study. Due to time constraints, the case was transferred to another batch of undergraduate students to furnish the root-treated teeth with permanent restorations. In certain conditions, the case was abandoned and not completed, leaving the tooth in long-term temporary restoration. Further clinical examination during the review recall revealed that 27.3% of the temporary restorations were either partially or fully dislodged. This finding became the primary concern among the restorative and endodontists as the endodontic success rate may be decreased when the restoration was inadequate or absent.<sup>[31]</sup> Therefore, all the temporarily restored teeth and teeth that were presented with unacceptable restorations were immediately scheduled for immediate repair or replacement with permanent restoration by the institution.

The RCT that was performed to a high technical standard as having both adequate length<sup>[40]</sup> and homogeneity, will ensure the healing of the periapical pathosis and produce a predictable long-term success.<sup>[21,41,42]</sup> This is confirmed by the results of the present study. About 92% of the acceptable obturation quality evaluated from this study was presented with a healthy periapical ( $P < 0.005$ ). The teeth that were inadequately filled were three times more likely to develop apical periodontitis. Apart from quality root fillings, the frequency of apical periodontitis is said to decrease in teeth that were adequately restored.<sup>[43]</sup> Similar outcome was observed in the current study, whereby 72.5% of the root-treated teeth that were adequately restored were associated with a 50% reduced chance of developing apical periodontitis as compared to inadequately restored teeth. In addition, an optimum outcome for the RCT was observed when both endodontic treatment and coronal restoration were adequately conducted.<sup>[43,44]</sup> Evidently, when combined, 63.8% of the adequately root-filled and restored teeth in the current study were significantly associated with less incidences of apical periodontitis. Conversely, the 36.2% of inadequately filled and restored teeth had three times the chance of developing apical periodontitis.

A further analysis assessing the periapical healing following RCT showed a statistically significant reduction

of the periapical lesion from 70.3% preoperatively to 36% during reassessment. This indicates complete healing of the periapical tissues in 64% of the endodontically treated teeth, which was slightly lower than the previous audit at 66.5%. To ensure complete healing of the remaining teeth that were still presented with apical radiolucency in asymptomatic cases, reassessment of up to 4 years is required.<sup>[10]</sup> The overall success rate of this study was higher than Moreno *et al.* 2013 at 61%<sup>[30]</sup> and inferior to 85% found by Craveiro *et al.* 2015.<sup>[45]</sup> The delay in providing permanent restoration following the RCT may have contributed to this finding. Therefore, there is a need to further improve the quality of the RCT performed by undergraduate students, especially on the provision of the permanent restoration in endodontically treated teeth. The placement of indirect composite onlay that can be placed immediately following RCT is a viable alternative other than the extensive tooth preparation and time-consuming dental crowns. Training on indirect composite onlay has been recently introduced to the students, and thus, it would be interesting to evaluate its outcome in future study. Even though the sample size is considered small, the data on the quality of the root canal filling and restoration observed in this study may serve as a basis for the enhancement to the faculty's endodontic curriculum as well as an improvement in the provision of the treatment protocol and practices.

## CONCLUSION

The radiographic technical quality and quality of coronal restoration of the root treated teeth performed by undergraduate students in a public dental school in Malaysia was acceptable in 63.8% of cases with a success rate of 64%. Adequately filled and restored teeth in this study were significantly associated with healthy periapical status.

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## Conflicts of interest

There are no conflicts of interest.

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