

The success rate of primary root canal treatment performed by undergraduate students using NiTi rotary instruments: a retrospective study

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Objective: The aim of this study was to evaluate the success rate and various factors influencing the treatment outcome of primary root canal treatment performed by undergraduate students using NiTi rotary instruments.

Material and Methods: A total of 258 out of 379 dental chart records and corresponding radiographic photographs from endodontic treatments conducted from 2014-2019 at the College of Dental Medicine, Rangsit University, were included. Data on patient characteristics comprising age, sex, type of tooth, type of restoration, presence of pre-operative lesions, quality of the coronal restoration, and recall period were collected. Digital periapical radiographs taken before treatment initiation and during recall visits were assessed using the periapical index (PAI). The treatment success was evaluated based on healing criteria, as both the clinical and radiographic presentations were normal.

Results: The recall period ranged from 6-58 months, with a mean of 12.82 (SD9.20) months. The overall recall rate was 68.0%, with a dropout rate of 32.0% (ranging from 6-24 months). The overall success rate was 85.7%, and the healing rate was 10.5%. Significant correlations were found between treatment outcomes and pre-operative lesion presence as well as the quality of the root canal filling ($p < 0.001$). Additionally, significant correlations were identified between the success and pre-operative lesion presence as well as the quality of the root canal filling.

Conclusion: The overall success rate for primary root canal treatment performed by undergraduate students using NiTi rotary instruments was 85.7%. The variable factors that significantly correlate with the success are pre-operative lesions and the quality of the root canal filling.

Keywords: primary root canal treatment, root canal filling, rotary instrument, undergraduate students

How to cite: Yodmanotham P, Tungsawat P, Lertnantapanya S. The success rate of primary root canal treatment performed by undergraduate students using NiTi rotary instruments: a retrospective study. M Dent J 2024;44(2): 79-88.

Introduction

The primary goals of root canal treatment are to protect the condition of the periradicular tissue or treat periapical diseases while maintaining the continued functionality of the root canal-treated tooth. The treatment procedures involve steps for cleaning, and disinfection, followed by filling the root canal.

The success rate of root canal treatment can be determined by the clinical signs, symptoms, and radiographic findings of the root canal-treated teeth. One of the criteria for assessing the root canal treatment outcomes is the periapical index (PAI) score. The PAI score is a valuable tool for evaluating the outcome of root canal treatments. It provides a standardized method to assess periapical health using radiographic criteria, allowing for consistent and objective monitoring of treatment success [1, 2].

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Received: 17 May 2024

Revised: 1 July 2024

Accepted: 4 July 2024

Numerous factors contribute to treatment failure, including uneliminated bacteria and their by-products, root fractures, perforations, and the occurrence of broken instruments during the procedure [3]. Moreover, clinical success is determined by several factors, including the proficiency of the dentist, the state of the tooth, and the patient's condition [4]. These factors significantly affect the success of an endodontically treated tooth.

In the past, hand files were the predominant mechanical tools commonly used for training undergraduate students. Students are expected to quickly acquire the essential knowledge and develop practical skills that are related to that knowledge [5]. Currently, the use of Nickel-Titanium Rotary Instruments (NiTi) is common for the correct preparation of root canals because rotary files are more efficient, economically advantageous, and result in greater accuracy [6]. The NiTi rotary approach has been introduced in many undergraduate dental schools, under the guidance of endodontists. Rangsit University's College of Dental Medicine (RSU) allows undergraduate students to start using rotary devices, according to case selection criteria. However, from 2009 until now, the success rate and quality of the root canal procedures conducted by undergraduate students using NiTi rotary instruments at the College of Dental Medicine have not been evaluated. The aim of this study was to evaluate the success rate and root canal quality of primary root canal treatment in patients treated by NiTi rotary instrument performed by 5th and 6th-year dental students at the College of Dental Medicine, Rangsit University, Thailand, from 2014-2019. Data was also collected to identify factors related to the success of root canal treatment and to determine which factors affect the success rate of root canal treatment.

Materials and Methods

The study protocol received approval from the RSU-ERB research ethics committee on March 19, 2020, (ref # COA. No. RSUERB2020-029). The group was selected from the patients who visited the College of Dental Medicine, Rangsit University, from 2014-2019. The dental chart documented teeth that had undergone endodontic treatment by undergraduate students supervised by endodontists from the Endodontic faculty throughout that period, with each tooth receiving root canal treatment with completed documentation, including initial, final, and follow-up digital periapical radiographs. The dental record was examined; at least a 6-month reevaluation was required to assess the endodontic outcomes.

Sample size

The sample size was calculated using a finite proportion formula. From 2014-2019, data records showed that the number of endodontic patients was 717 teeth at the RSU dental clinic. The expected proportion (P) was referred from Friedman S, *et al* [3] which was 0.81 and the allowable error (d) was 3% different from the true proportion, and the value of the area under the normal curve associated with a 95% confidence interval (Z) was 1.96. According to the formula, the sample size should be 344. The authors estimated 10% incomplete data information; thus, data was collected from 379 patients.

Inclusion and Exclusion Criteria

All primary root canal treatments performed by undergraduate students were included. The patients were recalled at least 6 months post-treatment. The inclusion criteria required complete treatment records and high-quality digital periapical radiographs. Incompletely treated cases, retreatment cases, and teeth that were not instrumented with NiTi rotary instruments were excluded. Additionally,

patients who were unavailable for recall had insufficient treatment records, or had unclear periapical radiographs were excluded.

Treatment protocols

All patients underwent root canal treatment with the use of a rubber dam. After access preparation, the working length was determined using an electronic apex locator and confirmed with a periapical radiograph. Mechanical cleaning of the teeth was performed using NiTi rotary instruments (Mtwo, VDW, Antaeus, Munich, Germany). The root canal was irrigated with a 2.5% sodium hypochlorite solution using a syringe and a 25-gauge needle, with the irrigation needle inserted to a depth of 2-3 mm short of the working length, followed by placing calcium hydroxide as a medication. After a thorough cleaning with a combination of 2.5% sodium hypochlorite, 17% ethylenediaminetetraacetic acid (EDTA) solution, and 2.5% sodium hypochlorite, the root canals were filled. Gutta-percha and a zinc oxide eugenol-based sealer were used for the root canal filling using the lateral condensation technique. Following the root canal procedure, each tooth was restored according to the predetermined treatment plan.

Every case was followed up for at least 6 months. During these appointments, the patients were reassessed by undergraduate students who administered the treatment under the supervision of an Endodontist. The evaluations included history taking, clinical assessments, and radiographic examinations. Pain, swelling, palpation, percussion, tooth mobility, periodontal condition, and quality of the coronal restoration were documented in the endodontic charts. Periapical radiographs were taken using the paralleling approach and a RINN XCP® positioning apparatus from Dentsply-RINN in PA, USA.

The radiographic data were obtained from the pre-operative and post-operative follow-up periapical radiographs. An endodontist evaluated the periapical radiographic data using the PAI score index [1]. The size of any periapical radiolucency was assessed by measuring its broadest diameter in millimeters (mm x mm). The radiographic images were analyzed using the SOPRO program on a Dell Optiplex 760 computer with a resolution of 1600x900 pixels and 32-bit color quality. The criteria for evaluating the success and quality of the root canal filling in the present study are presented in Table 1.

Table 1 The criteria for evaluating the success and quality of root canal filling.

Parameter	Criteria	Definition
Success	Healed	Both the clinical and radiographic presentations are normal (PAI index ≤ 2)
Non-success	Healing	A decrease in the size of the periapical radiolucency combined with a normal clinical presentation.
	Disease	An increase in the periapical radiolucency size or persistence in periapical radiolucency, including when the clinical presentation is normal, or clinical signs or symptoms are present, including if the radiographic presentation is normal.
Quality of root canal filling	Acceptable	Root canal filling 0-2 mm short from the radiographic apex Homogeneous root canal filling, good condensation, no visible voids
	Unacceptable	Root canal filling beyond the radiographic apex or root canal filling > 2 mm from the radiographic apex Non-homogeneous root filling, poor condensation, or voids.

Statistical analysis

The data recorded from the charts included general factors comprising age, sex, type of tooth, type of restoration, pre-operative lesion, quality of the coronal restoration, procedural errors, and recall period.

Descriptive statistics, consisting of percentages, frequencies, means, medians, and standard deviations, were used to explain both general and clinical characteristics. The quality of the root canal filling and the success rate of the root canal treatment were quantified as percentages.

The success was statistically examined using univariate and multivariate analysis. Univariate analysis was employed to investigate the relationship between variable factors and success, and multivariate analysis was utilized to assess the significant correlation of variable factors at p -value < 0.05.

Results

Undergraduate students utilized NiTi rotary devices to treat 379 teeth from 2014-2019. Of these, 258 teeth (68.0%) were analyzed, and 121 teeth met the exclusion criteria. The authors calculated the power of the test backward from a sample size of 258 individuals, obtaining a power value from 0.972-1.00. The reasons for exclusion were 1) the dental chart records of 27 teeth were lost, 2) the radiographs of 32 teeth were missing from the system, 3) the recall data of 29 teeth were

insufficient, 4) 11 teeth were extracted during endodontic treatment, and 5) 22 teeth were re-treatment cases. The sample consisted of 145 women (56%) and 175 (68%) posterior teeth. The tooth types comprised 83 incisors and canines (32.2%), 73 premolars (28.3%), and 102 molars (39.5%) (Table 3).

Overall, the number of healed teeth was 221 (85.7%), 27 teeth (10.5%) were still in the healing process, and 10 (3.8%) were classified as diseased. Among anterior teeth, 73 (88.0%) were healed, 7 teeth (8.4%) were still healing, and 3 (3.6%) were diseased. For posterior teeth, the success rates were determined in 148 teeth (84.6%) as healed, 20 (11.4%) in the healing stage, and 7 (4.0%) were classified as diseased (Table 2).

The success rate was 85.0% in males and 86.2% in females. The success rate of primary root canal treatment in anterior teeth was 88.0%, and in posterior teeth it was 84.6%. For patients aged less than or equal to 45 years old, the success rate of endodontically treated teeth was 84.8%, whereas for those older than 45 years old, it was 86.5%. When classifying the sample based on the presence of preoperative lesions in anterior teeth, 45 teeth (54.2%) had no preoperative lesions, and 38 teeth (45.8%) exhibited a periapical radiolucency. In the posterior tooth sample, 91 teeth (52.0%) had no preoperative lesions, and 84 teeth (48.0%) exhibited a periapical radiolucency.

Table 2 Number and percentage of healed, healing, and diseased teeth.

	Overall	Anterior	Posterior
Healed n (%)	221 (85.7)	73 (88.0)	148 (84.6)
Healing n (%)	27 (10.5)	7 (8.4)	20 (11.4)
Disease n (%)	10 (3.8)	3 (3.6)	7 (4.0)

Table 3 Univariate analysis of the variable factors related to the success rate of non-surgical root canal treatment.

Independent variable	Outcome N (%)		Total	OR (95% CI)	P-value
	Success	Non-success			
Preoperative factors					
Sex					
Male	96 (85.0)	17 (15.0)	113	1.00	
Female	125 (86.2)	20 (13.8)	145	1.11 (0.55-2.23)	0.776
Age (years)					
≤ 45	112 (84.8)	20 (15.2)	132	1.00	
> 45	109 (86.5)	17 (13.5)	126	1.15 (0.57-2.30)	0.704
Type of tooth					
Anterior teeth	73 (88.0)	10 (12.0)	83	1.00	
Posterior teeth	148 (84.6)	27 (15.4)	175	0.75 (0.35-1.63)	0.470
Preoperative lesion					
Absent	132 (97.1)	4 (2.9)	136	1.00	
Present	89 (73.0)	33 (27.0)	122	0.08 (0.03-0.24)	<0.001*
Postoperative factors					
Type of coronal restoration					
Composite filling	58 (84.1)	11 (15.9)	69	1.00	
Crown	34 (89.5)	4 (10.5)	38	1.61 (0.48 – 5.46)	0.443
Post core with crown	103 (84.4)	19 (15.6)	122	1.03 (0.46-2.31)	0.946
Survey crown	15 (88.2)	2 (11.8)	17	1.42 (0.28-7.12)	0.688
Temporary restoration	11 (91.7)	1 (8.3)	12	2.10 (0.24-17.84)	0.502
Characteristic of coronal seal					
Sealed	209 (87.1)	31 (12.9)	240	1.00	
Not sealed	12 (66.7)	6 (33.3)	18	0.30 (0.10-0.85)	0.023*
Quality of root canal filling					
Acceptable	163 (92.6)	13 (7.4)	176	1.00	
Unacceptable	58 (70.7)	24 (29.3)	82	0.19 (0.09-0.40)	<0.001*

(*) $p < .05$ were considered to indicate statistical significance

The sample comprised 69 teeth (26.7%) with composite fillings, 122 teeth (47.2%) with post-core and crown restorations, 38 teeth (14.7%) with crown restorations, 17 teeth (6.6%) with surveyed crown restorations, and 12 teeth (4.7%) with temporary fillings. The success rates for teeth with composite fillings, post-core with crown, crown, surveyed crown, and temporary filling were 84.1%, 84.4%, 89.5%, 88.2%, and 91.7%, respectively (Table 3). Comparing the success and failure groups, the factors related to the success rate of treatment comprised a preoperative lesion, coronal seal, and the quality of the root canal ($p < 0.05$) (Table 3).

The entire sample size consisted of 177 patients who returned for a 6-month recall, 54 for a 12-month recall, 9 for an 18-month recall, and 12 for a 24-month recall, with 2 and 4 patients returning for recalls beyond 36 months. These proportions were calculated as 68.6%, 20.9%, 3.5%, 4.7%, 0.8%, and 1.6%, respectively.

Recall period

The recall period ranged from 6-58 months, with a mean of 12.82 (SD9.20) months. The success rate of endodontically treated teeth for patients returning after 6 months, 12 months,

18 months, 24 months, 36 months, and more than 36 months was 88.1%, 81.5%, 88.9%, 66.7%, 100.0%, and 75.0%, respectively. The overall recall rate was 68%. There was no significant association between the recall periods and the success rate (Table 4).

Factors associated with the success of endodontic treatment

The factors that were associated with the success of primary root canal treatment were preoperative radiolucency and the quality of the root canal filling material. The adjusted Odds ratio (OR_{adj}) of the presence of a preoperative periapical radiolucency was 0.10 (95% CI = 0.03-0.27) and OR_{adj} of an unacceptable quality of the root canal filling material was 0.17 (95% CI = 0.10-0.41). This implied that the presence of a pre-operative lesion results in a success rate of only 0.1-fold compared with the absence of a pre-operative lesion. Furthermore, an unacceptable root canal filling results in a success rate of only 0.17-fold compared with an acceptable root canal filling. However, the OR_{adj} of coronal leakage was 0.91 (95% CI = 0.26-3.21), which was not observed as a factor influencing the success rate (Table 5.).

Table 4 Univariate analysis of the recall period and the success rate of endodontic treatment.

Recall period (month)	Outcome N (%)		Total	OR (95% CI)	P-value
	Success	Non-success			
6	156 (88.1)	21 (11.9)	177	1.00	
12	44 (81.5)	10 (18.5)	54	0.59 (0.26-1.35)	0.213
24	16 (76.2)	5 (23.8)	21	0.43 (0.14-1.30)	0.134
≥ 36	5 (83.3)	1 (16.7)	6	0.67 (0.10-6.04)	0.724

$p < 0.05$ indicated statistical significance

Table 5 Factors associated with the success rate of endodontic treatment by undergraduate students.

Variable	Success rate n (%)		Total	OR _{adj} (95% CI)	P-value
	Success	Non-success			
Characteristics of coronal restoration					
Not sealed	12 (66.7)	6 (33.3)	18	0.30 (0.10-0.85)	0.023
Sealed	209 (87.1)	31 (12.9)	240	1.00	
Preoperative periapical radiolucent					
Presence	89 (73.0)	33 (27.0)	122	0.10 (0.03 - 0.27)	< 0.001*
Absence	132 (97.1)	4 (2.9)	136	1.00	
Quality of root canal filling					
Unaccepted	82	58 (70.7)	24 (29.3)	0.17 (0.10-0.41)	< 0.001*
Accepted	176	163 (92.6)	13 (7.4)	1.00	

Statistic: Multivariate analysis, * $p < 0.01$ indicated statistical significance, OR_{adj}: adjusted odds ratio which was controlled the confounder factors of sex, age, type of tooth, type of coronal restoration, and recall period

Discussion

The success rate of root canal therapy performed by undergraduate students utilizing NiTi rotary devices has not been reported. In the present study, the overall success rate was 85.7%. A study conducted in Thailand by Sivavetpikul P, *et al* (2019) investigated the outcomes of initial endodontic treatments performed by undergraduate dental students at Naresuan University's Faculty of Dentistry. The study found that the overall success rate was 72.8% [7]. Subsequent studies in 2021 determined the success and failure rates of root canal treatment performed by undergraduate students at the same institution, with an overall success rate of 84.1 [8]. da Rocha JG, *et al.* (2022) evaluated the success rate of endodontic treatment performed by Brazilian undergraduate students with a follow-up period of 3-8 years in 91 patients, showing an overall success rate of 60.7% [9].

The advantages of shaping root canals with NiTi rotary files include well-tapered preparations that minimize the risk of root canal transportation [10]. Moreover, NiTi rotary instruments center the root canal shape, maintain the canal curvature and reduce the risk of procedural errors [11]. However, a recent meta-analysis study stated that there was no significant difference in outcomes across studies based on instrumentation methods [12]. Although NiTi rotary instruments likely contribute to the efficiency and effectiveness of the treatment performed by undergraduate students, the high success rate observed in this study is likely due to a combination of factors, including enhanced training and supervision, standardized protocols, and overall student competence.

The results from the multivariate logistic regression model revealed that the factors contributing to the success of primary root canal treatment in this study were the presence of preoperative lesions and the quality of the root

canal filling material. Many prior studies have suggested that the presence of a pre-operative periapical radiolucency significantly impacts the success rate of endodontic treatment [3, 6, 9, 13], similar to the present study, where teeth presenting with a pre-operative periapical radiolucency (73.0%) had a lower success rate compared with those without preoperative lesions (97.1%) ($p < 0.001$). According to a recent systematic review and meta-analyses, teeth that did not present pre-operative periapical lesions have a 2.75-fold higher potential of success compared with teeth that did not have previous periapical lesions. Moreover, biological factors continue to have the most significant impact on the success rate of root canal treatment [12].

A study from the University of Thessaloniki in Greece radiographically evaluated the quality of the root canal filling performed by undergraduate students and their relation to the outcome of endodontic treatment. The results revealed a strong association between higher success rates and root fillings of acceptable quality; roots with canal fillings of acceptable quality demonstrated success rates close to 90%, regardless of the other variables [14]. This result is similar to the present study. In contrast, some studies reported that the quality of the root filling did not significantly influence endodontic outcome quality [6, 15]. The results of this research may be attributed to the relatively small number of cases with unacceptable root canal quality [6, 15]. There is concern about the reliability of the data because this assessment typically relies on radiographs. This concern is due to the numerous variables that can affect the quality of radiographs and their interpretation. Additionally, the definition of what constitutes a good-quality root canal filling varies among studies. Although there is no standardized protocol for assessing the quality of root canal fillings, several previous studies have found

a positive correlation between an acceptable root canal filling quality and high success rates [16-19].

The present investigation found no correlation between sex, age, and treatment failure. Similar findings were observed in previous studies, indicating that the patient's age does not affect the success of root canal treatment, consistent with several prior research findings [13]. This is despite the fact that old age and youth may be expected to have some influence via immune responsiveness [20].

The present study's recall rate was 68%, which is higher than the previous study, which showed that the recall rate was 49% for the 5641 patients who completed endodontic treatment [21]. The results of a higher recall rate might be because all undergraduate students must recall their patients who received endodontic treatment for the minimum requirement. The dropout rate was 32% might be because some patients find it not necessary to return to endodontic recall if their symptoms have subsided.

The recall period in the present study could be a limitation. The mean recall period was 12.82 months, a relatively short period, which influenced the success rate. The reason for the short recall period was because the patients were not compliant with following the treatment protocol. The presence of a preoperative lesion was reported as a significant factor for success that could be affected because of the too-short recall period for complete healing.

The European Society of Endodontology (ESE) [22] has recently published papers providing guidelines for the endodontic undergraduate curriculum. These articles aim to enhance the theoretical and clinical training of dental students in treating premolar and molar teeth. To do this, undergraduate students are required to complete preclinical and clinical practice. In Thailand, dentistry school programs provide NiTi rotary

instruments only for laboratory practice in some institutions, according to the current evidence. In contrast, the College of Dental Medicine of RSU has allowed undergraduate students to utilize NiTi rotary devices on their patients since 2009. The current success rate of these data might be advantageous for enhancing the pre-clinical and clinical curricula, as well as the endodontic abilities of undergraduate students.

Conclusion

For the limitation in this study, the mean of recall period was 12.82 months (SD 9.20), and the overall success rate of primary root canal treatment performed by undergraduate students using NiTi rotary instruments was 85.7%. The variable factors that significantly correlated with treatment outcomes were the presence of pre-operative lesions and the quality of the root canal filling (Odd ratio 0.1-0.17).

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