SUCCESS AND FAILURE OF NONSURGICAL ROOT CANAL TREATMENT PERFORMED BY DENTAL STUDENTS OF NARESUAN UNIVERSITY

KRIANGSAK CHAISOPHIN

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Science in Master of Sciences in Dentistry (Endodontics) - Type A 2
2021

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By KRIANGSAK CHAISOPHIN

has been approved by the Graduate School as partial fulfillment of the requirements for the Master of Science in Master of Sciences in Dentistry (Endodontics) - Type A 2 of Naresuan University

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Title	SUCCESS AND FAILURE OF NONSURGICAL ROOT CANAL TREATMENT PERFORMED BY DENTAL STUDENTS OF NARESUAN UNIVERSITY
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ABSTRACT

Background/Objective: The purposes of this research were to determine the success and failure rate of root canal treatment and also determine factors affecting the success and failure of root canal treatment performed by undergraduate students at the Faculty of Dentistry, Naresuan University from May 2015 to April 2020.

Materials and methods: Data of 176 anterior teeth and premolars from dental treatment records and radiographs were collected and evaluated. Digital periapical radiographs were evaluated by the Periapical index (PAI) score system. The treatment outcome was assessed based on the clinical and radiographic findings. Factors affecting the outcome were analyzed using the Chi-square test and logistic regression model.

Results: The recall rate was 32.8%. The overall success rate was 84.1%, whereas the failure rate was 15.9%. The multivariate analysis identified that factors affecting outcome were the presence of pre-operative periapical lesion size < 5 mm (P=.025), periapical lesion size ≥ 5 mm (P=.005), and the occurrence of occlusal trauma (P=.040), with odds ratios of 0.18, 0.13, and 0.09, respectively.

Conclusions: The teeth without periapical lesions had a better success rate than those with lesions. The occlusal trauma is an important factor in prolonging periapical healing of root canal treated teeth.

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CHAPTER I
INTRODUCTION

Background problem and significance of study

Many studies reported the success and failure rate of root canal treatment. The systematic review showed the success of root canal treatment ranges from 31% to 96% (1). The results of the studies varied depending on the different study characteristics and criteria for outcome assessment. The criteria for evaluating the success and failure of root canal treatment are different in each study. Factors may influence the outcome of the treatment, such as the presence of the preoperative periapical lesion, the occurrence of complications, apical extent of treatment, follow-up period, and the quality of coronal restoration (2-5). Most studies used clinical findings in combination with radiographic findings (2, 6-8). For the histological assessment, it cannot be performed in nonsurgical root canal treatment (9).

There are few studies reported on the long-term evaluation of the success rate of root canal treatment treated by dental students in Thailand. Previous studies reported the overall success rate of root canal treatment ranges from 61% to 81.6% (2, 4, 5). Knowing the success rate of treatment and related factors makes it possible to evaluate the treatment outcome, which will help for clinical decision making, treatment planning, and providing the information for the patients about predicting the root canal treated tooth (5).

Research questions

- What is the overall success and failure rate of initial root canal treatment performed by undergraduate dental students of Naresuan University from May 2015 to April 2020?
- What are the factors affecting the outcome of initial root canal treatment?

Research objectives

The purposes of this research were to determine the success and failure rate of root canal treatment and also determine factors affecting the success and failure of root canal treatment performed by undergraduate students at the Faculty of Dentistry, Naresuan University from May 2015 to April 2020.

Research hypothesis

H_0: There is no relationship between the factors and the success and failure rate of initial root canal treatment

H_1: There is a relationship between the factors and the success and failure rate of initial root canal treatment

Research scope

Data from dental treatment records and radiographs of root canal treated teeth performed by undergraduate dental students at the Department of Endodontics, Faculty of Dentistry, Naresuan University from May 2015 to April 2020 will be used.

Expected results

1. To know the success rate and failure of treatment and related factors of root canal treatment.

2. To apply the results of this study for clinical decision making, treatment planning, and predicting of the root canal treated teeth.

CHAPTER II
REVIEW LITERATURE

The purpose of root canal treatment is to eliminate bacteria within the root canal system by using mechanical instrumentation together with chemical irrigation and root canal filling with inert material. These procedures promote the recovery of the periapical tissue (10).

Several studies report the outcome of root canal treatment, providing useful prognostic data of apical periodontitis for clinical decision making, treatment planning, and predicting of the root canal treated teeth (11, 12). The lack of standardized criteria for an evaluation in endodontic clinical studies is the main cause of inconsistent prognosis (12). Therefore, it is important to consider aspects of the criteria for the clinical success of those studies (1, 11).

Criteria for endodontic treatment outcome assessment

The methods used to evaluate the results of root canal treatment include clinical signs and symptoms, radiographic examination of the periapical status, and histopathologic findings. Histopathological analysis cannot be performed in the case of nonsurgical root canal treatment. Hence, the assessment of the periapical status is clinical symptoms and radiographic images only (9).

There are various criteria used for evaluating the outcome of root canal treatment for standardization as follows:

Strindberg's criteria

In 1959, Strindberg (13) suggested that evaluation of outcome is based on analysis of clinical and radiographic findings of the treated tooth at the time of treatment and follow-up examination.

The Strindberg criteria are recognized as the standard by which the outcome of the endodontically treated teeth is evaluated and are still widely used. These criteria were strict. For example, only teeth that complete absence of clinical signs and symptoms and normal radiographic presentation are classified as "success". In contrast, an asymptomatic tooth with the appearance of broken or unclear lamina dura is classified as "uncertain", and clinical decision necessary for subsequent management (14). These criteria categorized the treatment outcome as follows in Table1.

Table 1 Clinical and radiographic assessment of Strindberg's criteria

Treatment outcome	Clinical	Radiographic
Success	No symptoms	- Contours and width of the periodontal ligament (PDL) are normal. - PDL contours are widened mainly around excess root filling. - Lamina dura is intact.
Failure	Symptoms present	- Unchanged periradicular rarefaction. - Decrease in periradicular rarefaction, but no resolution. - Appearance of new rarefaction or an increase in the size of initial rarefaction. - Discontinuous or poorly defined lamina dura
Uncertain		- Ambiguous or technically unsatisfactory radiograph which could not be interpreted with certainty. - Periradicular rarefaction less than 1 mm and disrupted lamina dura. - The tooth was extracted before recall due to reasons not related to endodontic outcome.

Bender's criteria

In 1966, Bender *et al.* (15) established criteria based on observing the correlation between clinical, histologic, and radiographic features of endodontically treated teeth. These criteria are suggested as being more realistic criteria for successful endodontic therapy. These criteria categorized the treatment outcome as follows in Table 2.

Table 2 Clinical and radiographic assessment of Bender's criteria

Treatment outcome	Clinical	Radiographic
Success	- Absence of pain or swelling. - Disappearance of fistula. - No loss of function. - No evidence of tissue destruction.	- Radiographic evidence of an eliminated or arrested area of rarefaction after a posttreatment interval of 6 months to 2 years.
Failure	- Present of pain or swelling. - Present of fistula. - Loss of function. - Evidence of tissue destruction.	- Increasing size of bone rarefaction or persistent of the bone lesion after a posttreatment. - Development of bone lesion not originally present.

Friedman's criteria

In 2004, Friedman & Mor (16) suggested that the goal of root canal treatment is to prevent or treat apical periodontitis. Therefore, endodontics treatment outcomes should be determined by healing and disease.

These criteria have suggested a novel category "functional" for asymptomatic teeth, regardless of radiological findings that were considered more appropriate when evaluating treatment outcomes (11, 17). These criteria categorized the treatment outcome as follows in Table3.

Table 3 Clinical and radiographic assessment of Friedman's criteria

Treatment outcome	Clinical	Radiographic
Healed	Clinical presentation is normal	Radiographic presentation is normal
Healing	Clinical presentation is normal	Reduced radiolucency can be interpreted as healing in progress
Disease	Clinical presentation is normal, or clinical signs or symptoms are present	Radiolucency has emerged or persisted without change
Functional retention	Clinical presentation is normal	Radiolucency may be absent or present

American Association of Endodontists (AAE)

In 2005, the American Association of Endodontists (AAE) led a review of existing criteria used in endodontics and compared these with the outcome measures used by other specialties. Subsequently, the AAE established news terminology for evaluation and outcoming appropriate measures for endodontics (18).

AAE (19) approved definitions of the endodontic outcomes as follows in Table 4.

Table 4 Clinical and radiographic assessment of AAE

Treatment outcome	Definition of terms
Healed	Functional, asymptomatic teeth with no or minimal radiographic periradicular pathosis.
Non-healed	Nonfunctional, symptomatic teeth with or without radiographic periradicular pathosis.
Healing	- Teeth with periradicular pathosis, which are asymptomatic and functional - Teeth with or without radiographic periradicular pathosis, which are symptomatic but the whose intended function is not altered.
Functional	A treated tooth or root that is serving its intended purpose in the dentition.

Gutmann's criteria

In 2006, Gutmann *et al*. (20) suggested the evaluation criteria for the success and failure of root canal treatment using clinical and radiographic assessment which included the quality of root canal filling as follows in Table 5.

Table 5 Clinical and radiographic assessment of Gutmann's criteria

Treatment outcome	Clinical	Radiographic
Acceptable/Healed	- No tenderness to percussion or palpation - Normal mobility - No sinus tracts or associated periodontal disease - Tooth function - No signs of infection or swelling - No evidence of subjective discomfort	- Normal to slightly thickened PDL space (less than 1 mm) - Elimination of previously radiolucency - Normal lamina dura in relation to adjacent teeth - No evidence of resorption - Dense, three-dimensional obturation of visible canal space within the confines of the root canal space, extending to the cementum-dentine junction (CDJ), approximately 1 mm from the anatomic apex
Uncertain/Healing	- Sporadic vague symptoms, often not reproducible - Pressure sensation or feeling of fullness - Low-grade discomfort after percussion, palpation, or chewing - Discomfort when the pressure is applied by the tongue - Superimposed sinusitis with a focus on the treated tooth - Occasional need for analgesics to relieve minimal discomfort	- Increased PDL space (less than 2 mm) - Radiolucency of similar size or slight evidence of repair - Irregular thickened lamina dura in relation to adjacent teeth - Evidence suggestive of slight progressive resorption - Voids in the density of the canal obturation, especially in the apical third of the canal - Extension of filling material beyond the anatomic apex

Table 5 (cont.)

Treatment outcome	Clinical	Radiographic
Unacceptable/Disease	- Persistent subjective symptoms - Recurrent sinus tract or swelling - Predictable discomfort to percussion or palpation - Evidence of irreparable tooth fracture - Excessive mobility of progressive periodontal breakdown - Inability to chew with the tooth	- Increased width of PDL space (greater than 2 mm) - Lack of osseous repair within a periradicular rarefaction or increase in the size of radiolucency - Lack of new lamina dura formation - Presence of osseous radiolucency in periradicular areas which nonpreviously existed including lateral radiolucency - Visible, patent canal space that is unfilled or represents significant voids in canal obturation - Extensive overextension of filling material with obvious voids in the apical third of the canal - Definitive evidence of progressive resorption

"Strict" and "Loose" criteria

In 2007, Ng *et al.* (1) defined additional criteria as "Strict" and "Loose". The strict definition of success is characterized by the absence of clinical signs and symptoms and with conventional radiographic measures of complete resolution of periapical lesions and the presence of normal periodontal ligament. While, the success on loose criteria may be determined by the absence of clinical signs and symptoms with the reduction in the size of the existing periapical lesion or incomplete healing upon recall (1, 10).

The Periapical Index (PAI)

In 1986, Ørstavik *et al.* (21) introduced the use of PAI for radiographic analysis in root canal treated teeth. The PAI relies on the comparison of the evaluated with a set of five radiographic images, which represent histologically confirmed periapical conditions. It is a 5-point ordinal scale as listed in Table 6 and Figure 1. Scores 1 and 2 indicate healthy periapex, while scores 3-5 indicate increasing extent and severity of apical periodontitis.

The PAI provides more targeted criteria for radiographic evaluation of the periapical status of root canal treated teeth. This system is reasonably accurate, repeatable, and able to distinguish between sub-populations. It may also allow for results from different researchers to be compared (21). Therefore, it has been used in several studies of root canal treatment outcomes for periapical status evaluation (11, 17, 22-24).

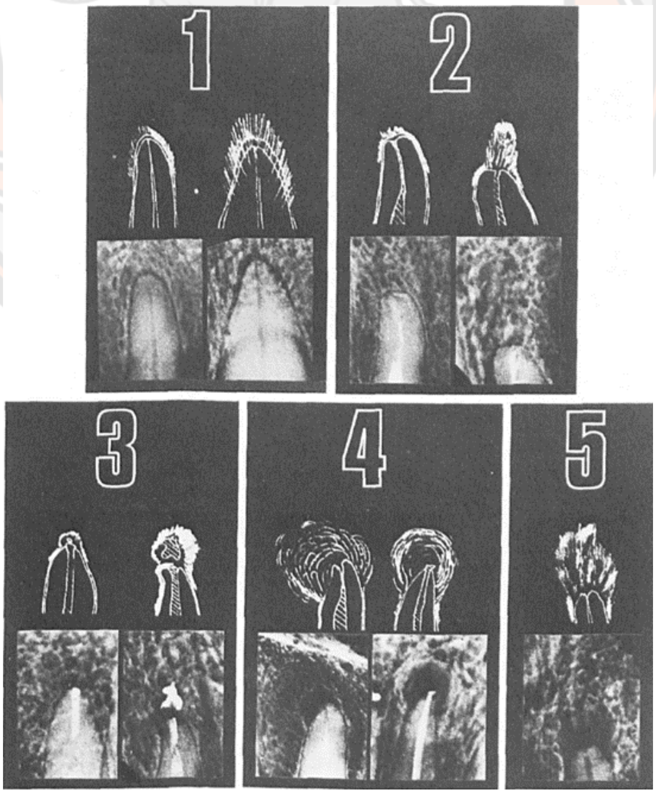

Figure 1 The set of five radiographic images for the evaluation of the roots with the PAI score system (21)

Table 6 PAI scoring with radiographic evaluation

PAI score	Radiographic
1	Normal periapical structures
2	Small changes in bone structures
3	Change in bone structure with mineral loss
4	Periodontitis with a well-defined radiolucent area
5	Severe periodontitis with exacerbating features

The outcome of endodontic treatment

Strindberg's study (25) of outcomes of endodontic treatment at the end of the 4-year follow-up showed that success rates in endodontic treatment are significantly lower for necrotic teeth with apical periodontitis than teeth with normal periapical tissue. This similar finding has been repeatedly shown in outcomes of several studies (11, 26-29). Studies on teeth with apical periodontitis that integrated microbiologic sampling into the clinical protocol demonstrated that teeth with positive culture before root canal filling had a significantly lower success rate compared to teeth with negative culture (27, 30, 31). Similar findings have been shown in studies using the PAI score for measuring healing (11).

A systematic review of clinical studies on the success and failure of nonsurgical root canal treatment reported that the overall radiographic success rate was 81.5% over a 5-year period (32). The various success rates in individual studies were the result of the criteria used, however, success rates of these studies were significantly lower for infected teeth with preoperative apical periodontitis (29, 33).

In Thailand, a study assessed the success and failure of nonsurgical root canal treatment in upper and lower anterior teeth performed by undergraduate dental students at Chiangmai University. The clinical and radiographic evaluation was found with a success rate of 81.6%, whereas uncertain and failure rates were 6.4% and 12.1%, respectively. In cases of failures, the main reason was due to the dislodgement of temporary filling, as the temporary filling was not suitable for the period of waiting for permanent restoration (4).

A study assessed the success of root canal treatment at Mahidol University and used clinical and radiographic evaluation. This study showed that the recall rate was 41.6%. The overall success, uncertain, and failure rates of root canal treatment were 61.0%, 28.0%, and 11.0%, respectively. The factors that caused the decreased success rate were the presence of preoperative periapical lesions, the distance between root canal filling and root apex was more than 2 mm, complications during the treatment period, and poor quality of coronal restoration (2).

There was also another study that studied the success rate of root canal treatment performed by undergraduate students at Khon Kaen University, after root canal filling for at least 12 months. The recall rate of this study was 21.17%. By using Gutmann's criteria, the success rate was 80.7%, whereas the uncertain and failure rates were 6.0% and 19.3%, respectively. The quality of root canal filling, the quality of the restorative material, and the recall period were factors that influenced the success of root canal treatment (5).

In addition, there was a previous study of Naresuan University that evaluated the outcome of endodontic treatment performed by dental students from 2010 to 2015. This study showed that the recall rate was 36.3%. They found that the overall success rate of endodontic treatment was 72.8%, the failure rate was 27.2%, and the functional rate was 96.2%. The factors that significantly influenced the outcome found in this study were the periapical status, and the recall period (34).

Factors influence the outcome of initial endodontic treatment

The outcome of treatment varies widely in each study. The factors that influence the treatment outcome from each study cause confusion and cannot compare to other studies (12). Different treatment outcomes depend on study characteristics and clinical factors (1, 10, 12).

Study characteristics

<u>Composition of study material</u>

Tooth type and number of roots

Many studies include only anterior or single-rooted teeth, while some studies pooled single and multirooted teeth. Results of a study can vary between single- and multirooted teeth because of differences in the definition of the unit of evaluation, the root, or the whole tooth. When a multirooted tooth is evaluated as a single unit and disease occur at one of those roots, the opportunity to observe that persistent apical periodontitis is multiplied. While, when each root of a multirooted tooth is evaluated as an independent unit of evaluation, one root may be recorded as healed and the other as a disease (8).

Sample size

Sample size determines the power of a clinical study and the ability to prove statistically significant differences among groups. Because in most studies the sample size is very small, some specific variables may not be significant, while in the large-scale study the same variables may have a significant influence on the prognosis (12).

Case selection criteria

Case selection is a process of prognosis and determines the results of a clinical study (35). In which some studies, all treated teeth are also included, even if there are severe periodontitis or treatment errors (8), and negatively impacted the overall outcome. As case selection in studies differed from none to strict, the reported outcomes differed accordingly (36).

The Proportion of teeth with apical periodontitis

The presence of apical periodontitis at the beginning of treatment was shown to have a negative effect on the outcome of treatment (36). When most of the subjects in the study had preoperative periapical lesions, and a high proportion of teeth with apical periodontitis on the overall success rate of treatment was lower than those with a low proportion (11, 17, 24, 26, 36).

Methodology

Study design

Most of the studies are retrospective studies and prospective studies. The pre-, intra-, and post-operative data from those studies sometimes are missed, such as material, treatment procedures, and complications. The results of studies lacking such important information cannot be used as a basis for clinical prognosis evaluation, but only a hypothesis can be developed (12).

Recall rate

When many subjects in a study are not available for follow-up. It causes the unawareness of the actual outcome of the treatment and making predictions about the outcome (13, 37, 38). For example, it has been speculated that a low recall rate could distort the results to an unfavorable outcome (35) unless it results from objective factors, such as deceased or relocated subjects who were inaccessible (13, 37). Because the recall rates in different studies varied from 12% (39) to close to 100% (31, 40), and in some studies did not report (41-45), the prognosis reported in the studies is also not consistent (12).

Interpretation of radiographs

The results of radiography may depend on changes in angulation and contrast, and the interpretation of the radiography. Inconsistency in radiographic interpretation and bias may undermine the reliability of treatment results. Blinded examiners and standardized the interpretation of radiographs are the important component of the treatment evaluation (12).

Follow-up period

Healing of apical periodontitis is a dynamic process, and sufficient time is needed to assess its progression and completion (13, 46, 47). Observations after a short follow-up may only show signs of healing (8, 13, 47, 48). Therefore, the results of a short follow-up study do not reflect the true prognosis (13, 22, 35, 49). Follow-up at least 1 year is required for meaningful changes (47, 50), but an extension of the follow-up to 3 or 4 years is required for a stable record of treatment results (13, 22, 26, 46, 47). Because with time, root canal treated teeth are subject to negative effects of periodontal and restorative deterioration, extensive follow-up periods tend to reveal the influence of those effects on the outcome (12).

Unit of evaluation

Counting roots as the evaluated unit results in the weight of the study in the proportion of multirooted teeth than the single-rooted teeth study. Also, the healing rate is higher if using the evaluation to count the whole teeth (12).

Outcome measures and criteria

The lack of standardized criteria for an evaluation in endodontic clinical studies is the main cause of inconsistent prognosis (12). In many studies, the radiographic findings were used only as the outcome measure (26, 39, 51-53). Because in those studies, any symptomatic but radiographically normal teeth were not observed, the results were often skewed towards higher healing rates (9, 15). Moreover, a bias occurs when incompletely healed lesions are grouped with completely healed lesions (39, 42, 51, 52).

Qualification of treatment providers

Experienced and skillful operators are less likely to make procedural errors that might affect the prognosis (35). Therefore, study outcomes may vary based on the providers of treatment and their expertise. As operators in the different studies varied from undergraduate students to qualified endodontists (3), the study outcomes vary accordingly. Ingle *et al.* (35) reported no significant difference in success rates of treatment performed by undergraduate students or private practitioners, in agreement with Cheung (54) who found the qualification and experience of treatment providers did not influence treatment outcome.

Clinical factors

<u>Pre-operative factors</u>

Age and gender

Ørstavik *et al.* (55) found that the root canal treatment outcome in the older patient was a high success rate due to tertiary dentine formation in the root canal, which reduced the complex root canal. On the other hand, Grossman *et al.* (41) reported that root canal treated teeth follow-up 1 to 5 years by clinical and radiographic evaluation in the younger age group was a higher repair rate than in the older age group.

Several studies study the factors of age and gender on the results of root canal treatment. These factors do not significantly influence the prognosis of endodontic therapy (26, 27, 36, 56).

Systemic health

Systemic health factors have not been discussed in any studies. Although the patient's health was one of the research questions in Strindberg's study (13), it was not mentioned in the results. Therefore, it can be assumed that this factor did not affect the prognosis.

Tooth location and number of roots

The location of teeth in the maxillary or mandibular arches did not make a difference in the probabilities of tooth survival. (57, 58). Kerekes & Tronstad (26) observed that maxillary canines, mandibular canines, and second premolars have a better prognosis than other teeth, but they have not observed the difference between anterior and posterior teeth. The satisfactory results obtained in anterior teeth may be due to the greater extent of enlargement of the canals with the standardized techniques as compared with a previous technique.

Moreover, Engström *et al.* (30) reported that single-rooted teeth showed a better prognosis than multi-rooted teeth. However, this may be related to the fact that the whole tooth was considered the unit of evaluation, multiplying the chances of the occurrence of persistent disease by the number of roots. The analysis of teeth survival after endodontic treatment reveals the mandibular molars had significantly lower than the other teeth (54).

Symptoms

Pre-operative symptoms may reflect the type and number of microbes living within the root canal system (59). However, the healed rate is comparable for teeth appearing with preoperative symptoms and for asymptomatic teeth (27, 36, 46, 60). Many studies reported that preoperative symptoms do not influence the outcome of root canal treatment (27, 46, 60).

Pulp condition

Friedman *et al.* (11) reported that the healing rate of vital pulp was higher than nonvital pulp, but not statistically significant. In contrast, the meta-analysis revealed that the pulp condition had a significant effect on the success rate (61).

Periapical status

Most studies concluded that teeth without preoperative periapical lesions had a better healing and survival rate than preoperative periapical lesion teeth (10, 58, 62, 63).

Lesion size

Lesion sizes smaller than 5 mm have been reported to have a better prognosis than lesions larger than 5 mm (13, 60). In contrast, in other studies that examined this factor, the prognosis difference between small and large lesions was not statistically significant (27, 31, 36, 46, 56). However, the relationship between the size of the lesion and the number of microbes in the root canal can affect the prognosis, the root canals of teeth with lesions larger than 5 mm contained significantly more bacterial cells than teeth with smaller lesions (46).

Periodontal condition

Pre-operative periodontal condition of the tooth undergoing endodontic treatment has received little consideration about the prognosis of apical periodontitis. According to Sjögren *et al.* (27), the periodontal condition does not affect the prognosis.

Periodontal disease may lead to premature loss of teeth due to periodontal disease. Abitbol (36) noted that a total of 21 lost teeth, 52% had been extracted due to periodontal disease.

Intra-operative factors

The apical extent of treatment

This factor was found to influence the prognosis of the treatment in some studies (13, 27, 30, 56) but did not influence prognosis in the other studies (36, 46, 60).

Several studies in the systematic review by Ng *et al.* (10) classified the various extents into three types for statistical analyses:

1. > 2 mm short of the radiographic apex (short)

2. 0-2 mm within the radiographic apex (flush)

3. Extruded beyond the radiographic apex (long)

Most found that apical extent had a significant influence on the success rates; flush root fillings were involved in higher success rates than short root fillings or long root fillings (13, 27, 56, 64), and short root fillings had significantly higher success rates than long root fillings (42, 51, 65).

The extrusion of the filling materials beyond the root end generally results in a poorer prognosis (16, 29-31). Because gutta-percha is well tolerated by the tissue, the presence of impaired prognosis may result from over-instrumentation and periapical displacement of the infected debris more than from the extrusion of root filling materials (30, 41). Extruded filling materials can be completely or partially removed during the healing process (16, 42, 43).

The inability to instrument the canal to the root apex and the root filling is too short (2 mm or shorter), making the prognosis poorer when compared with an adequate filling (0-2 mm) (27). Therefore, the poorer prognosis in underfilled roots may be due to the incompetence to debride the apical segment of the canal or to the accumulation of infected dentin chips which may be the source of persistent infections at the root apex (66, 67).

Apical enlargement

Strindberg (13) reported that large apical preparation is associated with a poorer prognosis. However, Kerekes & Tronstad (26) observed a comparative prognosis for apical enlargement to sizes ISO 20-40 and 45–100. These findings seem to contradict the conceptual importance of removing infected dentin in root canal treatment. Intracanal microorganisms can penetrate up to 150-250 µm deep in the root dentin, where they may be protected from irrigants and medicaments (68). Enlarging the size of the canal to 300–500 µm (for example, using the MAF file size 50-70 from the IAF file size 20) can eliminate the infected dentin. Extensive apical enlargement is thus believed to increase the removal of infected dentin and the disinfection of the apical portion, which improves the prognosis (59, 69, 70). However, extensive apical enlargement is often associated with canal transportation and may be harmful to canal disinfection, and worsen the prognosis. The procedure of extensive apical enlargement is technique-sensitive, and it requires considerable skill, especially the use of stainless-steel hand files in the treatment process. It is possible that the inability to demonstrate the differences in prognosis between extensive or minimal apical enlargement, which, if not enlarged without proficiency, may cause canal transportation, whereas minimal enlargement may leave infected dentin behind. Both of these effects may reduce the prognosis of the root canal treatment (3).

Culturing

Sjögren *et al.* (31), by using advanced anaerobic bacteriological techniques observed that 94% of teeth were completely healing in negative cultures before root canal filling. In contrast, only 68% of teeth had complete healing in positive cultures. In addition, some species of microorganisms in the root canal influence prognosis, and the investigation of failure revealed the presence of *Actinomyces* species (31).

Engström *et al.* (30) reported the effects of negative culture before root canal fillings that provided a good prognosis, but the use of microbiological techniques did not refer to the anaerobic bacteria that are the major endodontic pathogens. Because the methodology of microbiological root canal sampling is complicated, the culture test may be false positive or false negative results. For example, the bacterial biofilm may be difficult to sample, or remnants of the medication can affect the growth of bacteria (71).

Treatment sessions

When two or more treatment sessions are performed, the prognosis may not depend on the number of sessions (26). However, the survival analysis shows that teeth treated in two or fewer sessions have a better chance of surviving than the treated teeth in multiple sessions (54). Sjögren *et al.* (31) have demonstrated that intracanal infection cannot be eliminated in one session. To maximize disinfection, inter-appointment intracanal dressing is required (72-74). Constantly, differences in healing rates shown in the relevant studies for one or two treatment sessions are not statistically significant (36, 60, 75). Likewise, many systematic (10, 76-78) reviews concluded that success rates between single and multiple visits were not significantly different.

Flare-up

Even though it has been demonstrated that the causative factors of inter-appointment flare-ups contain mechanical, chemical and microbial injury to the pulp or periradicular tissues (79, 80), its occurrence does not affect the prognosis of apical periodontitis after root canal treatment (26, 27, 46). Similarly, none of the studies in the systematic review by Ng *et al.* (10) has presented outcome data by this factor.

Intracanal medicament

Cheung’s survival analysis (54) has shown that teeth medicated with calcium hydroxide improve the chances of survival than teeth that are not medicated or medicated with other materials. Consistently, Byström’s studies (46, 72) revealed that intracanal dressing with calcium hydroxide is effective in microbial elimination. According to Shuping *et al.* (81), there is about a 90% chance of obtaining a negative culture after dressing. However, Peters *et al.* (40) have conflicting results from previous studies, they observed the increased bacterial load after root canal dressing with calcium hydroxide. It is difficult to reconcile those conflicting results. There is some concern about the hydroxide application technique used by Peters *et al.* (40), the dressing was plugged with paper points, which could cause the calcium hydroxide mixture to become too dry (40). A similar technique was used in the clinical study (54), where teeth medicated with calcium hydroxide and treated in two visits have healed slightly less frequently than those filled in one visit.

Root canal preparation

Marending *et al.* (82) compared the success rate of root canal preparation techniques between the K-files and the NiTi-rotary instrument and found no significant difference between the two techniques.

Smith *et al.* (64) compared the treatment outcome of taper of canal preparation and found that a flared preparation (wide taper) resulted in significantly higher success rates than a conical preparation (narrow taper). In contrast, Hoskinson *et al.* (83) found no significant difference in treatment outcome between narrow (0.05) and wide (0.10) canal tapers.

Irrigation

Different types of irrigants have been used alone or in various combinations in many previous studies, such as sodium hypochlorite, iodine, chloramine, sulphuric acid, water, saline, ethylene-diamine-tetraacetic acid (EDTA), hydrogen peroxide, organic acid, Savlon®, Biosept® and quaternary ammonium compound (10).

Byström & Sundqvist (73) and Dalton *et al.* (84), have studied root canal instrumentation coupled with inactive irrigants that do not have antimicrobial activity, regardless of whether carried out with stainless steel hand instruments or with nickel-titanium engines-driven ones. The chances to eliminate microorganisms and obtain a negative culture using filing and inactive irrigants are approximately 30%. In contrast, irrigation with 0.5% or 1.25% sodium hypochlorite increases the efficiency of the microbial elimination and a negative culture has increased to about 60% (84).

Zamany *et al.* (85) investigated the rate of the successful disinfection of the root canal system *in vivo* of the addition of 2% chlorhexidine to the conventional treatment protocol that rinse with 1% sodium hypochlorite alone and reported that the addition of 2% chlorhexidine was significantly more effective than the conventional protocol in providing a bacteria-free root canal.

Root filling material and technique

Many root canal filling materials have been used, such as gutta-percha, silver points, amalgam, Hydron® (poly-hydroxyethyl methacrylate), Alytit®, and iodoform paste. Most of the studies filled the canals using gutta-percha with various types of sealer or gutta-percha softened in chloroform, and most others used a combination of filling materials or techniques (10). Many previous studies (8, 13, 42, 44, 51, 86, 87) which have examined the effects of root filling materials, and/or techniques on treatment outcome, did not find any significant influence. As reported Abitbol (36) compared the prognosis of lateral and vertical condensation and found no significant difference. In addition, other studies did not find any difference in treatment outcome of teeth filled using different techniques between cold lateral condensation and warm gutta-percha (88), or Thermafil (89).

The different types of sealers have been used, such as zinc oxide eugenol-based, resin-based, calcium hydroxide-based, glass-ionomer-based, and Endomethasone. Several studies in the systematic review (10) concluded that the types of sealer had no significant effect on the prognosis (22, 44, 50, 65, 90).

Complications

Complications during treatment, such as perforation of the pulp chamber or root, broken instruments that are unable to clean the canal, and excessive extrusion of filling materials, make the prognosis worse (13, 26, 27). Marquis et al. (26) concluded that intraoperative complications had a significant negative impact on treatment outcomes, especially in teeth with preoperative apical periodontitis. By their nature, all perforation, instrument breakage, untreated canals, cracks, and abnormal anatomy can either promote infection or interfere with its elimination which affects the treatment outcome.

Cvek *et al.* (91) and Sjögren *et al.* (27) found that root canal treatment with iatrogenic perforations decreased the success rates significantly. Similarly, Gutmann & Harrison (92) reported that artificial communication between the root canal system and supporting tissues of the tooth or oral cavity reduces the prognosis, and often leads to tooth loss. Fuss & Trope (93) concluded that the prognosis of root perforations is rely on the prevention or treatment of bacterial infection of the perforation site. Moreover, the use of a non-irritating material that repairs the perforation will limit periodontal inflammation. Many factors associated with infection of the perforation site influence the prognosis of the treatment of root perforations, and the important factors are the time between occurrence and treatment, size, and location of the perforation.

Strindberg (13) reported that separated instruments during treatment resulted in a significantly lower success rate. While, the other studies have demonstrated the minimal influence of fractured instruments on the success rate of the treatment (26, 94, 95). The stage of root canal instrumentation at which the instrument separates can influence the prognosis. However, the broken instrument was less involved in failure because most of the time, the success is only influenced when a concomitant infection is present (96). A clinical investigation on the relationship of separated rotary instruments to endodontic case prognosis confirmed that in the absence of any pre-operative infection and periapical changes, a broken instrument is most likely not to affect the prognosis (97).

Breaking of interim restorations

Factors of breaking of interim restorations have not been discussed in any previous studies. However, Siren *et al.* (98) showed that if the root canals had been unsealed at some point during the endodontic treatment, enteric bacteria were found more frequently than in canals with an adequate seal between the appointments. Therefore, this finding shows a possible decrease in favorable long-term treatment outcomes if the interim or temporary restorations are breakdowns at any time during the endodontic treatment process (99).

Post-operative factors

Quality of coronal restoration after root canal treatment

Friedman *et al.* (100) clearly showed that root canal infection and associated apical periodontitis can occur after root canal treatment when microbes become established in the coronal portion of the tooth, i.e. the pulp chamber. This finding confirms previous indications of microbial proliferation in the filled root canal *in vitro* (101-103). Abitbol (36) reported that of the total of 21 lost teeth, 29% were extracted due to restoration considerations, compared to 19% that were extracted for other causes including persistent apical periodontitis. Similarly, Cheung's survival analysis (54) reported that 53% of teeth lost after endodontic treatment were extracted due to fracture, with additional teeth extracted due to a prosthetic need.

Several studies had analyzed the influence of quality of coronal restoration on treatment results and reported conflicting conclusions. The studies had categorized the quality of restoration differently, for instance, restored versus unrestored, satisfactory versus unsatisfactory, or permanent versus temporary (10). Hoskinson *et al.* (83) described satisfactory restorations as those with no evidence of discrepancy, discoloration, or recurrent caries at the restoration margin with an absence of a history of decementation. Some studies reported that treated teeth with restorations, satisfactory restorations, or permanent restorations were associated with significantly higher success rates than their contrary counterpart (8, 45, 104). In contrast, others found no significant differences (83, 105).

Regarding posts, their presence or absence may affect the prognosis if the remaining root filling is reduced to less than 3 mm (106). Posts clearly show a risk to endodontically treated teeth. They have been found as the cause of vertical root fracture and tooth loss in approximately 9% of cases (107). In addition, root perforation related to a post impairs the prognosis (108).

The type of restoration (temporary, definitive, filling, cast) does not appear to affect the prognosis (31, 36). In contrast, Sjögren *et al.* (27) reported that teeth restored with crowns or serving as bridge abutments indicated a worse prognosis than teeth restored with fillings. Moreover, the systematic review concluded that teeth restored with a permanent restoration or crown were involved in significantly higher survival than direct restorations (63).

Use as the abutment of prosthesis

Several studies had investigated the influence of use as the abutment for prosthesis on treatment outcomes. Some studies (27, 109-111) found that bridge and denture abutments had significantly lower success rates than individual units. In addition, root canal treated teeth used as bridge abutments had a lower survival probability than those used as removable denture abutments (111). However, Storms (43) did not find such a significant difference.

The meta-analysis by Ng *et al.* (63) reported that the teeth not functioning as fixed or removable prosthesis abutments were related to a significantly higher chance of survival than those that functioned as fixed-prosthesis abutments.

Duration of final restoration after root canal treatment

Pratt *et al.* (112) investigated that the duration of crown placement after root canal treatment was significantly associated with a survival rate of root canal treated teeth. Teeth that received crown 4 months after root canal treatment were almost 3 times more likely to be extracted than teeth that received a crown within 4 months of root canal treatment. Moreover, Ahmad & Sadaf (113) found a highly significant association between extraction of root canal treated teeth with a delay of more than 60 days placement of final coronal restoration after completion of root canal treatment.

Occlusal trauma

Less is known about the effect of occlusal trauma on the pulp and periapical apparatus, or specifically on the outcome of root canal treatment. Traumatic occlusion has been involved in periapical osteosclerosis or excessive mineralization of bone around the apices of asymptomatic vital teeth (114). However, the effect of chronic occlusal trauma on the progression of pulpal and periapical disease is relatively unknown. Matsumoto *et al.* (109) found occlusal trauma to be a key factor in prolonging periapical healing of endodontically treated teeth. In contrast, Kumazawa *et al.* (115) found a positive relationship between traumatic occlusion and periapical lesions in rats.

They suggested that occlusal trauma may be involved in a delay in the spread of inflammation to the periapical area.

Of all the factors that were reviewed, factors affecting the outcome, factors not affecting the outcome, and controversial factors can be summarized as follows in Table 7.

Table 7 Lists the factors affecting the outcome, factors not affecting the outcome, and controversial factors

Factors affecting the outcome	Factors not affecting the outcome	Controversial factors
- Tooth type and number of roots - Pulp condition - Lesion size - Periapical status - Apical extent of treatment - Culturing - Intracanal medicament - Complication - Recall period - Quality of coronal restoration - Use as the abutment of prosthesis - Duration of final restoration	- Age - Gender - Tooth location - Preoperative symptoms - Periodontal condition - Systemic health - Treatment session - Flare-up - Root canal preparation technique - Root-filling material and technique	- Apical enlargement - Irrigation - Breaking of interim restorations - Types of restoration - Occlusal trauma

CHAPTER III
RESEARCH METHODOLOGY

Selection of cases

This retrospective study obtained ethical approval from the Human Research Ethics Committee of Naresuan University (No. P10047/64). This study obtained data from dental treatment records and radiographs of root canal treated teeth performed by undergraduate dental students at the Endodontic Clinic, Faculty of Dentistry, Naresuan University, Phitsanulok, from May 2015 to April 2020.

Inclusion and exclusion criteria

Inclusion criteria included all initial root canal treated teeth either anterior teeth or premolars with an absent or present procedural error such as iatrogenic tooth perforation, separated instrument, root canal blockage, or transportation. The treated teeth were recalled after the treatment for at least 6 months. Inclusion criteria also included completed treatment records and good quality digital periapical radiographs (including pre-operative, post-operative, and follow-up).

The teeth were excluded from this study if they were not completely treated or if not being initial root canal treated teeth. Patients who were not available to recall, incomplete treatment records due to lacking adequate data, and ambiguous periapical radiographs were also excluded from this study.

Treatment protocol

The root canal treatment procedures were performed by undergraduate dental students under the supervision of experienced endodontists. Preoperative pulpal and periradicular diagnoses and treatment plans were made at the initial examination, and recorded in endodontic records. All teeth were treated with an aseptic technique under rubber dam isolation, and if needed, reconstruction of missing walls with glass ionomer cement or resin composite. After access cavity preparation, the working length was established at 0.5 mm, using an electric apex locator and digital radiography. All root canals were mechanically prepared by stainless-steel K-files with the step-back technique until a master apical file size #30 or larger was obtained. Irrigation was frequently performed with 2.5% sodium hypochlorite (NaOCl). Calcium hydroxide applied with a lentulo-spiral was used as an interappointment dressing for teeth treated at least 2 weeks before canals were obturated. The interappointment temporary dressing routinely used were Cavit™ and IRM®.

At the obturation appointment, the root canal was obturated when the tooth was normal clinical signs and symptoms, absence of sinus tract, and dried and odorless dressing. Before obturation, root canal irrigation was performed with 2.5% NaOCl, 17% EDTA solution, normal saline, and 2% chlorhexidine gluconate as a final rinsing. The canals were dried with paper points and obturated by lateral condensation technique with gutta-percha and either zinc oxide eugenol-based root canal sealer or epoxy resin-based root canal sealer (AH Plus®). After root canal treatment, the treated teeth were intermediately restored with Cavit™ and resin composites await the permanent restorations. Finally, the teeth were either permanent restorations with direct composite fillings or indirect restorations with post and core crowns.

This study included the cases with procedural errors, which were recorded as absent or present. The types of procedural errors such as perforation, separated instruments, or root canal transportation were also recorded. The perforation defect was repaired with either Glass ionomer cement (GIC) or Mineral trioxide Aggregated (MTA) under the dental operating microscope by the experienced endodontist.

The treated teeth were recalled at least 6 months or longer after obturation by undergraduate dental students as a part of the Endodontic course. When any treated teeth had been extracted, and those who did not respond to the recall, the dental charts were recorded. Follow-up examinations consisted of history taking and clinical and radiographic examinations.

All digital periapical radiographs (pre-, post-operative, and follow-up) were obtained using an intraoral radiographic unit (MyRay®, Ivoclar Vivadent, Bologna, Italy [65 kVp, 7 mA]), size 2 image plates (DÜRR DENTAL AG, Bietigheim-Bissingen, Germany), a positioning device (RINN XCP®, Dentsply-RINN, PA, USA) according to the paralleling-technique, and an image plate scanner (VistaScan Mini Plus®, DÜRR DENTAL AG, Bietigheim-Bissingen, Germany).

Radiographic Calibration

The reference calibration set of twenty digital periapical radiographs was selected by the researcher from periapical radiographs which were taken before May 2015. Three independent examiners (one general practice and two endodontists) were trained for standardized PAI scoring with the reference calibration set. After 1 week, the same set of radiographic images was analyzed by the same examiner to assess intra-examiner agreement (116). Intra-examiner and inter-examiner agreement with the calibration set was assessed by using Cohen's kappa. In this study, the agreement was accepted when the value of Kappa is greater than 0.70, meaning a substantial agreement (117).

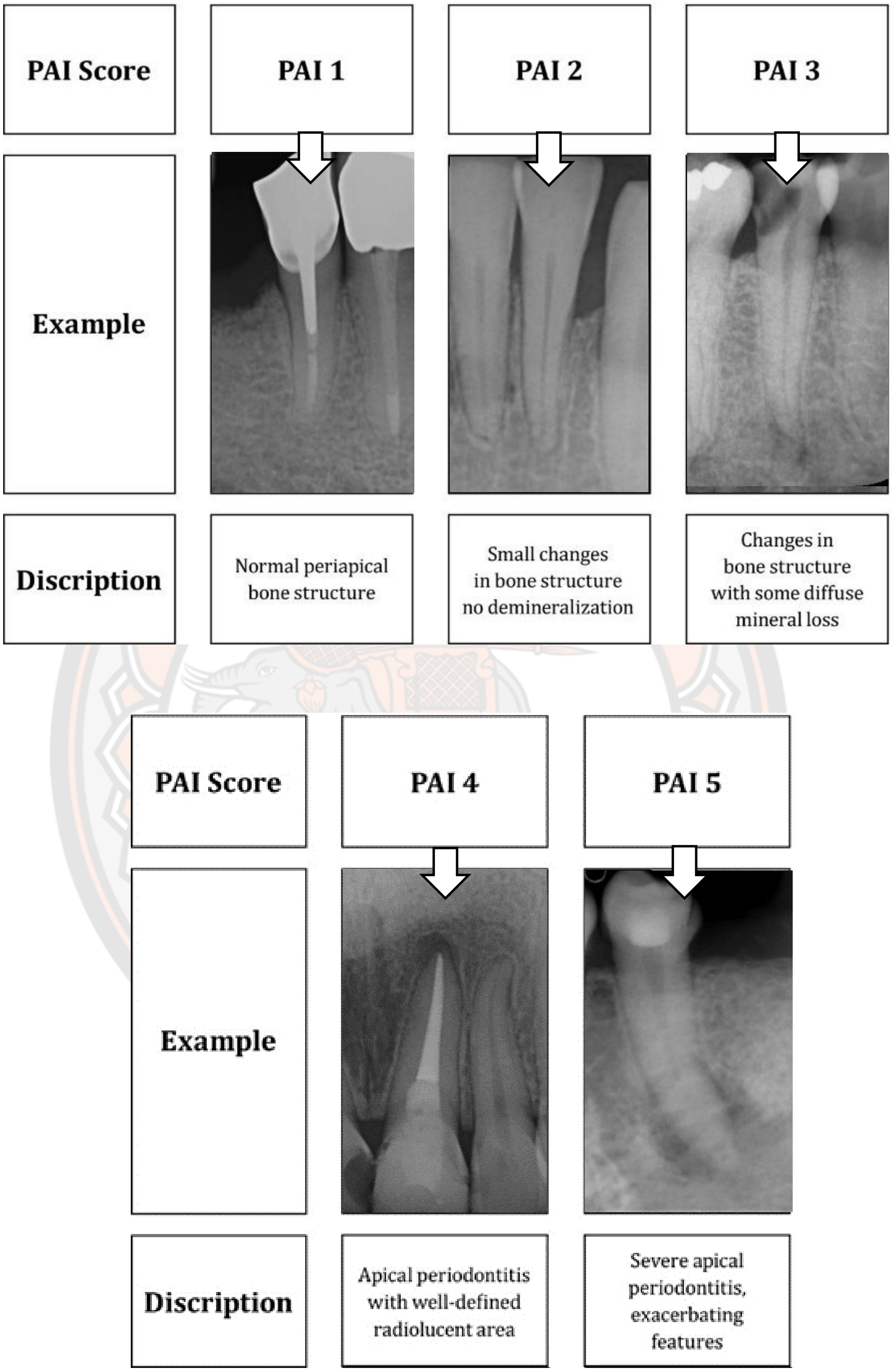

Figure 2 Examples of radiographs for PAI scoring calibration in this study and the verbal descriptions of the PAI score

Data collection

Patient information and treatment records were normally recorded in the dental charts of each patient at the time of treatment by the operator (undergraduate students supervised by the experienced endodontist). The following factors were obtained from dental charts: age, gender, tooth location, tooth type, pulp status, the occurrence of procedural complications, breaking of interim restorations, the recall period, type of restoration, the quality of coronal restoration, abutment for prosthesis, duration before the final restoration and occurrence of occlusal trauma. The other factors were obtained from digital periapical radiographs: periapical status, size of the periapical lesion, and apical extent of root canal filling.

Assess pre-operative, intra-operative, and post-operative data

1. The pre-operative data were assessed to the treatment records, including
   - 1.1 Age in years old was specified in dental charts.
   - 1.2 Gender was specified in dental charts.
   - 1.3 Tooth location was classified into maxilla or mandible.
   - 1.4 Tooth type was classified into anterior or premolar.
   - 1.5 Pulp status was specified in the endodontic record, and was classified into 3 conditions: healthy, pulpitis, and necrosis.
   - 1.6 The periapical status was scored according to the PAI system and apical periodontitis was classified as absent (PAI ≤ 2), or present (PAI ≥ 3). The unit of the evaluation was a whole tooth. In multirooted teeth, the condition of the most severely affected root was considered.
   - 1.7 The size of the periapical lesion was measured in the widest and recorded in < 5 mm or ≥ 5 mm.
2. The intra-operative data were assessed to the treatment records, including
   - 2.1 Occurrence of procedural complications was seen on digital periapical radiographs and was recorded in dental charts as:
     - a. Iatrogenic tooth perforation:
       - i. Location of the perforation was classified into 3 locations according to Fuss & Trope (93):

1. Coronal perforation: coronal to the level of crestal bone, and epithelial attachment with trauma to adjacent tissues.
2. Crestal perforation: at the level of the epithelial attachment into the crestal bone.
3. Apical perforation: apical to the crestal bone and the epithelial attachment.

ii. Types of repair materials were recorded as glass ionomer cement or MTA.

b. Separated instrument was classified into 3 locations: coronal third, middle third, and apical third.

c. Root canal blockage

d. Transportation

2.2 Breaking of interim restorations was obtained from intra-operative treatment records and was recorded as: present or absent

2.3 The apical extent of root canal filling was evaluated according to Ng *et al.* (10):

a. Short: > 2 mm short of radiographic apex.

b. Adequate: 0-2 mm within the radiographic apex.

c. Long: extruded beyond the radiographic apex.

3. The post-operative data were assessed to the treatment records and data were obtained from the last follow-up visit, including

3.1 The recall periods in months were recorded as 6-11 months, 12-23 months, 24-35 months, or ≥ 48 months.

3.2 Types of restoration were was classified into 2 types:

a. Intermediate restoration: Cavit™ and resin composite

b. Final restoration: direct composite filling or indirect restoration (post and core with crown, core with crown, and bridge abutment)

3.3 The quality of the coronal restoration was classified into 2 conditions according to Hoskinson *et al.* (83):

a. Satisfactory restoration: no evidence of discrepancy, discoloration, or recurrent caries at the restoration margin with an absence of a history of decementation.

b. Unsatisfactory restoration: loss or fracture of restoration, presence of evidence of discrepancy, discoloration, or recurrent caries at the restoration margin with a history of decementation.

3.4 Use as the abutment for prosthesis was recorded as: yes (removable or fixed prosthesis) or no

3.5 Duration of final restoration after root canal treatment in months was recorded as < 2 months, 2-6 months, or > 6 months

3.6 Occurrence of occlusal trauma was recorded as present/absent

3.7 The periapical status was scored like the pre-operative periapical status.

3.8 The size of the periapical lesion was measured like the pre-operative size of the periapical lesion.

Radiographic evaluation

The radiographic data were obtained from pre-operative and last follow-up periapical radiographs. The pre-operative and follow-up periapical status were defined by the PAI score system by two examiners (one general practice and one endodontist). In case of disagreement, the final evaluation was decided by a third examiner (an experienced endodontist). The size of the periapical lesion was measured in the widest diameter, recorded in mm x mm by the researcher. Then, the size of the periapical lesion was dichotomized as < 5 mm or ≥ 5 mm.

Table 8 Lists the data recorded on pre-operative, intra-operative, and post-operative for each clinical case

Factors	Scores	Notes
Pre-operative		
Age	In years old	
Gender	Male/female	
Tooth location	Maxilla/mandible	
Tooth type	Anterior/premolar	
Pulp status	Healthy/pulpitis/necrosis	
Periapical status	1-5	Based on the periapical index (PAI) score
Size of periapical lesion	< 5 mm/ ≥ 5 mm	The widest diameter of any radiolucency
Intra-operative		
Occurrence of procedural complications	Present/absent	Iatrogenic tooth perforation (location of the perforation, type of repair material), separated instrument (location of the separated instrument), root canal blockage, or transportation
Breaking of interim restorations	Present/absent	
The apical extent of root canal filling	Short/adequate/long	Short, > 2 mm short of radiographic apex; Adequate, 0-2 mm within the radiographic apex; Long, extruded beyond the radiographic apex
Post-operative		
Recall period	In months	
Type of restoration	Intermediate restoration/final restoration	Type of final restoration: Direct/indirect
Quality of coronal restoration	Satisfactory/unsatisfactory	
Abutment for prosthesis	Yes/no	Type of prosthesis: Removable/fixed
Duration of final restoration	In months	
Occurrence of occlusal trauma	Present/absent	
Periapical status	1-5	Based on the periapical index (PAI) score
Size of periapical lesion	< 5 mm/ ≥ 5 mm	The widest diameter of any radiolucency

Outcome assessment

The treatment outcome was assessed based on the clinical and radiographic findings. The outcome of root canal treatment was judged based on the previous study of Naresuan University (34) by using Bender's criteria (15) together with the PAI score system (21).

The treatment outcome in this study was dichotomized as "success" and "failure". Furthermore, the treatment outcome was evaluated as "functional". The criteria for treatment outcome were described in Table 9.

Table 9 The criteria for treatment outcome

Treatment outcome	Clinical criteria	Radiographic criteria
Success	- No clinical signs or symptoms - Absence of pain or swelling - Absence of the sinus tract - No loss of function - No evidence of tissue destruction	- Normal or small changes in periapical structures with no mineralization (PAI ≤ 2)
Failure	- Presence of clinical signs or symptoms - Presence of pain or swelling - Presence of the sinus tract - Loss of function - Evidence of tissue destruction - Post-treatment endodontic intervention - Extraction for endodontic disease	- Changes in bone structures with demineralization (PAI ≥ 3)
Functional	- No clinical signs or symptoms - Absence of pain or swelling - Absence of the sinus tract - No loss of function - No evidence of tissue destruction	- Regardless of the PAI score

Statistical analysis

All data were processed and analyzed via IBM SPSS Statistics Version 26. The univariate describes the data using percentage frequencies. The bivariate associations were tested between the treatment outcomes and pre-, intra-, and post-operative factors by using a Chi-square test. The multivariate associations were tested for evaluating associations between various factors by using logistic regression. The dependent variable for this analysis was the dichotomous outcome of success versus failure. All statistical tests were performed as two-tailed and interpreted at a 5% significance level.

CHAPTER IV
RESULTS

According to radiographic interpretation, the Kappa scores of the inter-examiner agreement of examiners 1 and 2, 1 and 3, 2 and 3 were k = 0.875, 0.810, and 0.745 respectively. The Kappa scores of the intra-examiner agreement of the three examiners were k = 0.812, 0.874, and 1.000 respectively. These Kappa scores indicated excellent agreement.

Of the 555 treated teeth, 373 teeth were excluded as patients declined to recall. Of the responding samples, including 182 teeth examined for the outcome, 6 teeth were excluded: 2 teeth having an incomplete set of digital periapical radiographs, and 4 teeth not being initial root canal treated teeth. One hundred and seventy-six teeth were subjected to statistical analysis. The analyzed samples also were characterized in Table 10. The recall rate in this study was 32.79%.

In this study, patients < 60 of age (88.6%; 156 teeth) came for recall more frequently compared to those ≥ 60 of age (11.4%; 20 teeth). The mean age of the patients was 31.95 years, ranging from 14 to 77. According to gender, males came evaluated at 33.0% (58 teeth) and females came evaluated at 67% (118 teeth). Teeth included in this study were maxillary teeth counted for 80.7% (142 teeth), while mandibular teeth counted for 19.3% (34 teeth). Based on tooth type, 62.5% (110 teeth) were anterior teeth and 37.5% (66 teeth) were premolars. The recall periods in this study were divided into 5 groups: 6-11 months, 12-23 months, 24-35 months, 36-47 months, and ≥ 48 months. The number of samples in each group were 65 teeth (36.9%), 68 teeth (38.6%), 27 teeth (15.3%), 11 teeth (6.3%), and 5 teeth (2.8%) respectively. The mean of the recall periods was 17.67 months, ranging from 6 to 60 months.

Table 10 Frequency distribution of data and successful outcome by tooth

Factors		Total		Success		
		n	%	n	%	p-value
Pre-operative						
Age	< 60	156	88.6	131	84.0	0.906
	≥ 60	20	11.4	17	85.0	
Gender	Male	58	33.0	46	79.3	0.224
	Female	118	67.0	102	86.4	
Tooth location	Maxilla	142	80.7	118	83.1	0.462
	Mandible	34	19.3	30	88.2	
Tooth type	Anterior	110	62.5	86	78.2	0.006*
	Premolar	66	37.5	62	93.9	
Pulp status	Vital	58	33.0	55	94.8	0.006*
	Nonvital	118	67.0	93	78.8	
Periapical status	No lesion	92	52.3	87	94.6	0.000*
	< 5 mm	35	19.9	27	77.1	
	≥ 5 mm	49	27.8	34	69.4	
Intra-operative						
Occurrence of procedural complications	Absence	158	89.8	134	84.8	0.440
	Presence	18	10.2	14	77.8	
Breaking of interim restorations	Absence	169	96.0	143	84.6	0.350
	Presence	7	4.0	5	71.4	
The apical extent of root canal filling	Adequate	166	94.3	140	84.3	0.716
	Short	0	0	0	0	
	Long	10	5.7	8	80.0	
Post-operative						
Recall period	6-11 months	65	36.9	53	81.5	0.686
	12-23 months	68	38.6	59	86.8	
	24-35 months	27	15.3	24	88.9	
	36-47 months	11	6.3	8	72.7	
	≥ 48 months	5	2.8	4	80.0	
Types of restoration	Final	104	59.1	91	87.5	0.137
	Intermediate	72	40.9	57	79.2	
Quality of coronal restoration	Satisfactory	166	94.3	139	83.7	0.599
	Unsatisfactory	10	5.7	9	90.0	
Abutment for prosthesis	No	165	93.8	137	83.0	0.136
	Yes	11	6.3	11	100.0	
Duration of final restoration	< 2 months	36	34.6	30	83.3	0.641
	2-6 months	21	20.2	19	90.5	
	> 6 months	47	45.2	42	89.4	
Occurrence of occlusal trauma	Absence	170	96.6	145	85.3	0.020*
	Presence	6	3.4	3	50.0	
Clinical findings	Absence	171	97.2			
	Presence	3	1.7			
	Extracted	2	1.1			

* Indicates a statistical significance (p<0.05)

At the recall visit, there were 171 teeth (97.2%) with the absence of clinical signs and symptoms, 2 extracted teeth (1.1%), and 3 teeth (1.7%) with the presence of clinical signs or symptoms, including 1 tooth with pain on chewing and 2 teeth with tenderness to palpation. Based on the data of this study, the overall success rate of 176 teeth was 84.1% (148 teeth), whereas the failure rate was 15.9% (28 teeth). Of the 176 teeth treated, there were 171 teeth with the absence of clinical signs or symptoms regardless of the PAI score, therefore the functional rate of treated teeth was 97.2%.

According to the bivariate analysis, factors significantly affecting treatment outcome of initial root canal treatment were tooth type (p=0.006), pulp status (p=0.006), pre-operative periapical status (p=0.000), and the occurrence of occlusal trauma (p=0.020) as presented in Table 10. Anterior teeth had a success rate of 78.2% (86 from 110 teeth) and premolars had a success rate of 93.9% (62 from 66 teeth) as presented in Figure 3. The success rates according to the pulp status were 94.8% (55 from 58 teeth) of teeth with vital pulp and 78.8% (93 from 118 teeth) of teeth with non-vital pulp as presented in Figure 4. As reported by pre-operative periapical status, the success rates of teeth with the absence of periapical lesion, with periapical lesion size < 5 mm, and with periapical lesion size ≥ 5 mm. were 94.6% (87 from 92 teeth), 77.1% (27 from 35 teeth), and 69.4%, (34 from 49 teeth), respectively as presented in Figure 5. The success rates based on the occurrence of occlusal trauma were 85.3% (145 from 170 teeth) with the absence of occlusal trauma and 50.0% (3 from 6 teeth) with the presence of occlusal trauma as presented in Figure 6. Factors not affecting treatment outcome of initial root canal treatment were age (p=0.906), gender (p=0.224), tooth location (p=0.462), the presence of complications (p=0.440), breaking of interim restorations (p=0.350), the apical extent of root filling (p=0.716), recall period (p=0.686), types of restoration (p=0.137), quality of restoration (p=0.599), abutment of prosthesis (p=0.136), and duration of final restoration (p=0.641) as presented in Table 10.

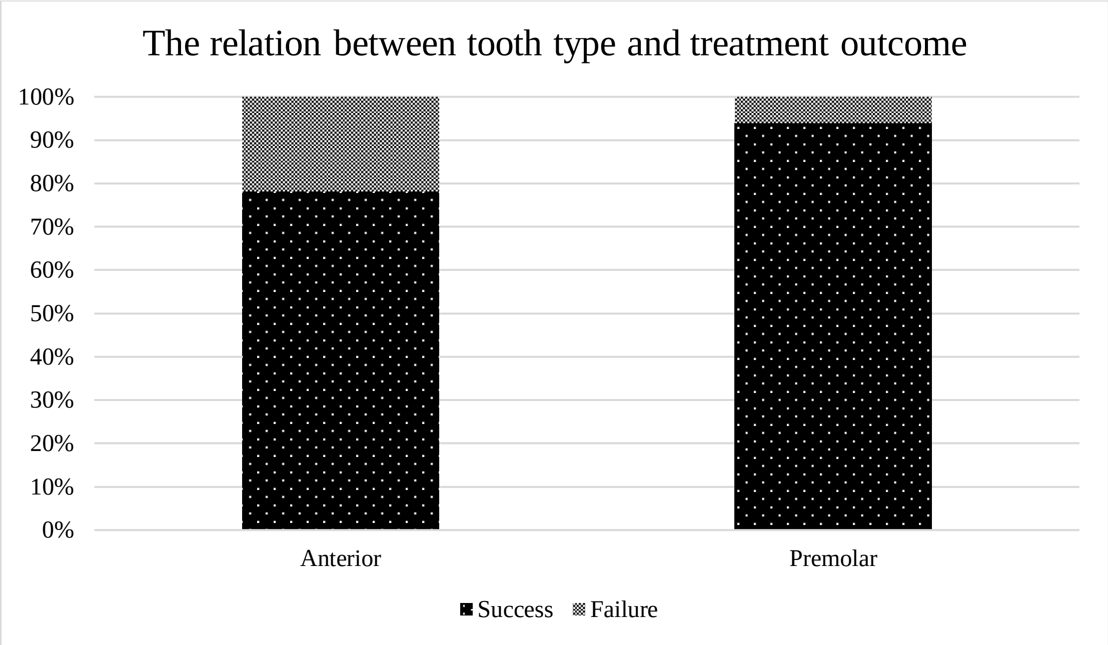

Figure 3 The relation between tooth type and treatment outcome

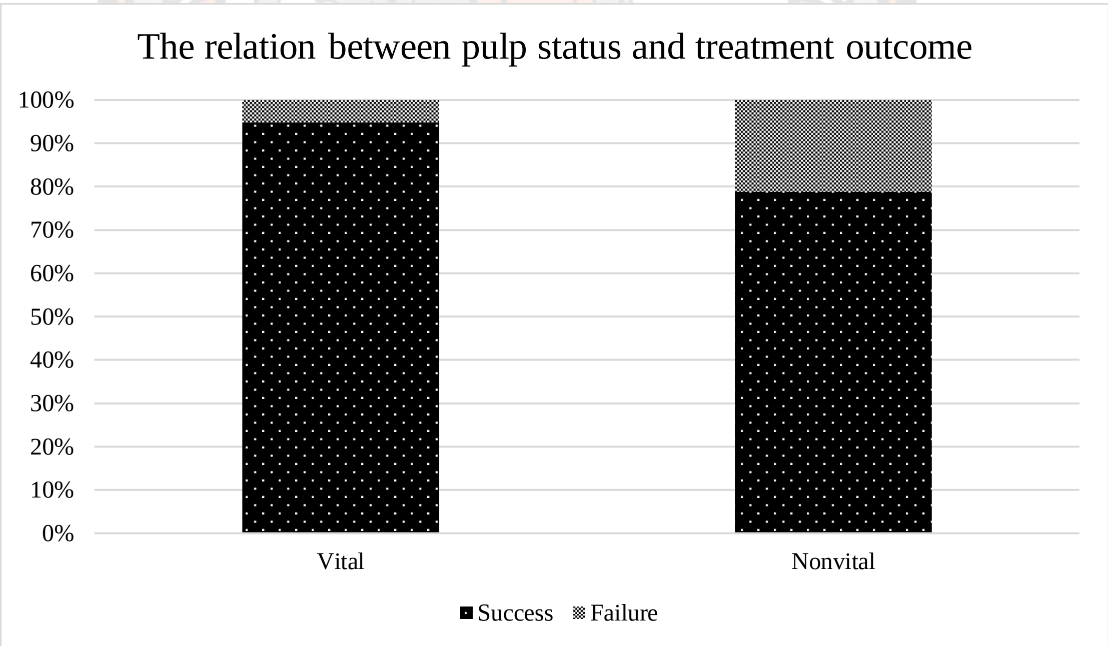

Figure 4 The relation between pulp status and treatment outcome

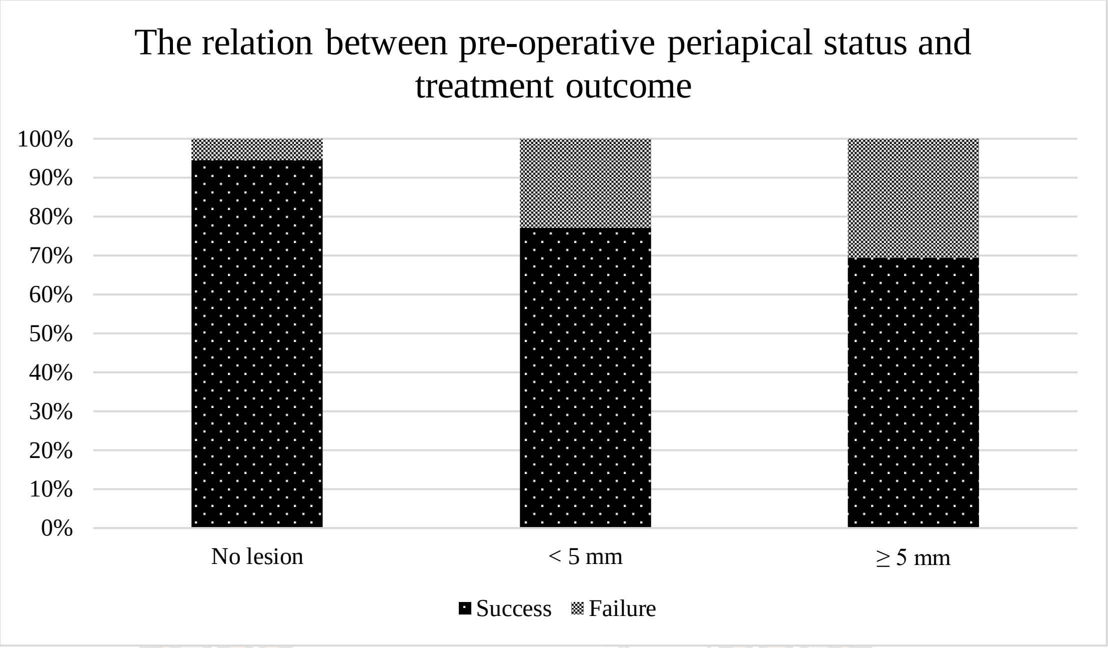

Figure 5 The relation between pre-operative periapical status and treatment outcome

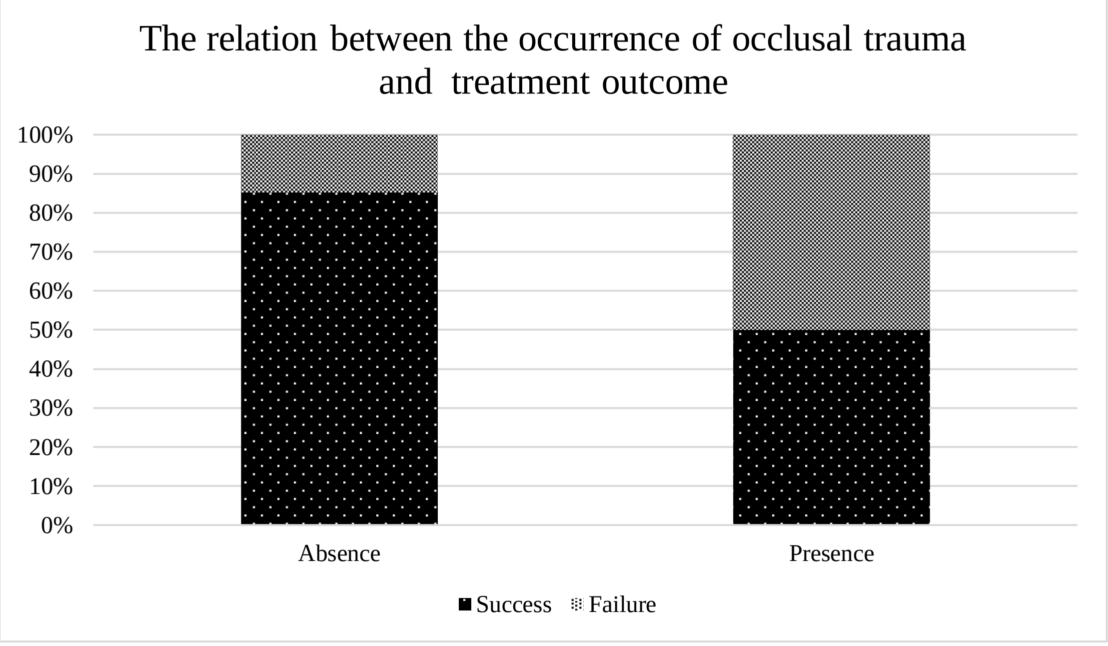

Figure 6 The relation between the occurrence of occlusal trauma and treatment outcome

The confounding factors that may have affected the results were also considered. To eliminate the effects of the confounding factors, multiple logistic regression was used. The particular factors and magnitude of their effect on success, presented by adjusted odds ratios (OR), are also presented in Table 11. The logistic regression analysis revealed only two factors that statistically affected the outcome of treatment the presence of pre-operative periapical status, and the occurrence of occlusal trauma. Based on periapical status, the probability of success in teeth with pre-operative periapical lesion size < 5 mm was 0.18 that of teeth with no lesion ($p=0.025$), and in teeth with pre-operative periapical lesion size ≥ 5 mm was 0.13 that of teeth with no lesion ($p=0.005$). When analyzing the occurrence of occlusal trauma, the probability of success of teeth with the presence of occlusal trauma was 0.09 than that of teeth with the absence of occlusal trauma ($p=0.040$).

On the report of factors not affecting treatment outcome, among the 142 treated teeth in the maxilla, the success rate was 83.1% (118 teeth), while 34 treated teeth in the mandible, the success was 88.2% (30 teeth). During the treatment periods, 18 teeth (10.2%) had complications, including 11 root perforations (3 in the coronal third and 8 in the apical third), 2 ledges, and 5 apical transportations. There were 14 teeth (77.8%) with the presence of complications that were a success, and 4 teeth (22.2%) with the presence of complications (1 had coronal root perforation, 1 had a ledge, and 2 had apical transportations) were failed. The success rate in teeth with complications was 77.8%, and the failure rate in teeth with complications was 22.2%. In teeth without complications, the treatment outcome was successful in 134 teeth (84.8%), and failed in 24 teeth (15.2%). According to the breaking of interim restorations, there were 169 teeth (96.0%) with the absence of breaking of interim restorations, and 7 teeth (4.0%) with the presence of breaking of interim restorations. The success rate of teeth in these groups was 84.6% (143 teeth) and 71.4% (5 teeth) respectively. Based on the apical extent of root canal filling, 166 teeth (94.3%) had adequate root canal fillings with a success rate of 84.3% (140 teeth). The 10 remaining teeth with long root canal filling had a success rate of 80.0% (8 teeth). As stated by recall periods, the success rate for recall period 6-11 months, 12-23 months, 24-35 months, 36-47 months, and ≥ 48 months was 81.5% (53 teeth), 86.8% (59 teeth), 88.9% (24 teeth), 72.7% (8 teeth), and

80.0% (4 teeth), respectively. According to types of restoration, there were 104 teeth (59.1%) with final restoration and 72 teeth (40.9%) with intermediate restoration. The success rate was 87.5% (91 teeth) and 79.2% (57 teeth), respectively. There were 166 teeth (94.3%) with satisfactory coronal restoration and 10 teeth (5.7%) with unsatisfactory coronal restoration. When the distribution of treatment outcomes was based on the quality of coronal restoration, the success rate was 83.7% (139 teeth) with satisfactory coronal restoration and 90.0% (9 teeth) with unsatisfactory coronal restoration. Treatment in 165 teeth (93.8%) was not used as the abutment of the prosthesis, while 11 teeth (6.3%) were used as the abutment of the prosthesis. The success rate was 83.0% (137 teeth) in the non-abutment group and 100.0% (11 teeth) in the abutment group. Finally, the success rate for duration of final restoration < 2 months in 36 teeth (34.6%), 2-6 months in 21 teeth (20.2%) and > 6 months in 47 teeth (45.2%) was 83.3% (30 teeth), 90.5% (19 teeth) and 89.4% (42 teeth), respectively.

Table 11 The results of multivariate analysis of the particular factors affecting the treatment outcome (N=176)

Factors (n)	Success (N=148)		Failure (N=28)		Cruded OR [95% CI]	p-value of cruded OR	Adjusted OR [95% CI]	p-value of adjusted OR
	n	%	n	%				
Tooth type								
Anterior (110)	86	58.1	24	85.7	ref		ref	
Premolar (66)	62	41.9	4	14.3	4.33 [1.43-13.10]	0.006*	3.21 [0.85-12.13]	0.086
Pulp status								
Vital (58)	55	37.2	3	10.7	ref		ref	
Nonvital (118)	93	62.8	25	89.3	0.20 [0.06-0.70]	0.006*	0.75 [0.16-3.60]	0.721
Periapical status								
No lesion (92)	87	58.8	5	17.9	ref		ref	
< 5 mm (35)	27	18.2	8	28.6	0.19 [0.06-0.64]	0.209	0.18 [0.04-0.81]	0.025*
≥ 5 mm (49)	34	23.0	15	53.6	0.13 [0.04-0.39]	0.001*	0.13 [0.03-0.54]	0.005*
Complications								
Absence (158)	134	90.5	24	85.7	ref		ref	
Presence (18)	14	9.5	4	14.3	0.63 [0.19-2.07]	0.440	0.47 [0.10-2.09]	0.319
Breaking of interim restorations								
Absence (169)	143	96.6	26	92.9	ref		ref	
Presence (7)	5	3.4	2	7.1	0.46 [0.08-2.47]	0.350	0.23 [0.03-1.76]	0.157
The apical extent of root canal filling								
Adequate (166)	140	94.6	26	92.9	ref		ref	
Long (10)	8	5.4	2	7.1	0.74 [0.15-3.70]	0.716	0.61 [0.07-5.47]	0.654

*Indicates a statistical significance ($p < 0.05$)
OR = Odds ratio
CI = Confidence interval

Table 11 (cont.)

Factors (n)	Success (N=148)		Failure (N=28)		Cruded OR [95% CI]	p-value of cruded OR	Adjusted OR [95% CI]	p-value of adjusted OR
	n	%	n	%				
Recall period								
6-11 months (65)	53	35.8	12	42.9	ref		ref	
12-23 months (68)	59	39.9	9	32.1	1.48 [0.58-3.80]	0.442	1.08 [0.36-3.26]	0.887
24-35 months (27)	24	16.2	3	10.7	1.81 [0.47-7.02]	0.459	1.21 [0.19-7.57]	0.836
36-47 months (11)	8	5.4	3	10.7	0.60 [0.14-2.62]	0.287	0.43 [0.07-2.61]	0.362
≥ 48 months (5)	4	2.7	1	3.6	0.91 [0.09-8.85]	0.800	0.55 [0.04-7.04]	0.644
Types of restoration								
Final (104)	91	61.5	13	46.4	ref		ref	
Intermediate (72)	57	38.5	15	53.6	0.54 [0.24-1.22]	0.137	0.58 [0.19-1.75]	0.336
Quality of restoration								
Satisfactory (166)	139	93.9	27	96.4	ref		ref	
Unsatisfactory (10)	9	6.1	1	3.6	1.75 [0.21-14.37]	0.599	1.36 [0.12-15.22]	0.801
Occurrence of occlusal trauma								
Absence (170)	145	98.0	25	89.3	ref		ref	
Presence (6)	3	2.0	3	10.7	0.17 [0.03-0.90]	0.020*	0.09 [0.01-0.89]	0.040*

*Indicates a statistical significance ($p < 0.05$)
OR = Odds ratio
CI = Confidence interval

CHAPTER V
DISCUSSION

Numerous studies indicated that there was inter-examiner disagreement in the interpretation of radiographs. There are many different results when the same radiograph was interpreted by different examiners (118-120). Moreover, the intra-examiner disagreement may occur when the examiners interpreted the same radiograph over time (121). In this study, we controlled these factors by calibrating the three examiners before the beginning of the study. In the calibration, the Kappa value should be greater than 0.7, meaning a substantial agreement (117). The results of this study showed the means of Kappa values of the inter- and intra-examiner as 0.81 and 0.90 respectively, which indicated excellent agreement.

This retrospective study accessed the outcome of initial root canal treatment. The outcome of this study is based on data collected from chart records and digital periapical radiographs of patients who received initial root canal treatment at Naresuan University from 2015 to 2020. The samples in this study were excluded due to incomplete sets of digital periapical radiographs or not being initial root canal treated teeth. The recall rate in this study was 32.79% whereas the recall rate in the previous study of Naresuan University from 2010 to 2015 was 36.33% (34). Consistently to previous studies, recall rates in Thai dental schools ranged from 21 to 41% (2, 5), and recall rates in other previous studies ranged from 12 to 100% (31, 39, 40). A large proportion of patients in the dental school of Naresuan University are students who may be discontinuers due to graduation and relocation. Therefore, they were inconvenient to come for a recall. In addition, many dropouts were either unavailable, unresponsive to recall, and/or did not have any signs or symptoms that had no motivation to attend.

Analyzes of outcomes were performed considering each tooth as a unit of analysis. The treatment outcome was assessed based on the clinical and radiographic findings. The outcome of root canal treatment was judged based on the previous study (34). The treatment outcome was dichotomized as “success” or “failure”. The clinical evaluation reported by Bender *et al.* (9) was used in this study. They reported that pain, swelling, presence of a sinus tract, loss of function, and evidence of tissue destruction were clinical signs and symptoms. The radiographic evaluation of this study was based on the PAI score system (21). This system is reasonably accurate, repeatable, and can distinguish between sub-populations. It may also allow comparing results from different researchers. According to these outcome criteria, 148 teeth (84.1%) were classified as a success, with a PAI ≤ 2 and no clinical signs or symptoms, and 28 teeth (15.9%) as a failure, with a PAI ≥ 3, or presence of clinical signs or symptoms, or post-treatment endodontic intervention or extraction for endodontic disease. Furthermore, the treatment outcome was evaluated as "functional", therefore 171 teeth (97.2%) with the absence of clinical signs or symptoms regardless of the PAI score were classified as functional. These results agreed with the systematic review of clinical studies that reported the success rate was 74 to 86%, and the functional rate was 91 to 97% (32).

The success rate in this study was higher than the previous study of Naresuan University (34) which reported the success rate was 72.8%, and the functional rate was similar to that reported the functional rate was 96.2%. These results can be explained by the proportion of teeth with pre-operative periapical lesions in the previous study (62.4%) higher than in this study (47.7%). The presence or absence of pre-operative periapical lesion significantly influences the success rate of root canal treatment (29). In addition, the treatment protocol of final rinsing in this study was changed from the previous study. Final rinsing in this treatment protocol added 2% chlorhexidine to the previous treatment protocol that rinse with 2.5% sodium hypochlorite and 17% EDTA. This may be implied by the study by Zamany *et al.* (85) that the addition of 2% chlorhexidine was significantly more effective than the conventional protocol in providing a bacteria-free root canal. Chlorhexidine is a broad-spectrum cationic antiseptic with a bisbiguanide base and has been shown a substantivity to the dental structure which has the unique ability of hydroxyapatite binding (122). Moreover, chlorhexidine is particularly efficient against *Enterococcus faecalis*, a microorganism involved in treatment failures (123). However, the systematic review and meta-analysis (124) concluded that there was no difference in the antimicrobial efficacy of chlorhexidine and NaOCl.

Of the 28 teeth classified as failure, 22 teeth showed radiographic failures with a PAI ≥ 3. Three teeth (1.7%) presented clinical signs or symptoms, including 1 tooth with pain on chewing and 2 teeth with tenderness to palpation. The recall period of these 3 teeth was 9-36 months. One failed tooth had post-treatment endodontic intervention by periapical surgery (apicoectomy and retrofilling). The tooth had extraradicular infection with the persistence of the sinus tract after multiple medications of calcium hydroxide and triple antibiotic paste (TAP), therefore periapical surgery was planned after root canal filling. This tooth was recalled at 11 months with a PAI score of 5, which may require a longer recall period to see the healing process (55, 125). Two extracted teeth (1.1%) were recorded in the dental charts that fractures were the cause of extraction before placement of permanent restorations. Similarly, Cheung's survival analysis (54) reported that most of the teeth lost after endodontic treatment were extracted due to fracture, with additional teeth extracted due to a prosthetic need.

In bivariate analysis, the four factors significantly affecting treatment outcome were tooth type, pulp status, pre-operative periapical status, and the occurrence of occlusal trauma. According to tooth type, there was a statistically significant difference in success rate (p=0.006) that the outcome was better in premolars (93.9%) than anterior teeth (78.2%). Moreover, the multivariate analysis did not identify any significant predictor of success. By contrast, Engström *et al.* (30) reported that single-rooted teeth showed a better prognosis than multi-rooted teeth, and the previous study of Naresuan University (34) found that there were no statistically significant differences in success rate between premolars (79.4%) and anterior teeth (69.7%). This could be because in this study it was found that anterior teeth (57%) had more pre-operative periapical lesions than premolars (32%), whereas the previous study (34) found that pre-operative periapical lesions in anterior teeth (79%) were not different from those in premolars (62%).

In teeth with vital pulp, the success rate was significantly higher than that in teeth with nonvital pulp (p=0.006). The results of this study correspond with the meta-analysis reported by Kojima *et al.* (61). In necrotic teeth, there are more infections and a higher risk of bacteria remaining after endodontic treatment, which can cause persistent periapical inflammation (64). However, this relationship is not significant when using multivariate analysis. This could be explained by the low proportion of vital teeth group (33%).

According to pre-operative periapical status, 92 teeth (52.3%) without periapical lesion, and 84 teeth (47.7%) with periapical lesion revealed a success rate of 94.6% and 72.6% respectively. Similarly, most studies concluded that the presence or absence of pre-operative periapical lesion significantly affects the rate of success of endodontic treatment. Teeth without periapical lesions had a better success rate than those with lesions (10, 58, 62, 63). In addition, the multivariate analysis in this study also confirmed the presence of pre-operative periapical lesion as the predictor of outcome in initial root canal treatment.

The size of periapical lesions affected the treatment outcomes in this study, the success rate of 77.1% for teeth with periapical lesion size < 5 mm, was significantly higher than for periapical lesion size ≥ 5 mm (69.4%). The results of this study correspond with previous studies (13, 60). Consistently with multivariate analysis, which also identified the presence of pre-operative periapical lesion size < 5 mm and periapical lesion size ≥ 5 mm significantly influenced the outcome of treatment, with odds ratios of 0.18 and 0.13 respectively. These results can be explained by the relationship between the size of the lesion and the number of microbes in the root canal. The root canals of teeth with lesions larger than 5 mm contained significantly more bacterial cells than teeth with smaller lesions (46). Moreover, larger lesions required a longer healing time than the smaller lesions (27, 39).

Another factor affecting the treatment outcomes in this study was the occurrence of occlusal trauma. The success rate of 50.0% in teeth with occlusal trauma, was significantly lower than that in teeth without occlusal trauma (85.3%). Of the 6 teeth with occlusal trauma, 3 teeth with success had fremitus, and 3 teeth with failure, including 1 tooth had pain on chewing, 1 tooth had tenderness to percussion and palpation, and another 1 extracted tooth had pain on chewing, tenderness to percussion and palpation and grade 2 mobility with fracture. All teeth with occlusal trauma were adjusted occlusion for removing a high spot in the recall visit. Among 3 teeth classified as failure showed no periapical lesion but the presence of clinical signs or symptoms of occlusal trauma at recall periods 9, 11, and 36 months. The effect of occlusal trauma on the pulp and periapical apparatus, or specifically on the outcome of root canal treatment, has been rarely studied. However, this can be explained by the study by Matsumoto *et al.* (109) that the occlusal trauma is a key factor in prolonging periapical healing of endodontically treated teeth. Harn *et al.* (126) showed case reports with some failures of endodontic treatment that were caused by the presence of occlusal trauma modulating the responses of inflamed periapical tissues or apical pathoses with persistent infection. In consistent with the multivariate analysis of this study, which identified the occurrence of occlusal trauma significantly influenced the outcome of root canal treatment, with an odds ratio of 0.09. In contrast, ElDeeb & Andreasen (127) found that hyper- and hypo-occlusion did not affect the healing of the periodontal tissue in rats. Furthermore, Kumazawa *et al.* (115) found a positive relationship between traumatic occlusion and periapical lesions in rats. They suggested that occlusal trauma may be involved in a delay in the spread of inflammation to the periapical area.

In this study, the following factors not affecting treatment outcome were age, gender, tooth location, the presence of complications, breaking of interim restorations, the apical extent of root filling, recall period, types of restoration, quality of restoration, abutment for prosthesis, and duration of the final restoration. Age, gender, and tooth location were factors that generally have no significant influence on treatment outcomes (26, 27, 57, 58).

The procedural complication is also an important factor influencing the outcome of treatment. Contrary to other studies (23, 24, 26), due to the small number of teeth with complications (10.8%), this study could not show a relationship between the presence of complications and treatment outcome. Of the 18 teeth with complications, 11 teeth had perforations (3 in the coronal third and 8 in the apical third), 2 had ledges and 5 had apical transportations. Teeth with ledge and transportation were filled root canal with gutta-percha and 3 teeth with coronal perforation were repaired with GIC immediately or within 1 week after perforation. Of the 8 teeth with apical perforations, 6 were filled root canal with gutta-percha and 2 were repaired with MTA after 2 and 3 months of perforation. In those with complications, the treatment outcome was successful in 14 teeth (77.8%), and failure in 4 teeth (22.2%). Of 4 teeth with failure, 1 was coronal perforation using GIC as a repaired material, 1 was ledge using gutta-percha as a root canal filling material, and 2 were apical transportation using gutta-percha as a root canal filling material. Among 4 teeth classified as failure, 3 (1 coronal perforation; 19-month recall, 1 ledge; 23-month recall, and 1 apical transportation; 14-month recall) showed remaining periapical lesions, and 1 (apical transportation; 29-month recall) was extracted due to fracture. Iatrogenic perforations were long considered major complications reducing the success rates significantly (27, 91). The prognosis of perforation depends on the location, size of the perforations, time of repair (128), and repair materials (23, 24, 129). Several studies demonstrated that the biocompatibility and the sealing ability of GIC (130, 131) and MTA (130, 132, 133) were effective in repairing root perforations. According to clinical studies, the root perforations that were repaired with GIC (134) or MTA (132) had satisfactory treatment outcomes. Therefore, the treatment outcome in teeth with perforations in this study was attributed to both GIC and MTA properties.

Factors of breaking of interim restorations have not been discussed in any previous studies. However, there is a possible decrease in favorable long-term treatment outcomes if the interim or temporary restorations are breakdowns at any time during the endodontic treatment process (99). This study could not find any association between the breaking of interim restorations and treatment outcome. This could be explained by the small number of teeth with the breaking of interim restorations (4.0%).

The apical extent of root canal fillings was found to influence the prognosis of the treatment in some studies (13, 27, 30, 56) but did not influence prognosis in this study and others (36, 46, 60). This may be due to the small sample size of teeth with long root canal filling (n=10) and no teeth with short root canal filling. Moreover, all treated teeth in this study followed the treatment protocol using electric apex locators and digital radiographs, allowing the apical extent of root canal filling to be controlled.

According to the recall period, the previous studies (5, 34) showed that the different recall periods influenced treatment outcomes. On the contrary, there was no statistically significant difference in success rate between the different recall periods in this study. This insignificance is due to the small sample size in some groups of the recall period. In this study, the sample size gradually decreased with longer recall periods as Table 10, since most of the discontinuers were graduates as discussed above.

It has been suggested that a follow-up of at least 1 year is required for meaningful changes in teeth with periapical lesions (47, 50), but an extension of the follow-up to 3 or 4 years is required for a stable record of treatment outcomes (13, 22, 26, 46, 47). The European Society of Endodontology suggests a clinical and radiographic follow-up for at least 1 year and annual recall for up to 4 years before a case is judged as a failure (135). The American Association of Endodontists also proposes an assessment over a period of 4 to 5 years (1). Recently, Wu *et al.* in 2011 (136) also suggested the follow-up 1-year interval to determine the outcome. In our school, patients were scheduled to recall for at least 6 months and up to 48 months as the routine recall period for the dental students. The 6-months recall period is the initial follow-up to determine the clinical signs and symptoms, and the restoration after the root canal treatment. While up to the 48-months recall period is required for assessing the long-term treatment outcome.

Types of restoration were not significantly associated with treatment outcomes in this study. The results of this study were similar to the previous studies (31, 36). In contrast, the systematic review (63) revealed that teeth restored with a permanent restoration or crown were associated with significantly higher survival than direct restorations. As stated by the duration of final restoration after root canal treatment, there was no statistically significant difference in success rate between the different durations. In contrast, Ahmad & Sadaf (113) showed a very significant correlation in the extraction of root canal treated teeth with a delay of more than 60 days of placement of final coronal restoration after completion of root canal treatment. In our school, we use Cavit™ and resin composites as intermediate restorations in the treatment protocol, so the types of restoration and the duration of final restoration may not affect the outcome of this study. The use of resin composites to produce an intracoronal seal may prevent microleakage in a root canal treated tooth before placement of the permanent restoration, whereas the use of IRM® began to leak extensively at 1 month (137). Shindo *et al.* (138) demonstrated that adhesive and flowable materials had better sealing ability than non-adhesive materials (Super EBA and GIC). Moreover, Udayakumar *et al.* (139) showed that the use of provisional restorative materials such as Cavit™, IRM®, Coltosol® F, and GIC cannot provide an adequate seal after 14 days. They suggested that the final restoration should be completed within 1 week after root canal treatment.

Quality of coronal restoration was one of the factors that was also examined. This study and others (83, 105) were unable to show a correlation between the quality of coronal restoration and treatment outcome. Conversely, some studies reported that satisfactory restorations were associated with significantly higher success rates than unsatisfactory restorations (8, 45, 104). This may be due to the small proportion (5.7%) of unsatisfactory restorations. In general, the chance of healing periapical lesions increases with good endodontic and restorative treatments (140, 141).

According to use as the abutment of the prosthesis, the abutment teeth of this study consisted of 8 removable prosthesis abutments and 3 fixed prosthesis abutments (2 teeth with 3 units and 1 tooth with 4 units). Some studies (27, 109-111) reported that bridge and denture abutments had significantly lower success rates than individual units. The meta-analysis by Ng *et al.* (63) reported that the teeth not functioning as fixed or removable prosthesis abutments were related to a significantly higher chance of survival than those that functioned as fixed prosthesis abutments. Moreover, De Backer *et al.* (142) concluded that there was no statistically significant difference in survival rate between short-span and long-span fixed prosthesis in the endodontically treated teeth group, while there was a statistically significant difference in overall survival rate between short-span and long-span fixed prosthesis in both vital and endodontically treated teeth groups over a 20-year period. Use as the abutment of the prosthesis does not affect the treatment outcomes in this study. This may be due to the small sample size of abutment teeth (n=11).

This study is a retrospective study in which there were uncontrolled variables. Pre-, intra-, and post-operative clinical data of patients may not be recorded or examined with the same criteria, such as treatment procedures, complications, occlusal trauma, and quality of restoration. The lacking of such important information may affect the results of the study. In addition, the angulation of original and follow-up radiographs may not be the same, which may be incomparable and may affect the interpretation of radiographs. Within the limits of retrospective study, this study focused on the fact that the teeth without periapical lesions had a better success rate than those with lesions. The occlusal trauma is an important factor in prolonging periapical healing of root canal treated teeth.

Conclusions

The overall success rate of nonsurgical root canal treatment performed by undergraduate dental students of Naresuan University from 2015 to 2020 was 84.1%, whereas the failure rate was 15.9%, and the functional rate was 97.2%. The factors affecting the outcome of initial root canal treatment found in this study were the pre-operative periapical status and the occurrence of occlusal trauma.

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APPENDIX

APPENDIX A THE PROTOCOL WAS APPROVED BY THE ETHICAL REVIEW COMMITTEE OF NARESUAN UNIVERSITY

COA No. 170/2021

IRB No. P10047/64

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร

99 หมู่ 9 ตำบลท่าโพธิ์ อำเภอเมือง จังหวัดพิษณุโลก 65000 เบอร์โทรศัพท์ 05596 8752

หนังสือรับรองโครงการวิจัย

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร ดำเนินการให้การรับรองโครงการวิจัยตามแนวทางหลักจริยธรรมการวิจัยในคนที่เป็นมาตรฐานสากล ได้แก่ Declaration of Helsinki, The Belmont Report, CIOMS Guideline และ International Conference on Harmonization in Good Clinical Practice หรือ ICH-GCP

ชื่อโครงการ	: ความสำเร็จและความล้มเหลวของการรักษาคลองรากฟันแบบไม่ผ่าตัดโดยนิสิตทันตแพทย์ มหาวิทยาลัยนเรศวร
ผู้วิจัยหลัก	: นายเกรียงศักดิ์ ชัยโศภิน
สังกัดหน่วยงาน	: คณะทันตแพทยศาสตร์
วิธีทบทวน	: แบบเร่งรัด (Expedited Review)
รายงานความก้าวหน้า	: ส่งรายงานความก้าวหน้าอย่างน้อย 1 ครั้ง/ปี หรือส่งรายงานฉบับสมบูรณ์หากดำเนินโครงการเสร็จสิ้นก่อน 1 ปี

เอกสารรับรอง

1. AF 01-10 เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
2. AF 02-10 เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
3. AF 03-10 เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
4. สรุปโครงการเพื่อการพิจารณาทางจริยธรรมการวิจัยในมนุษย์ เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
5. โครงร่างวิทยานิพนธ์ เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
6. ประวัติผู้วิจัย เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
7. Data collection table เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
8. PAI scoring table เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
9. Periapical lesion size measurement table เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564
10. งบประมาณที่ได้รับ โดยย่อ (Budget) เวอร์ชั่น 2.0 วันที่ 30 เมษายน 2564

ลงนาม: [signature]

(นายแพทย์สมบูรณ์ ต้นสุภสวัสดิกุล)

ประธานคณะกรรมการจริยธรรมการวิจัยในมนุษย์

วันที่รับรอง : 14 พฤษภาคม 2564

วันหมดอายุ : 14 พฤษภาคม 2565

ทั้งนี้ การรับรองนี้มีเงื่อนไขดังที่ระบุไว้ด้านหลังทุกข้อ (ดูด้านหลังของเอกสารรับรองโครงการวิจัย)

~ 1 ~

นักวิจัยทุกท่านที่ผ่านการรับรองจริยธรรมการวิจัยต้องปฏิบัติดังต่อไปนี้

1. ดำเนินการวิจัยตามที่ระบุไว้ในโครงการวิจัยอย่างเคร่งครัด
2. ใช้เอกสารแนะนำอาสาสมัคร ใบยินยอม (และเอกสารเชิญเข้าร่วมวิจัยหรือใบโฆษณาถ้ามี) แบบสัมภาษณ์ และหรือแบบสอบถาม เฉพาะที่มีตราประทับของคณะกรรมการจริยธรรมในมนุษย์ มหาวิทยาลัยนเรศวรเท่านั้น และส่งสำเนาเอกสารดังกล่าวที่ใช้กับผู้เข้าร่วมวิจัยจริงรายแรกมาที่คณะกรรมการจริยธรรมการวิจัยในมนุษย์ เพื่อเก็บไว้เป็นหลักฐาน
3. รายงานเหตุการณ์ไม่พึงประสงค์ร้ายแรงที่เกิดขึ้นหรือการเปลี่ยนแปลงกิจกรรมวิจัยใด ๆ ต่อคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร ภายในระยะเวลาที่กำหนดในวิธีดำเนินการมาตรฐาน (SOPs)
4. ส่งรายงานความก้าวหน้าต่อคณะกรรมการจริยธรรมการวิจัยในมนุษย์ ตามเวลาที่กำหนดหรือเมื่อได้รับการร้องขอ
5. หากการวิจัยไม่สามารถดำเนินการเสร็จสิ้นภายในกำหนด ผู้วิจัยต้องยื่นขออนุมัติใหม่ก่อน อย่างน้อย 1 เดือน
6. หากผู้วิจัยส่งรายงานความก้าวหน้าหลังใบรับรองหมดอายุ และยังไม่ได้ใบรับรองฉบับใหม่ ผู้วิจัยจะต้องหยุดดำเนินการวิจัยส่วนที่เกี่ยวข้องกับการรับอาสาสมัครใหม่ นับตั้งแต่หลังวันใบรับรองหมดอายุจนกว่าจะได้รับใบรับรองฉบับใหม่
7. หากการวิจัยเสร็จสมบูรณ์ผู้วิจัยต้องแจ้งปิดโครงการตามแบบฟอร์มของคณะกรรมการจริยธรรมในมนุษย์ มหาวิทยาลัยนเรศวร

*รายชื่อของคณะกรรมการจริยธรรมการวิจัยในมนุษย์ (ชื่อและตำแหน่ง) ที่เข้าร่วมประชุม ณ วันที่พิจารณารับรองโครงการวิจัย (หากร้องขอล่วงหน้า)

APPENDIX B RESEARCH INSTRUMENTS

Data collection table

Factors	Scores	Notes
Pre-operative		
Age	…………… years old	
Gender	Male/female	
Tooth location	Maxilla/mandible	
Tooth type	Anterior/premolar	
Pulp status	Healthy/pulpitis/necrosis	
Periapical status	1/2/3/4/5	Based on the PAI score
Size of periapical lesion	< 5 mm/ ≥ 5 mm	The widest diameter of any radiolucency
Intra-operative		
Occurrence of procedural complications	Present/absent	If present, Iatrogenic tooth perforation (Location……………………………….. Repair material………………………….)/ separated instrument (Location…………………………………) /root canal blockage/transportation
Breaking of interim restorations	Present/absent	
The apical extent of root canal filling	Short/adequate/long	Short, > 2 mm short of radiographic apex; Adequate, 0-2 mm within the radiographic apex; Long, extruded beyond the radiographic apex
Post-operative		
Recall period	……………months	
Type of restoration	Intermediate restoration/final restoration	
Quality of coronal restoration	Satisfactory/unsatisfactory	Type of final restoration: Direct/indirect (Type……………………………………..)
Abutment for prosthesis	Yes/no	Type of prosthesis: Removable/fixed
Duration of final restoration	…………….months	
Occurrence of occlusal trauma	Present/absent	
Periapical status	1/2/3/4/5	Based on the PAI score
Size of periapical lesion	< 5 mm/ ≥ 5 mm	The widest diameter of any radiolucency

PAI scoring table

Patient number	PAI score	Patient number	PAI score
1	1/2/3/4/5	38	1/2/3/4/5
2	1/2/3/4/5	39	1/2/3/4/5
3	1/2/3/4/5	40	1/2/3/4/5
4	1/2/3/4/5	41	1/2/3/4/5
5	1/2/3/4/5	42	1/2/3/4/5
6	1/2/3/4/5	43	1/2/3/4/5
7	1/2/3/4/5	44	1/2/3/4/5
8	1/2/3/4/5	45	1/2/3/4/5
9	1/2/3/4/5	46	1/2/3/4/5
10	1/2/3/4/5	47	1/2/3/4/5
11	1/2/3/4/5	48	1/2/3/4/5
12	1/2/3/4/5	49	1/2/3/4/5
13	1/2/3/4/5	50	1/2/3/4/5
14	1/2/3/4/5	51	1/2/3/4/5
15	1/2/3/4/5	52	1/2/3/4/5
16	1/2/3/4/5	53	1/2/3/4/5
17	1/2/3/4/5	54	1/2/3/4/5
18	1/2/3/4/5	55	1/2/3/4/5
19	1/2/3/4/5	56	1/2/3/4/5
20	1/2/3/4/5	57	1/2/3/4/5
21	1/2/3/4/5	58	1/2/3/4/5
22	1/2/3/4/5	59	1/2/3/4/5
23	1/2/3/4/5	60	1/2/3/4/5
24	1/2/3/4/5	61	1/2/3/4/5
25	1/2/3/4/5	62	1/2/3/4/5
26	1/2/3/4/5	63	1/2/3/4/5
27	1/2/3/4/5	64	1/2/3/4/5
28	1/2/3/4/5	65	1/2/3/4/5
29	1/2/3/4/5	66	1/2/3/4/5
30	1/2/3/4/5	67	1/2/3/4/5
31	1/2/3/4/5	68	1/2/3/4/5
32	1/2/3/4/5	69	1/2/3/4/5
33	1/2/3/4/5	70	1/2/3/4/5
34	1/2/3/4/5	71	1/2/3/4/5
35	1/2/3/4/5	72	1/2/3/4/5
36	1/2/3/4/5	73	1/2/3/4/5
37	1/2/3/4/5	….	1/2/3/4/5

Periapical lesion size measurement table

Patient number	Size of periapical lesion (mm^2)	Patient number	Size of periapical lesion (mm^2)
1	…x…	38	…x…
2	…x…	39	…x…
3	…x…	40	…x…
4	…x…	41	…x…
5	…x…	42	…x…
6	…x…	43	…x…
7	…x…	44	…x…
8	…x…	45	…x…
9	…x…	46	…x…
10	…x…	47	…x…
11	…x…	48	…x…
12	…x…	49	…x…
13	…x…	50	…x…
14	…x…	51	…x…
15	…x…	52	…x…
16	…x…	53	…x…
17	…x…	54	…x…
18	…x…	55	…x…
19	…x…	56	…x…
20	…x…	57	…x…
21	…x…	58	…x…
22	…x…	59	…x…
23	…x…	60	…x…
24	…x…	61	…x…
25	…x…	62	…x…
26	…x…	63	…x…
27	…x…	64	…x…
28	…x…	65	…x…
29	…x…	66	…x…
30	…x…	67	…x…
31	…x…	68	…x…
32	…x…	69	…x…
33	…x…	70	…x…
34	…x…	71	…x…
35	…x…	72	…x…
36	…x…	73	…x…
37	…x…	….	…x…

APPENDIX C DATA ANALYSIS

Intra- and inter-examiner agreements were assessed by using Cohen's kappa.

Intra-examiner agreement

1. First examiner

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.812	.098	7.360	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of intra-examiner agreement of first examiner was 0.812.

2. Second examiner

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.874	.085	7.717	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of intra-examiner agreement of second examiner was 0.874.

3. Third examiner

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	1.000	.000	8.455	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of intra-examiner agreement of third examiner was 1.000.

Inter-examiner agreement

1. **First examiner – Second examiner**

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.875	.082	7.932	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of inter-examiner agreements between first examiner and second examiner were 0.875.

2. **First examiner – Third examiner**

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.810	.099	7.227	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of inter-examiner agreements between first examiner and third examiner were 0.810.

3. **Second examiner – Third examiner**

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.745	.111	6.546	.000
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The kappa value of inter-examiner agreements between second examiner and third examiner were 0.745.

Statistical analysis

All data were processed and analyzed via IBM SPSS Statistics Version 26. All statistical tests were performed as two-tailed and interpreted at a 5% significance level.

1. Univariate analysis

The univariate describes the data using percentage frequencies.

1.1 Age

Statistics

Age

N	Valid	176
	Missing	0
Mean		31.95
Minimum		14
Maximum		77

Age group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 60 yr	156	88.6	88.6	88.6
	>= 60 yr	20	11.4	11.4	100.0
	Total	176	100.0	100.0	

1.2 Gender

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	58	33.0	33.0	33.0
	Female	118	67.0	67.0	100.0
	Total	176	100.0	100.0	

1.3 Tooth location

Tooth location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Maxilla	142	80.7	80.7	80.7
	Mandible	34	19.3	19.3	100.0
	Total	176	100.0	100.0	

1.4 Tooth type

Tooth type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Anterior teeth	110	62.5	62.5	62.5
	Premolar	66	37.5	37.5	100.0
	Total	176	100.0	100.0	

1.5 Pulp status

Pulp status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Vital	58	33.0	33.0	33.0
	Nonvital	118	67.0	67.0	100.0
	Total	176	100.0	100.0	

1.6 Periapical status

Periapical status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No lesion	92	52.3	52.3	52.3
	< 5 mm	35	19.9	19.9	72.2
	>= 5 mm	49	27.8	27.8	100.0
	Total	176	100.0	100.0	

1.7 Complications

Complications

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Present	19	10.8	10.8	10.8
	Absent	157	89.2	89.2	100.0
	Total	176	100.0	100.0	

1.8 Breaking of interim restorations

Breaking of interim restorations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Present	10	5.7	5.7	5.7
	Absent	166	94.3	94.3	100.0
	Total	176	100.0	100.0	

1.9 The apical extent of root filling

Apical extent of root filling

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Adequate	166	94.3	94.3	94.3
	Long	10	5.7	5.7	100.0
	Total	176	100.0	100.0	

1.10 Recall period

Statistics

Follow_up_period

N	Valid	176
	Missing	0
Mean		17.67
Mode		11
Minimum		6
Maximum		60

Recall period group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6-11 months	65	36.9	36.9	36.9
	12-23 months	68	38.6	38.6	75.6
	24-35 months	27	15.3	15.3	90.9
	36-47 months	11	6.3	6.3	97.2
	> 48 months	5	2.8	2.8	100.0
	Total	176	100.0	100.0	

1.11 Types of restoration

Types of restoration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Intermediate restoration	72	40.9	40.9	40.9
	Final restoration	104	59.1	59.1	100.0
	Total	176	100.0	100.0	

1.12 Quality of restoration

Quality of restoration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Satisfactory	166	94.3	94.3	94.3
	Unsatisfactory	10	5.7	5.7	100.0
	Total	176	100.0	100.0	

1.13 Use as the abutment of prosthesis

Abutment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	11	6.3	6.3	6.3
	No	165	93.8	93.8	100.0
	Total	176	100.0	100.0	

1.14 Duration of final restoration

Duration of final restoration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 2 months	36	20.5	34.6	34.6
	2-6 months	21	11.9	20.2	54.8
	> 6 months	47	26.7	45.2	100.0
	Total	104	59.1	100.0	
Missing	System	72	40.9		
Total		176	100.0		

1.15 Occurrence of occlusal trauma

Occlusal trauma

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Present	6	3.4	3.4	3.4
	Absent	170	96.6	96.6	100.0
	Total	176	100.0	100.0	

1.16 Clinical findings

Clinical findings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Present	3	1.7	1.7	1.7
	Absent	171	97.2	97.2	98.9
	Extracted	2	1.1	1.1	100.0
	Total	176	100.0	100.0	

1.17 Radiographic findings

Radiographic findings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Healed	150	85.2	85.2	85.2
	Disease	24	13.6	13.6	98.9
	Extracted	2	1.1	1.1	100.0
	Total	176	100.0	100.0	

1.18 Treatment outcome

Treatment outcome

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Failure	28	15.9	15.9	15.9
	Success	148	84.1	84.1	100.0
	Total	176	100.0	100.0	

2. Bivariate analysis

The bivariate associations were tested between the treatment outcomes and pre-, intra-, and post-operative factors by using a Chi-square test.

2.1 Age and treatment outcome

Age_group * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Age_group	< 60 yr	25	131	156
	>= 60 yr	3	17	20
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.014[a]	1	.906		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.014	1	.905		
Fisher's Exact Test				1.000	.603
Linear-by-Linear Association	.014	1	.906		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.18.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between 2-age groups of patients (p=0.906).

2.2 Gender and treatment outcome

Gender * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Gender	Male	12	46	58
	Female	16	102	118
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.478[a]	1	.224		
Continuity Correction[b]	.993	1	.319		
Likelihood Ratio	1.429	1	.232		
Fisher's Exact Test				.273	.159
Linear-by-Linear Association	1.469	1	.225		
N of Valid Cases	176				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.23.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between male and female (p=0.224).

2.3 Tooth location and treatment outcome

Tooth location * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Tooth location	Maxilla	24	118	142
	Mandible	4	30	34
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.541[a]	1	.462		
Continuity Correction[b]	.225	1	.635		
Likelihood Ratio	.575	1	.448		
Fisher's Exact Test				.605	.329
Linear-by-Linear Association	.538	1	.463		
N of Valid Cases	176				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.41.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between maxillary and mandibular teeth (p=0.462).

2.4 Tooth type and treatment outcome

Tooth type * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Tooth type	Anterior teeth	24	86	110
	Premolar	4	62	66
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.656[a]	1	.006		
Continuity Correction[b]	6.524	1	.011		
Likelihood Ratio	8.641	1	.003		
Fisher's Exact Test				.005	.004
Linear-by-Linear Association	7.613	1	.006		
N of Valid Cases	176				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.50.

b. Computed only for a 2x2 table

There was statistically significant of success rate between anterior teeth and premolars (p=0.006).

2.5 Pulp status and treatment outcome

Pulp status * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Pulp status	Vital	3	55	58
	Nonvital	25	93	118
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.454[a]	1	.006		
Continuity Correction[b]	6.305	1	.012		
Likelihood Ratio	8.745	1	.003		
Fisher's Exact Test				.008	.004
Linear-by-Linear Association	7.412	1	.006		
N of Valid Cases	176				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.23.

b. Computed only for a 2x2 table

There was statistically significant of success rate between vital and nonvital teeth (p=0.006).

2.6 Periapical status and treatment outcome

Pre-operative periapical status * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Pre-operative periapical status	No lesion	5	87	92
	< 5 mm	8	27	35
	>= 5 mm	15	34	49
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	16.726[a]	2	.000
Likelihood Ratio	17.393	2	.000
Linear-by-Linear Association	16.154	1	.000
N of Valid Cases	176		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.57.

There was statistically significant of success rate between teeth with no lesion, small lesion (< 5 mm in diameter), and large lesion (≥ 5 mm in diameter) (p=0.000).

2.7 Complications and treatment outcome

Complications * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Complications	Present	4	14	18
	Absent	24	134	158
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.597[a]	1	.440		
Continuity Correction[b]	.187	1	.665		
Likelihood Ratio	.550	1	.458		
Fisher's Exact Test				.494	.315
Linear-by-Linear Association	.594	1	.441		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.86.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between teeth with absence and presence of complications (p=0.440).

2.8 Breaking of interim restorations and treatment outcome

Breaking of interim restorations * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Breaking of interim restorations	Present	2	5	7
	Absent	26	143	169
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.874[a]	1	.350		
Continuity Correction[b]	.166	1	.684		
Likelihood Ratio	.745	1	.388		
Fisher's Exact Test				.308	.308
Linear-by-Linear Association	.869	1	.351		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 1.11.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between teeth with presence and absence of breaking of interim restorations (p=0.350).

2.9 The apical extent of root filling and treatment outcome

Apical extent of root filling * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Apical extent of root filling	Adequate	26	140	166
	Long	2	8	10
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.133[a]	1	.716		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.125	1	.724		
Fisher's Exact Test				.661	.493
Linear-by-Linear Association	.132	1	.716		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 1.59.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between teeth with root canal filling reached within 2 mm of the apex (adequate) and teeth with root canal filling excess beyond the apex (long) (p=0.716).

2.10 Recall period and treatment outcome

Recall period group * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Group recall period	6-11 months	12	53	65
	12-23 months	9	59	68
	24-35 months	3	24	27
	36-47 months	3	8	11
	>= 48 months	1	4	5
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.269[a]	4	.686
Likelihood Ratio	2.165	4	.705
Linear-by-Linear Association	.001	1	.974
N of Valid Cases	176		

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .80.

There was no statistically significant of success rate among 6-11 months, 12-23 months, 24-35 months, 35-47 months, and ≥ 48 months recall periods ($p=0.686$).

2.11 Types of restoration and treatment outcome

Type of restoration * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Type of restoration	Intermediate restoration	15	57	72
	Final restoration	13	91	104
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.208[a]	1	.137		
Continuity Correction[b]	1.630	1	.202		
Likelihood Ratio	2.173	1	.140		
Fisher's Exact Test				.148	.102
Linear-by-Linear Association	2.196	1	.138		
N of Valid Cases	176				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.45.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between teeth with intermediate and final restoration (p=0.137).

2.12 Quality of restoration and treatment outcome

Quality of restoration * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Quality of restoration	Satisfactory	27	139	166
	Unsatisfactory	1	9	10
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.277[a]	1	.599		
Continuity Correction[b]	.007	1	.935		
Likelihood Ratio	.309	1	.578		
Fisher's Exact Test				1.000	.507
Linear-by-Linear Association	.275	1	.600		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 1.59.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between teeth with satisfactory and unsatisfactory of restorations (p=0.599).

2.13 Use as the abutment of prosthesis and treatment outcome

Abutment * Treatment outcome Crosstabulation

Count

		Treatment outcome		Total
		Failure	Success	
Abutment	Yes	0	11	11
	No	28	137	165
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.220[a]	1	.136		
Continuity Correction[b]	1.133	1	.287		
Likelihood Ratio	3.948	1	.047		
Fisher's Exact Test				.216	.140
Linear-by-Linear Association	2.207	1	.137		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 1.75.

b. Computed only for a 2x2 table

There was no statistically significant of success rate between abutment and non-abutment teeth (p=0.136).

2.14 Duration of final restoration and treatment outcome

Duration of final restoration * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Duration of final restoration	< 2 months	6	30	36
	2-6 months	2	19	21
	> 6 months	5	42	47
Total		13	91	104

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.890[a]	2	.641
Likelihood Ratio	.864	2	.649
Linear-by-Linear Association	.624	1	.430
N of Valid Cases	104		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.63.

There was no statistically significant of success rate among teeth with < 2 months, 2-6 months, and > 6 months of placement of final restorations (p=0.641).

2.15 Occurrence of occlusal trauma and treatment outcome

Occlusal trauma * Treatment outcome Crosstabulation

Count

		Treatment outcome		
		Failure	Success	Total
Occlusal trauma	Present	3	3	6
	Absent	25	145	170
Total		28	148	176

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.396[a]	1	.020		
Continuity Correction[b]	3.081	1	.079		
Likelihood Ratio	3.939	1	.047		
Fisher's Exact Test				.052	.052
Linear-by-Linear Association	5.366	1	.021		
N of Valid Cases	176				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is .95.

b. Computed only for a 2x2 table

There was statistically significant of success rate between teeth with presence and absence of occlusal trauma (p=0.021).

3. Multivariate analysis

The multivariate associations were tested for evaluating associations between various factors by using logistic regression.

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	176	100.0
	Missing Cases	0	.0
	Total	176	100.0
Unselected Cases		0	.0
Total		176	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
Failure	0
Success	1

Categorical Variables Codings

		Frequency	Parameter coding (1)	(2)	(3)	(4)
Group recall period	6-11 months	65	.000	.000	.000	.000
	12-23 months	68	1.000	.000	.000	.000
	24-35 months	27	.000	1.000	.000	.000
	36-47 months	11	.000	.000	1.000	.000
	> 48 months	5	.000	.000	.000	1.000
Pre-operative periapical status	No lesion	92	.000	.000		
	< 5 mm	35	1.000	.000		
	>= 5 mm	49	.000	1.000		
Occlusal trauma	Present	6	1.000			
	Absent	170	.000			
Pulp status	Vital	58	.000			
	Nonvital	118	1.000			
Complications	Present	18	1.000			
	Absent	158	.000			
Breaking of interim restorations	Present	7	1.000			
	Absent	169	.000			
Apical extent of root filling	Adequate	166	.000			
	Long	10	1.000			
Quality of restoration	Satisfactory	166	.000			
	Unsatisfactory	10	1.000			
Type of restoration	Intermediate restoration	72	1.000			
	Final restoration	104	.000			
Tooth type	Anterior teeth	110	.000			
	Premolar	66	1.000			

Block 0: Beginning Block

Classification Table[a,b]

Observed			Predicted: Treatment outcome Failure	Success	Percentage Correct
Step 0	Treatment outcome	Failure	0	28	.0
		Success	0	148	100.0
	Overall Percentage				84.1

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	1.665	.206	65.274	1	.000	5.286

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Tooth type(1)	7.656	1	.006
		Pulp status(1)	7.454	1	.006
		Pre-operative periapical status	16.726	2	.000
		Pre-operative periapical status(1)	1.576	1	.209
		Pre-operative periapical status(2)	10.973	1	.001
		Complications(1)	.597	1	.440
		Breaking of interim restorations(1)	.874	1	.350
		Apical extent of root filling(1)	.133	1	.716
		Group recall period	2.269	4	.686
		Group recall period(1)	.592	1	.442
		Group recall period(2)	.549	1	.459
		Group recall period(3)	1.133	1	.287
		Group recall period(4)	.064	1	.800
		Type of restoration(1)	2.208	1	.137
		Quality of restoration(1)	.277	1	.599
		Occlusal trauma(1)	5.396	1	.020
	Overall Statistics		31.846	14	.004

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	33.872	14	.002
	Block	33.872	14	.002
	Model	33.872	14	.002

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	120.360[a]	.175	.300

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Classification Table[a]

Observed			Predicted: Treatment outcome: Failure	Predicted: Treatment outcome: Success	Percentage Correct
Step 1	Treatment outcome	Failure	5	23	17.9
		Success	0	148	100.0
	Overall Percentage				86.9

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Step 1[a]	Tooth type(1)	1.166	.679	2.952	1	.086	3.209	.849	12.134
	Pulp status(1)	-.285	.798	.127	1	.721	.752	.157	3.595
	Pre-operative periapical status			7.927	2	.019			
	Pre-operative periapical status(1)	-1.715	.766	5.010	1	.025	.180	.040	.808
	Pre-operative periapical status(2)	-2.069	.738	7.848	1	.005	.126	.030	.537
	Complications(1)	-.762	.765	.993	1	.319	.467	.104	2.091
	Breaking of interim restorations(1)	-1.464	1.035	2.002	1	.157	.231	.030	1.758
	Apical extent of root filling(1)	-.503	1.123	.201	1	.654	.605	.067	5.465
	Group recall period			1.405	4	.843			
	Group recall period(1)	.080	.562	.020	1	.887	1.083	.360	3.259
	Group recall period(2)	.193	.934	.043	1	.836	1.213	.194	7.568
	Group recall period(3)	-.836	.917	.831	1	.362	.433	.072	2.616
	Group recall period(4)	-.602	1.303	.213	1	.644	.548	.043	7.043
	Type of restoration(1)	-.542	.563	.926	1	.336	.581	.193	1.754
	Quality of restoration(1)	.310	1.231	.063	1	.801	1.363	.122	15.220
	Occlusal trauma(1)	-2.435	1.183	4.236	1	.040	.088	.009	.890
	Constant	3.423	.862	15.766	1	.000	30.674		

a. Variable(s) entered on step 1: Tooth type, Pulp status, Pre-operative periapical status, Complications, Breaking of interim restorations, Apical extent of root filling, Group recall period, Type of restoration, Quality of restoration, Occlusal trauma.

The logistic regression analysis revealed only two factors that statistically affected the outcome of treatment were the presence of pre-operative periapical status, and the occurrence of occlusal trauma.

Based on periapical status, the probability of success in teeth with pre-operative periapical lesion size < 5 mm was 0.18 that of teeth with no lesion (p=0.025), and in teeth with pre-operative periapical lesion size ≥ 5 mm was 0.13 that of teeth with no lesion (p=0.005).

According to the occurrence of occlusal trauma, the probability of success of teeth with presence of occlusal trauma was 0.09 that of teeth with absence of occlusal trauma (p=0.040).