

**NON-SURGICAL ROOT CANAL THERAPY CLINICAL SUCCESS  
RATE COMPARED BETWEEN UNDERGRADUATE AND  
GRADUATE STUDENTS AND REASONS  
FOR FAILURE**

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A Thesis  
Submitted to  
the Temple University Graduate Board

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In Partial Fulfillment  
of the Requirements for the Degree  
MASTER OF SCIENCE

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by  
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## ABSTRACT

### **Introduction:**

Non-surgical root canal therapy (NSRCT) aims to eliminate infected or necrotic pulpal tissue from the root canal system while preserving the tooth's function within the oral environment. The definition of success in endodontic therapy varies, ranging from strict to more lenient criteria. Treatment outcomes are commonly categorized as good, questionable, poor or hopeless. The success of non-surgical root canal therapy has been widely studied, with reported success rates ranging from 70% to 95%, depending on factors such as operator experience, case complexity, tooth vitality and the presence of a restoration. Despite extensive research, few studies compare non-surgical root canal outcomes between graduate and undergraduate dental students within the same institution. This study examines success rates in both groups and key factors affecting treatment failure, such as tooth number, pulp vitality, and final restoration.

### **Purpose:**

The purpose of this study is to compare the clinical success rates of non-surgical root canal therapy (NSRCT) performed by undergraduate dental students and graduate endodontic residents. Additionally, this research aims to assess how factors such as tooth number, pulp vitality, and the presence of a final restoration influence treatment success or failure.

**Materials and Methods:**

A total of 881 cases of non-surgical root canal therapy (NSRCT) performed at Temple University Kornberg School of Dentistry from 2018 to 2023 were analyzed retrospectively. Patient data were extracted from the axiUm electronic health records system using the recall code D3999RC, with recalls completed by undergraduate dental students at a minimum follow up of three months. Cases were categorized by operator level: undergraduate dental students or graduate endodontic residents. Treatment outcomes were classified into four categories based on the Strindberg Index (1956): Good (successful treatment), Questionable (uncertain prognosis), Poor (unsuccessful treatment), and Hopeless (definitive failure). For analysis, “Good” outcomes were considered successful, while the remaining categories were classified as failures. Independent variables included operator level, tooth number (anterior vs. posterior), pulp vitality (vital, non-vital, or previously initiated), and restoration status (presence of a final restoration). The primary dependent variable was treatment success or failure.

**Conclusion:**

Non-surgical root canal therapy performed by undergraduate dental students showed higher success rates, likely due to structured case selection, while graduate residents treated more complex cases, leading to greater variability in outcomes. Restored teeth demonstrated significantly improved success rates. Future research should explore standardized follow-up protocols and increased recall data from graduate residents to enhance success rates and ensure comprehensive data analysis.

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## **CHAPTER 1 INTRODUCTION**

Non-surgical root canal therapy (NSRCT) is a fundamental procedure in endodontics, designed to remove infected or necrotic pulpal tissue while preserving the tooth's function within the oral environment (Olcay, 2018). This treatment aims to restore periapical health by eliminating bacterial contamination, preventing reinfection, and promoting tissue healing. However, defining success in NSRCT remains a topic of discussion, with criteria ranging from strict radiographic assessments to more lenient clinical observations. The Strindberg Index (1956) provides a standardized classification for assessing the success of NSRCT based on clinical and radiographic findings. It categorizes treatment outcomes into four distinct groups: Good, indicating successful treatment with normal radiographic and clinical findings; Questionable, denoting an uncertain prognosis where radiographic healing is evident but not fully resolved; Poor, representing unsuccessful treatment with persistent periapical radiolucency or unresolved symptoms; and Hopeless, signifying definitive failure characterized by worsening pathology or abscess formation, often necessitating extraction. This index serves as a crucial tool in endodontic research and clinical practice, allowing for consistent evaluation of treatment efficacy and guiding decision-making for further intervention.

Over the years, numerous studies have evaluated the success rates of NSRCT, reporting varying outcomes influenced by factors such as patient demographics, pulp vitality, and operator experience. Historically, success rates have been estimated between 70% and 95% (Weigner, 1998). A meta-analysis by Ng et al. (2008) found pooled success rates of 74.7% when applying strict radiographic criteria and 85.2% with more lenient criteria. Similarly, Sjögren et al. (1990) reported an overall success rate of 86%, with a

notable increase to 96% when no preoperative periapical lesion was present compared to 86% when such a lesion was initially present. Smith (1993) identified several factors influencing success rates, including sex, age, pulp vitality, and periapical pathology, with an overall success rate of 84.29%. Kojima et al. (2004) further analyzed outcomes based on pulp vitality, reporting a cumulative success rate of 82% for teeth with vital pulp and 78.9% for those with non-vital pulp, highlighting a statistically significant difference between the two groups.

While many studies have focused on the clinical success rates of NSRCT, fewer have examined how operator experience, particularly between graduate endodontic residents and undergraduate dental students, influences treatment outcomes. The Toronto Study (Friedman et al., 2004, 2008) reported that endodontic residents achieved an overall success rate of 86%, with better outcomes in cases without pre-existing periapical lesions (93%) compared to those with lesions (82%). Ng et al. (2011) reported similar success rates among residents, with vital teeth achieving a 91% success rate compared to 81% for non-vital teeth. In private practice settings, Imura et al. (2007) reported an overall success rate of 94%, with 95% success in vital teeth and 92% in non-vital teeth, further underscoring the role of experience. Ricucci et al. (2011) found success rates of 92% for vital teeth and 84% for necrotic teeth. Despite these findings, limited research compares NSRCT outcomes between undergraduate students and graduate residents, creating a gap in the literature regarding operator proficiency.

The level of experience plays a crucial role in clinical decision-making and procedural execution in NSRCT. While graduate residents receive advanced training in endodontic techniques, undergraduate dental students are introduced to root canal therapy

with limited exposure to complex cases. This discrepancy in experience may affect treatment outcomes, particularly in case selection and procedural efficiency.

Undergraduate students use the American Association of Endodontists (AAE) Case Difficulty Assessment Form which provides a standardized framework for evaluating the complexity of endodontic cases. This helps clinicians determine whether a case should be managed by a general dentist or referred to a specialist. This tool assesses various factors, including radiographic appearance, tooth morphology, patient history, and treatment challenges, assigning cases to categories of low, moderate, or high difficulty to guide clinical decision-making and optimize patient outcomes.

Another critical factor influencing NSRCT success is the presence of a final restoration. Numerous studies have highlighted the importance of coronal seal integrity in preventing bacterial leakage and reinfection. Teeth that receive adequate restoration following NSRCT demonstrate significantly higher success rates than those left unrestored or inadequately restored (Ng et al., 2011). The timing of restoration placement also plays a role, with delayed restorations increasing the risk of failure due to microleakage and coronal contamination. Further, Ray and Trope's 1995 study found that coronal restoration quality had a greater impact on endodontic success rates than the quality of the root canal filling. Their results showed that teeth with good coronal restorations had a 91.4% success rate, while those with poor restorations had only 67.6% success. In contrast, teeth with good root canal fillings but poor restorations had a lower success rate than those with poor fillings but good restorations, emphasizing the importance of a well-sealed restoration in preventing reinfection and ensuring long-term treatment success.

This study seeks to address the gap in research by comparing the success rates of NSRCT performed by undergraduate dental students and graduate endodontic residents within the same institution. Additionally, this study aims to evaluate key factors contributing to treatment success or failure, including tooth number, pulp vitality, and the presence of a final restoration. By analyzing these variables, the goal is to provide insights into the role of operator experience in NSRCT outcomes and identify potential strategies for optimizing endodontic education and clinical practice.

## CHAPTER 2 METHODS

This retrospective study initially identified 1,283 non-surgical root canal therapy (NSRCT) cases performed at Temple University Kornberg School of Dentistry between 2018 and 2023; however, 402 charts were excluded for incomplete data, leaving 881 cases for analysis. Institutional Review Board approval was obtained for this study (protocol #31416). Patient records were retrieved from axiUm, the electronic health records system used at Temple University. The records reviewed included the Endodontic Exam Form which included radiographic examination, diagnostic testing, pulpal and periapical diagnosis, initial post-op evaluation and follow-up. A follow-up recall code D3999RC was used as a designation for follow-up evaluations conducted by dental students of cases in their patient pool which had nonsurgical endodontics completed either by an endodontic resident or an undergraduate dental student at the dental school. This requirement for all students for completion of their clinical course ensures that all included cases had undergone a minimum three-month follow-up assessment. Patient data included demographic details, tooth characteristics, and treatment outcomes, which were reviewed and documented by resident clinicians to maintain consistency in evaluation.



Undergraduate dental students are trained to apply the American Association of Endodontists (AAE) Case Difficulty Assessment Form for decision making that assigns every potential case to a low, moderate, or high-difficulty tier. The checklist organizes risk factors into three broad panels: A. Patient considerations (e.g., a healthy ASA I or II patient with no anesthesia issues is “low,” whereas an ASA IV patient with anesthesia challenges is “high”); B. Diagnostic and treatment considerations (for example, a routine anterior tooth with straight canals and a visible canal system ranks “low,” while a C-shaped mandibular molar with extreme curvature, apical resorption, and proximity < 3 mm to the mandibular canal is “high”); and C. Additional considerations, which flags complicating histories such as a simple crown fracture (“low”) versus an avulsed immature tooth or a previous access with perforation (“high”). By scoring each sub-criterion, students can quickly see whether the overall profile remains appropriate for undergraduate management or whether it tips into territory best handled by an endodontic specialist, thereby promoting patient safety, predictable outcomes, and judicious referrals.

Criteria and Subcriteria	LOW DIFFICULTY	MODERATE DIFFICULTY	HIGH DIFFICULTY
<b>A. PATIENT CONSIDERATIONS</b>			
MEDICAL HISTORY	<input type="checkbox"/> No medical problem (ASA Class 1 or 2*)	<input type="checkbox"/> One or more medical problem (ASA Class 3*)	<input type="checkbox"/> Complex medical history/serious illness/disability (ASA Class 4*)
ANESTHESIA	<input type="checkbox"/> No history of anesthesia problems	<input type="checkbox"/> Vasoconstrictor intolerance	<input type="checkbox"/> Difficulty achieving and/or maintaining anesthesia
PATIENT DISPOSITION	<input type="checkbox"/> Cooperative and compliant	<input type="checkbox"/> Anxious but cooperative	<input type="checkbox"/> Uncooperative
ABILITY TO OPEN MOUTH	<input type="checkbox"/> No limitation	<input type="checkbox"/> Slight limitation in opening	<input type="checkbox"/> Significant limitation in opening
GAG REFLEX	<input type="checkbox"/> None	<input type="checkbox"/> Gags occasionally with radiographs/treatment	<input type="checkbox"/> Extreme gag reflex which has compromised past dental care
EMERGENCY CONDITION	<input type="checkbox"/> Minimum pain or swelling	<input type="checkbox"/> Moderate pain or swelling	<input type="checkbox"/> Severe pain or swelling

**Figure 4. Patient Considerations from the American Association of Endodontists (AAE) Case Difficulty Assessment Form**

Criteria and Subcriteria	LOW DIFFICULTY	MODERATE DIFFICULTY	HIGH DIFFICULTY
<b>B. DIAGNOSTIC AND TREATMENT CONSIDERATIONS</b>			
DIAGNOSIS	<input type="checkbox"/> Signs and symptoms consistent with recognized pulpal and periapical conditions	<input type="checkbox"/> Extensive differential diagnosis of usual signs and symptoms required	<input type="checkbox"/> Confusing and complex signs and symptoms: difficult diagnosis <input type="checkbox"/> History of chronic oral/facial pain
RADIOGRAPHIC DIFFICULTIES	<input type="checkbox"/> Minimal difficulty obtaining/interpreting radiographs	<input type="checkbox"/> Moderate difficulty obtaining/interpreting radiographs (e.g., high floor of mouth, narrow or low palatal vault, presence of tori)	<input type="checkbox"/> Extreme difficulty obtaining/interpreting radiographs (e.g., superimposed anatomical structures)
POSITION IN THE ARCH - TOOTH TYPE	<input type="checkbox"/> Anterior/premolar	<input type="checkbox"/> 1st molar	<input type="checkbox"/> 2nd or 3rd molar
POSITION IN THE ARCH - INCLINATION	<input type="checkbox"/> Slight inclination (<10°)	<input type="checkbox"/> Moderate inclination (10-30°)	<input type="checkbox"/> Extreme inclination (>30°)
POSITION IN THE ARCH - ROTATION	<input type="checkbox"/> Slight rotation (<10°)	<input type="checkbox"/> Moderate rotation (10-30°)	<input type="checkbox"/> Extreme rotation (>30°)
TOOTH ISOLATION	<input type="checkbox"/> Routine rubber dam placement	<input type="checkbox"/> Simple pretreatment modification required for rubber dam isolation	<input type="checkbox"/> Extensive pretreatment modification required for rubber dam isolation
CROWN MORPHOLOGY	<input type="checkbox"/> Normal original crown morphology	<input type="checkbox"/> Full coverage restoration <input type="checkbox"/> Porcelain restoration <input type="checkbox"/> Bridge abutment <input type="checkbox"/> Moderate deviation from normal tooth/root form (e.g., taurodontism microdens) <input type="checkbox"/> Teeth with extensive coronal destruction	<input type="checkbox"/> Restoration does not reflect original anatomy/alignment <input type="checkbox"/> Significant deviation from normal tooth/root form (e.g., fusion dens in dente)
CANAL MORPHOLOGY	<input type="checkbox"/> Slight or no curvature (<10°) <input type="checkbox"/> Closed apex (<1 mm in diameter)	<input type="checkbox"/> Moderate curvature (10-30°) <input type="checkbox"/> Crown axis differs moderately from root axis. <input type="checkbox"/> Apical opening 1-1.5 mm in diameter	<input type="checkbox"/> C-shaped morphology <input type="checkbox"/> Extreme curvature (>30°) or S-shaped curve <input type="checkbox"/> Mandibular premolar or anterior with 2 roots <input type="checkbox"/> Maxillary premolar with 3 roots <input type="checkbox"/> Canal divides in the middle or apical third <input type="checkbox"/> Very long tooth (>25 mm) <input type="checkbox"/> Other anomalies such as radix ento/paramolaris <input type="checkbox"/> Open apex (>1.5 mm in diameter)
RADIOGRAPHIC APPEARANCE OF CANAL(S)	<input type="checkbox"/> Canal(s) and chamber visible and not reduced in size	<input type="checkbox"/> Canal(s) and chamber visible but reduced in size <input type="checkbox"/> Pulp stones	<input type="checkbox"/> Indistinct canal path <input type="checkbox"/> Canal(s) and chamber not visible
PROXIMITY OF THE ROOT APICES TO VITAL STRUCTURES SUCH AS THE IAN OR MENTAL FORAMEN	<input type="checkbox"/> Vital structures 5 or more millimeters from apices	<input type="checkbox"/> 3-5 millimeters	<input type="checkbox"/> <3 millimeters
RESORPTION	<input type="checkbox"/> No resorption evident	<input type="checkbox"/> Minimal apical resorption	<input type="checkbox"/> Extensive apical resorption <input type="checkbox"/> Internal resorption <input type="checkbox"/> External resorption

**Figure 5. Diagnostic and Treatment Considerations from the American Association of Endodontists (AAE) Case Difficulty Assessment Form**

<b>C. ADDITIONAL CONSIDERATIONS</b>			
TRAUMA HISTORY	<input type="checkbox"/> No history of trauma, or <input type="checkbox"/> Uncomplicated crown fracture of mature or immature teeth	<input type="checkbox"/> Complicated crown fracture of mature teeth <input type="checkbox"/> Subluxation	<input type="checkbox"/> Complicated crown fracture of immature teeth <input type="checkbox"/> Horizontal root fracture <input type="checkbox"/> Alveolar fracture <input type="checkbox"/> Intrusive, extrusive or lateral luxation <input type="checkbox"/> Avulsion
ENDODONTIC TREATMENT HISTORY	<input type="checkbox"/> No previous treatment	<input type="checkbox"/> Previous access without complications	<input type="checkbox"/> Previous access with complications (e.g., perforation, non-negotiated canal, ledge, separated instrument) <input type="checkbox"/> Previous surgical or nonsurgical endodontic treatment completed
PERIODONTAL-ENDODONTIC CONDITION	<input type="checkbox"/> None or mild periodontal disease or concurrent moderate periodontal disease	<input type="checkbox"/> Combined endodontic/periodontic lesion	<input type="checkbox"/> Concurrent severe periodontal disease <input type="checkbox"/> Cracked teeth with periodontal complications <input type="checkbox"/> Root amputation prior to endodontic treatment

**Figure 6. Additional Considerations from the American Association of Endodontists (AAE) Case Difficulty Assessment Form**

The American Association of Endodontists Case Difficulty Assessment served as the blueprint for our two-tier clinical guideline: items highlighted in orange in Figure 7, “Predoctoral Clinic” sheet identify situations suitable for undergraduate treatment, whereas those in green on Figure 8, the “Graduate Clinic” sheet trigger referral to the

postgraduate endodontic service. For example, an ASA I–III patient who is merely “anxious but cooperative,” with a first-molar that shows only slight (<10°) canal curvature and a canal system clearly visible on radiographs, may be completed in the predoctoral clinic. In contrast, cases involving an ASA IV patient, extreme (>30°) curvature or C-shaped morphology, indistinct canal paths, previous access with perforation or separated instruments, or traumatic injuries such as avulsion or horizontal root fracture are automatically routed to the graduate clinic for advanced management.

Criteria	
<b>Predoctoral Clinic</b>	
1	No medical problem (ASA Class 1 or 2)
2	One or more medical problem (ASA Class 3)
3	No history of anesthesia problems
4	Anxious but cooperative
5	Slight limitation in opening
6	Gags occasionally with radiographs/ treatment
7	Moderate pain or swelling
8	Vasoconstrictor intolerance
9	Difficulty achieving and/or maintaining anesthesia
10	Moderate difficulty obtaining/interpreting radiographs (e.g., high floor of mouth/narrow or low palatal vault, presences of tori)
11	1st molar
12	2nd molar
13	Simple pretreatment modification required for rubber dam isolation
14	Slight inclination (<10°)
15	Moderate inclination (10-30°)
16	Slight rotation (<10°)
17	Moderate rotation (10-30°)
18	Slight or no curvature (<10°)
19	Moderate curvature (10-30°)
20	Canal(s) and chamber visible and not reduced in size
21	Vital structures 5 or more millimeters from apices
22	Vital structures 3-5 millimeters from apices
23	Vital structures, 3 millimeters from apices
24	Uncomplicated crown fracture of mature or immature teeth
25	Complicated crown fracture of mature teeth
26	Tooth has previous access without complications
27	Crown axis differs moderately from root axis
28	Teeth with extensive coronal destruction
29	Very long tooth (>25 mm)
30	Canal(s) and chamber visible but reduced in size
31	Pulp stones
32	Minimal apical resorption
33	Apical opening 1-1.5 mm in diameter
34	Restoration does not reflect original anatomy/alignment
35	Extensive differential diagnosis of usual signs and symptoms *
36	Confusing and complex signs and symptom difficult diagnosis *
37	History of chronic oral/facial pain *
38	Uncooperative *
39	Mandibular premolar with 2 roots **
* Undergrad Endo clinic will try to manage it, then refer to Grad Endo clinic if needed.	
** Depends on the root and canal morphology (e.g. case with bifucation at middle or apical portion will refer to Grad Endo)	

**Figure 7. Predoctoral Clinic Non-surgical Root Canal Criteria**

<b>Graduate clinic</b>	
1	Complex medical history/serious illness/ disability (ASA Class 4)
2	Extreme difficulty obtaining/interpreting radiographs (e.g., superimposed anatomical structures)
3	Extensive pretreatment modification required for rubber dam isolation
4	Moderate deviation from normal tooth/root form (e.g., taurodontism microdens)
5	Significant deviation from normal tooth/root form (e.g., fusion dens in dente)
6	Extreme gag reflex which has compromised past dental care
7	Significant limitation in opening
8	Full coverage restoration
9	Bridge abutment
10	3rd molar
11	Maxillary premolar with 3 roots
12	Mandibular anterior with 2 roots
13	Canal divides in the middle or apical third
14	Other anomalies such as radix ento/para molaris
15	Extreme rotation (>30°)
16	Extreme inclination (>30°)
17	Extreme curvature (>30°) or S-shaped curve
18	C-shaped morphology
19	Open apex (>1.5 mm in diameter)
20	Indistinct canal path
21	Canal(s) and chamber not visible
22	Previous access with complications (e.g., perforation, non-negotiated canal, ledge, separated instrument)
23	Previous surgical or nonsurgical endodontic treatment completed
24	Extensive apical resorption
25	Internal resorption
26	Complicated crown fracture of immature teeth
27	External resorption
28	Subluxation
29	Horizontal root fracture
30	Alveolar fracture
31	Intrusive, extrusive or lateral luxation
32	Avulsion
33	Cracked teeth with periodontal complications
34	Root amputation prior to endodontic treatment

**Figure 8. Graduate Clinic Non-surgical Root Canal Criteria**

Each case was categorized based on operator level, identifying whether the treatment was completed by undergraduate dental students or graduate endodontic residents. The classification process relied on axiUm treatment history records, which was documented by the provider responsible for performing the procedure. A resident examiner conducted the categorization to ensure the accuracy of data grouping and review.

Treatment success was determined using the Strindberg Index (1956), a widely recognized system for evaluating endodontic treatment outcomes based on clinical and

radiographic criteria. Cases were classified into four categories: Good, indicating successful treatment with normal clinical and radiographic findings; Questionable, denoting an uncertain prognosis where radiographic healing is evident but not fully resolved; Poor, representing unsuccessful treatment with persistent periapical radiolucency or unresolved symptoms; and Hopeless, signifying definitive failure characterized by worsening pathology or abscess formation, often necessitating extraction. For the purpose of statistical analysis, Good outcomes were classified as successful, whereas cases categorized as Questionable, Poor, or Hopeless were considered treatment failures.

The study evaluated several independent variables related to treatment outcomes. Operator level was classified as either undergraduate dental students or graduate endodontic residents. Tooth number was categorized into anterior and posterior teeth, while pulp vitality was distinguished between vital, non-vital, or previously initiated. Restoration status was recorded based on the presence or absence of a final restoration.

The first group included 63 cases treated by graduate endodontic residents, while the second group consisted of 818 cases treated by undergraduate dental students. To determine an appropriate sample size for statistical analysis, a power analysis was performed using the "pwr" package in R software. The analysis was conducted at a power of 80%, with a significance level ( $\alpha$ ) of 0.05 and a small effect size of 0.2. Based on these parameters, the recommended sample size for each group was 392. However, due to data constraints, the final sample sizes remained at 63 cases in the graduate group and 818 cases in the undergraduate group.

## **Statistical Analysis**

Statistical analysis was conducted in three phases to evaluate the relationship between operator level, clinical factors, and treatment outcomes. Descriptive analysis was performed to generate summary statistics, including measures of central tendency such as mean, median, and mode. Additional assessments were conducted to analyze data distribution and skewness, providing insight into case variations.

Bivariate analysis was conducted using chi-square tests to examine relationships between independent variables such as operator level, tooth number, pulp vitality, and restoration status, and the dependent variable, which was treatment success or failure. Statistical significance was established at  $p < 0.05$  to determine meaningful associations. Multivariate analysis was performed using logistic regression modeling to evaluate the predictive value of independent variables on NSRCT success rates. All statistical analyses were conducted using R software, ensuring a robust evaluation of clinical variables influencing NSRCT outcomes and providing a comprehensive comparison of treatments performed by undergraduate students and graduate residents.

## CHAPTER 3 RESULTS

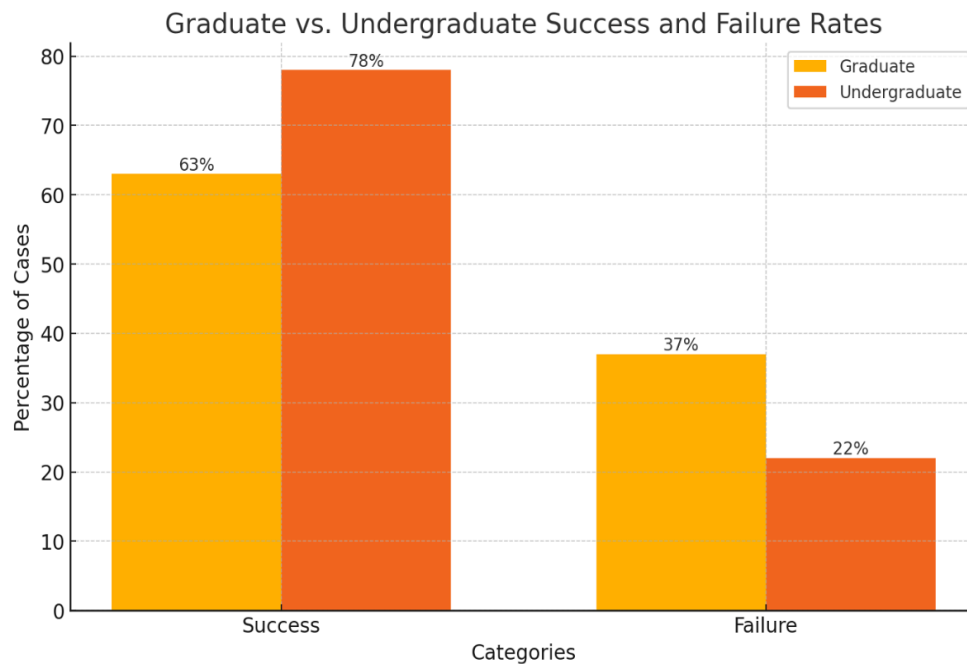
A total of 881 cases of non-surgical root canal therapy (NSRCT) were analyzed in this retrospective study, consisting of 63 cases treated by graduate endodontic residents and 818 cases treated by undergraduate dental students. Treatment outcomes were classified using the Strindberg Index into four categories: Good (successful), Questionable, Poor, and Hopeless (collectively considered failures for statistical analysis). Statistical analyses evaluated the association between treatment success and variables including operator level, tooth location, pulp vitality, restoration status and patient demographics.

### **Treatment Outcomes by Operator Level**

Graduate residents achieved a “Good” (successful) outcome in 63 % of their cases (40 of 63), whereas undergraduate operators reached a 78 % success rate (636 of 818). A chi-square analysis confirmed that the overall distribution of outcomes differed significantly between the two cohorts ( $p < 0.05$ ). Compared with undergraduates, residents treated a larger share of cases that ended in either a “Poor” result (11 % vs 4 %) or a “Questionable” prognosis (24 % vs 16 %). Conversely, “Hopeless” failures were infrequent and nearly identical across groups (2 % in each).

Outcomes by Operator Level				
Outcome	Graduate (n=63)	Undergraduate (n=818)	Graduate (%)	Undergraduate (%)
Good	40	636	63%	78%
Questionable	15	133	24%	16%
Poor	7	33	11%	4%
Hopeless	1	16	2%	2%
Success Rate			63%	78%
Failure Rate			37%	22%

**Table 1. Treatment Outcomes by Operator Level (Graduate vs. Undergraduate) and Success and Failure Rates**



**Figure 9. Graduate vs. Undergraduate Success and Failure Rates**

## **Influence of Pulp Diagnosis on Outcome**

Pulpal status, expressed in broad vitality terms (vital, non-vital, previously initiated), was not associated with treatment outcome when graduate and undergraduate operators were analyzed separately (all  $\chi^2$ ,  $p > 0.30$ ). Among residents, 72.7 % of teeth that healed uneventfully were vital and only 3 % were non-vital, while undergraduates recorded comparable figures (68.5 % and 8.6 %, respectively). When the data were regrouped by specific endodontic diagnosis, however, a clear risk signal emerged. Teeth diagnosed with symptomatic irreversible pulpitis (SIP) accounted for 37.7 % of the successful cases (255/676) but represented 20.3 % of those with a questionable prognosis (30/148), 45.0 % of the poor outcomes (18/40) and 41.2 % of the hopeless failures (7/17); this distribution was highly significant ( $\chi^2$ ,  $p < 0.001$ ). In contrast, asymptomatic irreversible pulpitis, reversible pulpitis and previously initiated treatment were evenly spread across outcome categories and showed no statistically meaningful association with success or failure (all  $p \geq 0.38$ ). Thus, while vitality status per se did not influence results at the operator level, the refined diagnosis of symptomatic irreversible pulpitis emerged as an independent predictor of treatment failure in the overall cohort.

Diagnosis	Good	Hopeless	Poor	Questionable	p-value
Symptomatic Irreversible Pulpitis	255 (37.7%)	7 (41.2%)	18 (45.0%)	30 (20.3%)	<0.001
Asymptomatic Irreversible Pulpitis	1 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.959
Reversible Pulpitis	30 (4.4%)	0 (0.0%)	0 (0.0%)	5 (3.4%)	0.411
Previously Initiated Treatment	85 (12.6%)	0 (0.0%)	6 (15.0%)	16 (10.8%)	0.389

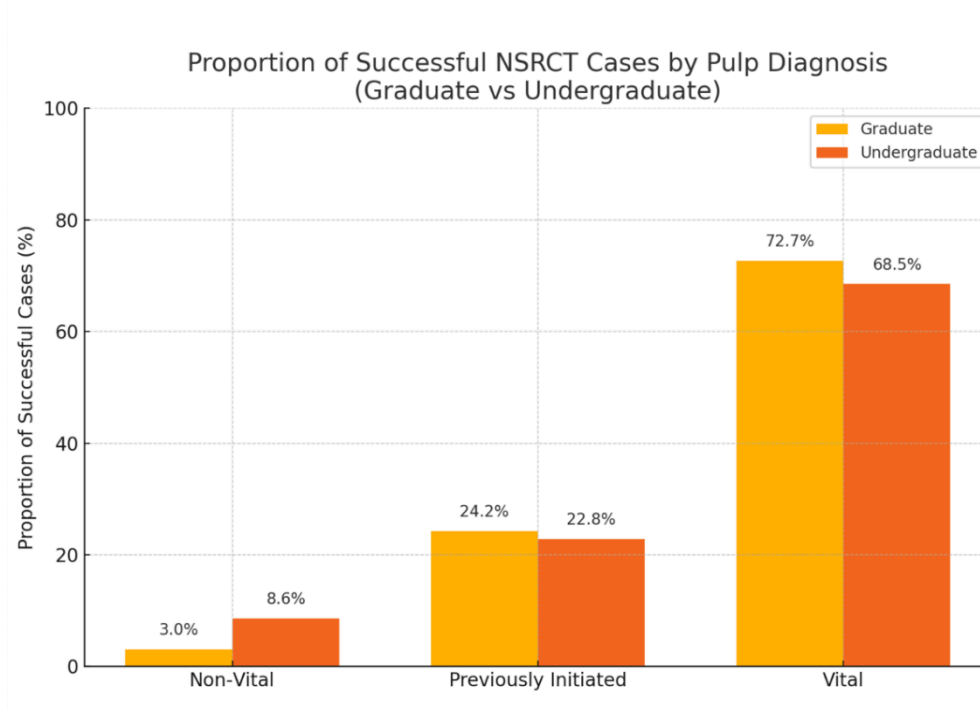
**Table 2. Pulp Diagnosis Effect on Outcome and Significance Level**

Diagnosis	Good (n=40)	Hopeless (n=1)	Poor (n=7)	Questionable (n=15)	p-value
Non-vital	1 (3%)	0 (0%)	0 (0%)	0 (0%)	0.316
Previously Initiated	8 (24.2%)	0 (0%)	2 (33.3%)	2(38.6%)	
Vital	24 (27.7%)	0 (0%)	4 (66.7%)	5(71.4%)	

**Table 3. Pulp Diagnosis for Graduate Residents on Outcome and Significance Level**

Diagnosis	Good (n=636)	Hopeless (n=16)	Poor (n=33)	Questionable (n=133)	p-value
Non-vital	29 (8.6%)	0 (0%)	0 (0%)	5 (10.9%)	0.318
Previously Initiated	77 (22.8%)	0 (0%)	4 (22.2%)	14(30.4%)	
Vital	231 (68.5%)	7(100%)	14 (77.8%)	27(58.7%)	

**Table 4. Pulp Diagnosis for Undergraduate Students on Outcome and Significance Level**



**Figure 10. Success Rate by Pulp Diagnosis Category (Graduate vs. Undergraduate)**

### **Influence of Tooth Location**

Tooth location emerged as a significant anatomic determinant of outcome. Posterior teeth accounted for 70.3 % of all cases and were disproportionately represented in each failure category: 75.0 % of Poor and 70.6 % of Hopeless results, compared with 71.0 % of Good outcomes (overall  $\chi^2$ ,  $p = 0.004$ ). Stratification by operator level confirmed this pattern for undergraduates' posterior teeth comprising 68.7 % of their successes but 57.1 % of their failures, a difference that remained significant in both bivariate and multivariate models ( $p < 0.001$ ). Among graduate residents, 92.3 % of successful cases also involved posterior teeth, and every Poor or Questionable outcome arose in a posterior tooth; however, the association did not reach statistical significance ( $p = 0.146$ ), most likely because of the smaller graduate sample.

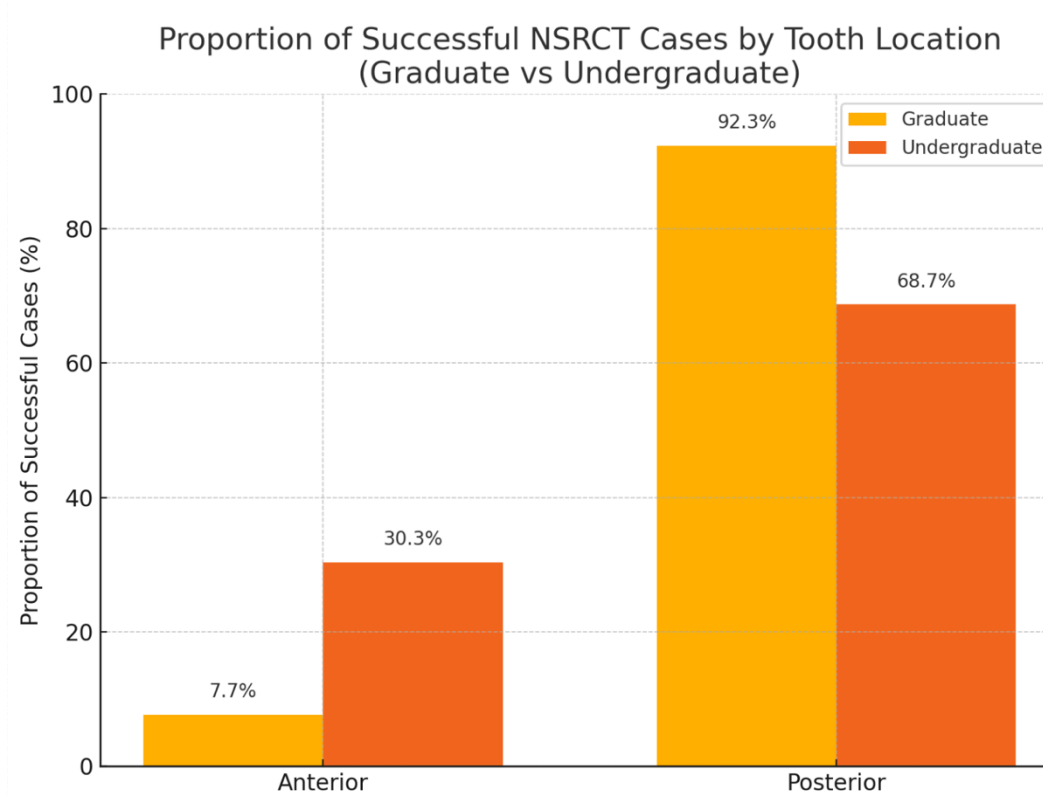
Analysis at the individual-tooth level supported these findings. Tooth #13 generated the single highest share of Good results (8.9 %) yet also appeared among the Poor outcomes, underscoring that even seemingly favorable teeth can fail in possible complex circumstances. Overall, the distribution of outcomes across tooth numbers differed significantly ( $\chi^2, p = 0.005$ ), highlighting tooth-specific anatomical variability as an additional factor influencing non-surgical root-canal therapy success.

Tooth Location	Good (n=676)	Questionable (n=148)	Poor (n=40)	Hopeless (n=17)	p-value
Anterior	196 (29.0%)	65 (43.9%)	10 (25.0%)	5 (29.4%)	0.004
Posterior	479 (71.0%)	83 (56.1%)	30 (75%)	12 (70.6%)	

**Table 5. Tooth Location Effect on Outcomes**

Tooth Location	Grad Success (n=40)	Grad Failure (n=23)	Undergrad Success (n=636)	Undergrad Failure (n=182)	p-value
Anterior	3 (7.7%)	2 (8.7%)	193 (30.3%)	78 (42.9%)	0.146 (grad)
Posterior	36 (92.3%)	21 (91.3%)	443 (68.7%)	104 (57.1%)	<0.001 (undergrad)

**Table 6. Tooth Location Effect on Outcomes Between Graduate and Undergraduate**



**Figure 11. NSRCT Success Rates by Tooth Location (Graduate vs. Undergraduate)**

### Presence of a Restoration

Restoration status was one of the strongest predictors of success. Among graduate cases, 60% of "Good" outcomes had final restorations placed, compared to 42.9% of "Poor" outcomes and 64.3% of "Questionable" ones. Although this relationship did not reach statistical significance in the graduate cohort alone ( $p = 0.506$ ), the trend was evident.

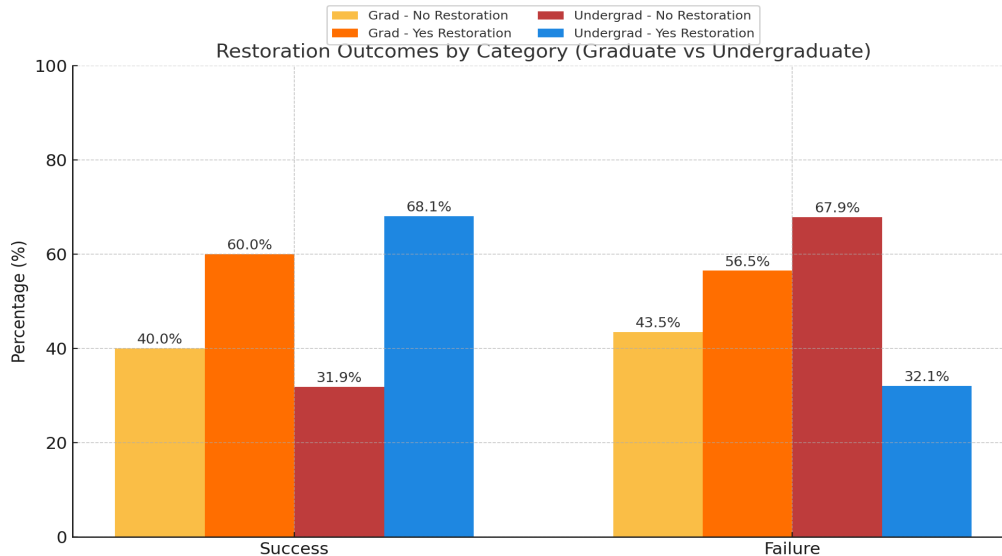
In contrast, for undergraduate cases, there was a statistically significant relationship between restoration status and outcome ( $p < 0.001$ ). Of the 432 undergraduate cases with final restorations, 68% were successful. Only 32% of

unrestored teeth had "Good" outcomes, while 81.2% of "Hopeless" and 69.7% of "Poor" cases lacked a final restoration.

Across the entire dataset, teeth with final restorations were significantly more likely to succeed ( $\chi^2, p < 0.001$ ), consistent with literature underscoring the importance of coronal seal integrity.

Restoration		Grad Success (n=40)	Grad Failure (n=23)	Undergrad Success (n=636)	Undergrad Failure (n=182)
No		16 (40%)	10 (43.5%)	203 (32%)	123 (67.9%)
Yes		24 (60%)	13 (56.5%)	432 (68%)	59 (32.1%)
p-value		0.506		<0.001	

**Table 7. Presence of a Restoration Effect on Success Rate (Graduate vs. Undergraduate)**



**Figure 12. Restoration Outcomes by Category (Graduate vs. Undergraduate)**

## Gender and Age

The patient population comprised 499 females (56.7%), 381 males (43.3%), and 1 transgender individual (0.1%), with an average age of 45.32 years (SD = 16.82). Patient gender and age were also evaluated. Female patients made up 56.7% of the sample and had a slightly higher proportion of "Good" outcomes (56.7%) compared to males (43.3%), though the difference was not statistically significant for most outcome categories.

However, among "Questionable" outcomes, gender was significantly associated with results ( $p = 0.001$ ): females comprised 56.1% of these cases. Age did not show a statistically significant difference between outcome categories overall ( $p = 0.134$ ), with the mean age for successful cases being 45.5 years and for failures ranging from 45.9 to 50.8 years.

Patient Gender	Good	Questionable	Poor	Hopeless
Female	56.7%	56.1%	60%	64.7%
Male	43.3%	43.9%	37.5%	35.3%
Transgender	0%	0%	2.5%	0%

**Table 8. Patient Gender Effects on Outcomes**

## **CHAPTER 4 DISCUSSION**

This retrospective review examined 881 non-surgical root canal treatments performed at a single academic institution, comparing outcomes between undergraduate dental students and graduate endodontic residents. It also evaluated several clinical variables to determine their association with treatment success. The results revealed several notable findings.

The level of operator training had a significant impact on treatment outcomes. Undergraduate students achieved a success rate of 78%, compared to 63% among residents. While this result may seem counterintuitive, it is best understood in the context of case selection. Undergraduate students are required to use the American Association of Endodontists (AAE) Case Difficulty Assessment Form and must transfer complex cases, such as those involving perforations or separated instruments, to the postgraduate clinic. As a result, student cases are typically limited to vital anterior teeth or straightforward posterior teeth with relatively simple anatomy. In contrast, residents are assigned more complex referrals, including teeth with calcified canals, large radiolucencies, and non-vital posterior teeth, all of which have been consistently associated with lower healing rates in the literature (Ng et al., 2008; Sjögren et al., 1990). Even though the cases undergraduates treated were deemed simple cases they were consistently aided clinically in treatment by endodontic faculty. These differences were reflected in the present dataset, where 92% of resident successes involved posterior teeth, but every resident case with a poor or questionable outcome also involved a posterior tooth. Undergraduate cases, by comparison, demonstrated a more balanced distribution between anterior and posterior teeth.

Follow-up protocols further influenced the available data. Undergraduate students are required to recall each patient at least twice prior to graduation, resulting in a high rate of follow-up and yielding 818 evaluable cases. Resident cases, however, often involve patients referred from outside dental providers who return to their general dentist after obturation, leading to fewer follow-up visits. This loss to follow-up disproportionately removes asymptomatic, successful cases from the resident cohort, which may result in an artificially elevated failure rate.

The presence of a well-sealed coronal restoration significantly improved the likelihood of treatment success, aligning with the findings of Ray and Trope (1995). In the overall sample, teeth with definitive restorations demonstrated nearly double the success rate compared to those without. This association was especially pronounced in the undergraduate group and reached strong statistical significance. A similar trend was observed in the resident cases but did not reach significance, likely due to limited sample size. These results reinforce the importance of prompt placement of a final restoration with adequate cuspal coverage following root canal therapy.

Tooth location also demonstrated a consistent relationship with prognosis. Posterior teeth were significantly overrepresented among failed cases and underrepresented among successful ones. In the undergraduate group, this association remained statistically significant in both univariate and multivariate analyses. Although the resident sample size was insufficient to confirm statistical significance, all resident cases with poor or questionable outcomes involved molars, underscoring the technical challenges associated with posterior anatomy. Even within individual tooth types, certain teeth showed varied outcomes. For instance, tooth number 13 was frequently successful

but was also present among the failed cases, suggesting that no single tooth is immune to failure in the presence of additional risk factors such as missed canals, curvature, or coronal leakage.

Pulpal diagnosis further influenced outcomes, though broad vitality categories did not consistently predict success. More refined diagnostic distinctions revealed that symptomatic irreversible pulpitis was a significant independent risk factor. While cases with this diagnosis comprised 38% of all successes, they accounted for 45% of poor and 4% of hopeless outcomes. This trend suggests that the heightened inflammatory burden in these cases may negatively impact healing, even when mechanical and chemical debridement are adequately performed. Other diagnoses, such as asymptomatic irreversible pulpitis, reversible pulpitis, and previously initiated therapy, did not exhibit significant prognostic value.

Several limitations should be considered when interpreting these findings. The graduate cohort was substantially smaller than the undergraduate group, reducing statistical power for detecting moderate associations. Additionally, radiographic follow-up beyond three months was inconsistent, limiting the identification of delayed failures. A further constraint is the very stringent definition of success: only cases classified as “Good” were deemed successful, and with a minimum three-month recall this narrow window may have precluded initially “Questionable” cases from demonstrating eventual healing and moving into the success category. Operator performance was not directly evaluated through clinical metrics such as obturation length or density but rather inferred through case allocation. Furthermore, the retrospective

design did not allow for randomization and could not fully adjust for confounding variables such as systemic illness or smoking history.

Despite these limitations, the study highlights several implications for academic endodontics. Case selection protocols play a critical role in supporting undergraduate clinical success and patient safety, though graduate programs may benefit from implementing structured recall protocols to ensure comprehensive outcome tracking. The timely placement of a definitive coronal restoration remains essential to long-term success and requires close coordination between endodontic and restorative departments. Additionally, cases diagnosed with symptomatic irreversible pulpitis warrant heightened clinical vigilance and may benefit from adjunctive antibacterial strategies. Future prospective, multicenter studies with balanced sample sizes and standardized follow-up protocols will be necessary to validate these findings and further refine evidence-based guidelines for clinical training and outcome assessment.

## **CHAPTER 5 CONCLUSIONS**

This study is the first to compare non-surgical root canal outcomes between undergraduate dental students and graduate endodontic residents within the same academic setting while accounting for pulpal diagnosis, tooth location, and restoration status. Despite managing a smaller but more complex case pool, residents showed lower overall success rates than undergraduates, who benefited from structured case selection and mandatory follow-up. Across both groups, timely placement of a definitive coronal restoration and treatment of anterior teeth were strongly linked to favorable outcomes, while symptomatic irreversible pulpitis and posterior anatomy increased the risk of failure.

These findings highlight the importance of thoughtful case assignment in predoctoral education and suggest that postgraduate programs may benefit from improved follow-up protocols. They also reaffirm that anatomical complexity and restoration quality, rather than training level alone, are key predictors of success. Future prospective, multi-institutional studies are needed to confirm these patterns and inform evidence-based guidelines for training and case management.

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