

Clinical and radiographic evaluation of root canal treatments performed by undergraduate students

Avaliação clínica e radiográfica de tratamentos endodônticos realizados por estudantes de graduação

Marcelle Melo Magalhães¹, Luciana Maria Arcanjo Frota², Tamara Abreu de Souza³, Bruno Carvalho de Vasconcelos⁴, Francisca Lívia Parente Viana^{5*}

¹ Master's student of the Postgraduate Program in Health Sciences at the Federal University of Ceará, Sobral Campus, Sobral, Ceará, Brazil, ² PhD in Dentistry from the Federal University of Ceará, Fortaleza, Ceará, Brazil. University Center UNINTA, Sobral, Ceará, Brazil, ³ PhD in Dentistry from the Federal University of Ceará, Fortaleza, Ceará, Brazil. Luciano Feijão College, Sobral, Ceará, Brazil, ⁴ PhD in Dentistry from the Federal University of Ceará, Fortaleza, Ceará, Brazil. Postgraduate Program in Dentistry, Federal University of Ceará, Fortaleza, Ceará, Brazil. ⁵ PhD in Dentistry from the Federal University of Ceará, Fortaleza, Ceará, Brazil. Luciano Feijão College, Sobral, Ceará, Brazil.

Correspondente/ Corresponding:

*Francisca Lívia Parente Viana

Travessa do Xerez 34 - Centro, Sobral - CE, 62010-270.

Email: livia.parente@flucianofejão.com.br

Abstract

To clinically and radiographically evaluate the success of root canal treatments performed by undergraduate students. 65 patients were evaluated by performing follow-up consultations at a minimum period of 1 year after the root canal treatment was concluded. In the follow-up consultations, clinical and radiographic examinations were performed to evaluate the presence of fistula, oedema, painful symptomatology, tooth functionality, and coronary conditions. In addition, the initial, post-treatment, and follow-up radiographs were digitalised and analysed by two examiners. The radiographic follow-up criteria were classified into three categories: complete healing, incomplete healing, and treatment failure. For statistical data, logistic regression was used to assess the correlation of variables with treatment success, with a significance level of $P < 0.05$. Of the cases evaluated, 11.6% failed. Follow-up times ranged from 1 to 3 years. Of the clinical signs and symptoms, pain was most often present (28%), followed by fistula and tooth loosening (3% each). Multivariate logistic regression identified only five significant variables for treatment success: female gender, absence of periodontal ligament thickening, absence of lesion, absence of pain, and definitive restoration. The failure rate for root canal treatments performed by graduate students was low, but a longer follow-up is necessary to accompany incomplete healing cases.

Keywords: Endodontics; Root canal treatment; Success of endodontic therapy.

Resumo

Avaliar clínica e radiograficamente o sucesso dos tratamentos endodônticos realizados por estudantes de graduação. Foram avaliados 65 pacientes realizando consultas de acompanhamento no período mínimo de 1 ano após a conclusão do tratamento endodôntico. Nas consultas de acompanhamento foram realizados exames clínicos e radiográficos nos quais foram avaliadas a presença de fístula, edema, sintomatologia dolorosa, funcionalidade dentária e condições coronarianas. Além disso, as radiografias iniciais, pós-tratamento e de acompanhamento foram digitalizadas e analisadas por dois examinadores. Os critérios de acompanhamento radiográfico foram classificados em três categorias: cicatrização completa, cicatrização incompleta e falha do tratamento. Para os dados estatísticos, utilizou-se regressão logística para avaliar a correlação das variáveis com o sucesso do tratamento, com nível de significância de $P < 0,05$. Dos casos avaliados, 11,6% falharam. O tempo de acompanhamento variou de 1 a 3 anos. Dos sinais e sintomas clínicos, a dor esteve mais presente (28%), seguida de fístula e mobilidade dentária (3% cada). A regressão logística multivariada identificou apenas cinco variáveis significativas para o sucesso do tratamento: sexo feminino, ausência de espessamento do ligamento periodontal, ausência de lesão, ausência de dor e restauração definitiva. A taxa de insucesso nos tratamentos endodônticos realizados por estudantes de pós-graduação foi baixa, mas é necessário um período de acompanhamento mais longo para acompanhar os casos que envolvem cicatrização incompleta.

Palavras-chave: Endodontia; Tratamento de canal radicular; Sucesso da terapia endodôntica.

1 INTRODUCTION

Root canal treatment is a therapeutic procedure that eliminates or reduces the number of microorganisms and their by-products in the root system through chemical-mechanical preparation (CMP) and hermetic duct sealing. It thus allows the cure of pulpal and periapical pathologies.¹

When root system contamination is not treated, microorganisms involved in the infection process assault

the periradicular region through enzymes, toxins, and cell debris through the apical foramen.² The response to this aggression is an inflammatory process (which occurs in the region) with posterior bone resorption. These cases are denominated periapical injuries, with abscesses, root cysts, and dental granuloma being the injuries that occur at the highest frequencies.³⁻⁴ Lesion repair occurs when microorganisms are neutralised through root canal

treatment. In cases presenting a decrease in the lesion or its permanence, follow-up normally extends for up to 4 years (recommended), after which root canal failure is considered.⁵⁻⁶

Despite great advances in endodontics, the success of root canal treatment is still a continuing challenge.⁷ Treatment failures are closely related to Intra and extra-radicular biofilm, fillings, inadequate coronary sealing, anatomical complexities, and iatrogenic errors during procedures.⁸ Werlang et al. report that the failure index of root canal treatment is about 15%, with root canal system (RCS) having bacterial persistence as the main cause.⁹

The American Association of Endodontics¹⁰ (1987) has established clinical and radiographic evaluation criteria for endodontic failure in which teeth that clinically present persistent symptomatology, recurrent fistulas or swelling, discomfort on palpation, or percussion, loosening, and marked bone loss are considered failures. For radiographic criteria, the thickness of the periodontal ligament, presence or increase of periapical rarefaction, unfilled spaces in the canal associated with periradicular lesions, absence of new hard lamina formation, and active resorptions are also considered.¹⁰ Due to endodontic prognosis being by nature multifactorial, it is fundamental to realise clinical and radiographic control for a minimum period of 1 year or more according to need.⁵

The operator's clinical experience is another factor that influences the success of root canal treatment. According to Pietrzycka et al., the quality of treatment can differ between dental students, general practitioners, and endodontists; discrepancies are associated with different levels of knowledge, experience, and skill.¹¹ Thus, we see the extreme importance of evaluating the factors that influence root canal treatment outcomes when performed by undergraduate students to improve training and realise appropriate treatments.

Despite high success rates, root canal treatments still present failures due to low-quality treatment and/or lack of experience. This work aims to evaluate root canal treatment success rates in an undergraduate dental clinic.

2 METHODOLOGY

2.1 Ethical aspects

Upon approval by the research ethics committee, under the opinion of number 5,419,935, we analysed the medical records of patients who underwent root canal treatment at the undergraduate dental clinic of the IN-TA-UNINTA University Center, Sobral, Ceará, Brazil, with a preservation time of 1 to 3 years.

2.2 Data collection

A total of 116 patients were selected in accordance with the research criteria, in which patients with completed root canal treatment and possessing well-developed initial and final radiographs, without stretching or

shortening, with good clarity and no distortion, with a minimal follow-up time of 1 year, and who underwent root canal treatment in which single- and double-rooted teeth were included. Patients with medical records that were not properly completed, without the necessary clinical information to perform the research, or whose treatment was performed with mechanised instrumentation were excluded.

Selected patients were invited to the UNINTA clinic for a check-up on the treated tooth. Cases requiring dental interventions or presenting complaints were referred to the disciplines related to each need. Of these, 51 patients refused to attend the follow-up consultation, yielding only 65 participants.

Sociodemographic data and information concerning the treatment performed with initial and final radiographs were collected from the medical records. During the follow-up examination, the presence of pain through percussion and palpation tests, the presence of oedema and fistula, loosening, and the type of restoration (permanent/temporary) were evaluated. After clinical examination, patients underwent periapical radiography with the use of Han Shin radiographic positioners (Maquira) and a Gnatus X-Ray, 70 kVp, 7 mA device with intraoral radiographic film Kodak E-Speed Film (Carestream), with exhibition averaging 0.63s. After the realisation of radiography, the film was processed at the clinic.

The initial and final radiographs of the treatment were already present in the patient's medical record, and the follow-up radiographs were digitised, organised in a PowerPoint presentation (Microsoft Office Professional Plus 2016), and dated according to the medical record of each patient under evaluation.

The follow-up images were evaluated using Image J software by two evaluators (FLPV and LMAF), experienced specialists in endodontics, and duly calibrated regarding the prognosis of the root canal treatment performed. In cases of disagreement between the two evaluators, the radiographs were evaluated by a third evaluator (TAS).

Radiographic images were evaluated for the number of canals filled, dental complications present, periodontal thickening, presence and size of periapical lesions, apical filling limit, filling quality, and accidents and/or complications that may have occurred during treatment. As for the apical limit of obturation, Canto et al. classify obturation as incomplete when it is 2.0 mm or more below the radiographic vertex and/or with empty spaces in the filling body and as overfilled when it is at the level of or beyond the radiographic vertex.¹²

In the follow-up radiograph, periapical status was observed and classified as normal periodontal ligament, thickened periodontal ligament, or presence of periapical lesion. In addition, the presence of reabsorption was also evaluated. In cases of lesion, the larger diameter size was evaluated. Finally, the periapical status of the postoperative radiographs was compared with the follow-up radiographs according to the index proposed by Ng et

al.¹³ (2008) Three categories were used: complete healing, when the periodontal ligament space on the control radiograph appeared to be normal; incomplete healing, when there was a reduction in the size of the radiographic lesion, but the periodontal ligament space remained altered; or treatment failure, when the periapical lesion had increased or remained unchanged, or if the periodontal ligament space had increased.

The data was organised into spreadsheets in the (Microsoft Office Professional Plus-2016) Excel program, and subsequently, descriptive statistical analysis with statistical percentage treatment was performed. Logistic regression was used to investigate the impact of demographics, clinical factors, and radiographic variables on the result (success/failure of the root canal treatment).

For logistic regression, variables were separated by age (≤ 40 years, or > 40 years), gender (female or male), restoration (definitive or provisional), ligament thickening (present or absent), periapical lesion (present or absent), pain (present or absent), and quality of the filling (final or provisional). Variables with statistical significance in the binary model were included in the multivariate model. The statistical significance level was established at $P < 0.05$. The data were analysed using Microsoft Office Excel (Microsoft Corp., Redmond, WA, USA) and SPSS (SPSS Inc., Chicago, IL, USA) software.

3 RESULTS

One hundred ninety root canal treatments were identified from the medical records survey. After applying the inclusion and exclusion criteria, 161 treatments were included. Forty-five were excluded due to the patient's inability to attend the follow-up consultation or loss of contact.

A total of 65 treatments were evaluated in the follow-up consultation, of which 41 (63%) were front teeth and 24 (37%) premolars. Five teeth (8%) were absent and thus excluded from analysis. The motives for dental losses were unclassified, as patients often look for treatment outside the University. From the clinical and radiographic results evaluated, the failure rate for root canal treatments performed by undergraduate students was 11.6% (7 teeth). The sampling was performed by convenience without pre-sample calculations. However, power was calculated post hoc from the regression logistics analysis $R^2 = 0.7157$, with 16 predictors, one sample size $n=60$, and an error probability of 0.05, yielding a sampling power of 99%.

The initial clinical, radiographic, and demographic characteristics of the sample ($n = 60$) and the failure proportion for each category are described in Table 1. There was no significant difference between the age groups evaluated, and men presented more failures than women, both proportionately and with a significant difference. Anterior teeth canals corresponded to 65% ($n = 39$) of the canals evaluated, and of these, 5 (12.8%) presented

failures. As to the type of treatment, all teeth presenting failure also presented necrotic pulp upon initial assessment, and together with thickened periodontal ligament and periapical lesion failures, reached 40% and 8.3%, respectively, with a significant difference ($P < 0.05$) in relation to the teeth with normal periodontal ligament. During root canal treatment, there were 4 accidents (3 fractured instruments and 1 root perforation).

Table 1 - Characteristics of endodontically treated teeth and those with failure

Variables	Endodontically treated teeth N = 60	Failed endodontically treated teeth N=7	P value
Age			
≤ 40 years	33 (55%)	4 (12%)	
> 40 years	27 (45%)	3 (11,1%)	
Sex			
Female	41 (68,3%)	4 (9,7%)	
Male	19 (31,6%)	3 (15,7%)	
Dental group			
Anterior	39 (65%)	5 (12,8%)	
Premolar	21 (35%)	2 (9,5%)	
1 conduit	13 (21,6%)	2 (15,3%)	
2 conduit	8 (13,3%)	0 (0%)	
Dental arch			
Maxillary	52 (86,6%)	7 (13,4%)	
Mandibular	8 (13,3%)	0 (0%)	
Type of treatment			
Biopulpectomy	10 (16,6%)	0 (0%)	
Necropulpectomy	50 (83,3%)	7 (14%)	
Periapical condition			
Normal PL*	14 (23,3%)	0 (0%)	P < 0.006
Widened PL*	10 (16,6%)	4 (40%)	
Periapical lesion	36 (60%)	3 (8,3%)	
Initial lesion diameter			
< 5 mm	18 (28,3%)	2 (11,1%)	
5-10 mm	13 (23,3%)	1 (7,6%)	
>10 mm	5 (8,3%)	0 (0%)	
Iatrogenic			
Fractured instruments	3 (5 %)	1 (33,3%)	
Root perforation	1 (1,6 %)	0 (0%)	

* Values are presented as number of elements (%). Fisher's exact test was used to test the association between variables and the proportion of failure ($P<0.05$).

The clinical and radiographic follow-up data are arranged in Table 2, with preservation times ranging from 1 year to 3 years and 2 months. Of the clinical signs, pain was the most common (28%), followed by fistula and loosening (3% each). Most teeth presented permanent crown restoration (75%). In radiographic follow-up, 45% of the teeth presented complete healing, followed by incomplete healing (43.3%), and radicular resorption was found in 3 teeth (5%), of which 1 treatment failed.

Table 2 – Clinical and radiographic data of the teeth evaluated in the follow-up

Variables	Endodontically treated teeth N = 60
Prosevation time	
≤ 2 years	49 (81.6%)
> 2 years	11 (18.3%)
Clinical signs	
Edema	1 (1.5%)
Fistula	2 (3%)
Mobility	2 (3%)
Pain	18 (28%)
Horizontal percussion	14
Vertical percussion	14
Palpation	0
Chewing	4
Spontaneous	0
Coronary condition	
Definitive restoration	45 (75%)
Fixed prothesis	2 (3.3%)

Temporary Restoration 13 (21.6%)

Prosevation

Full repair 1 27 (45%)

Incomplete repair 2 26 (43.3%)

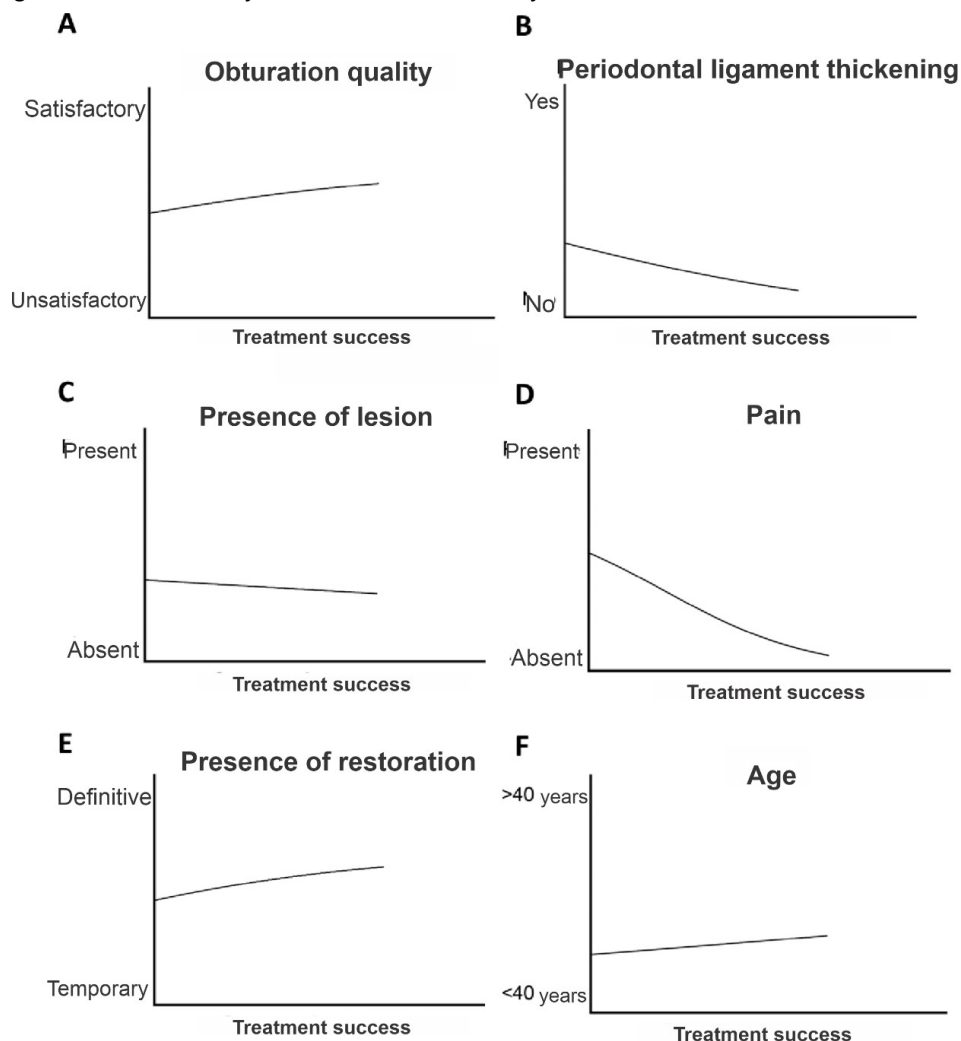
Treatment failure 3 7 (11.6%)

Evidence of root resorption 3 (5%)

¹ when the space on the LP presents an appearance of normality. ² when there was a reduction in the size of the radiographic lesion, but the periodontal ligament space remained altered. ³ when the injury periapical increased or remained unchanged, or if space of periodontal ligament increased. *Values are presented as number of elements (%).

It was noted that the majority of cases presenting flaws arose from the quality of the compromised filling. Of the teeth presenting incompletely filled canals, 23% presented failure, while 11.1% of the teeth with overfilled root canals also failed. The apical limit in filling presented no significant correlation to treatment success, however, on the apical limit x success curve, we observed that the teeth presenting satisfactory apical limit also presented a greater chance for treatment success (Figure 1A).

Figure 1 - Curves in trend for variables versus success of treatment



IC = 95%; Significant $P < 0.05$; * < 0.05 ; ** < 0.01 ; P calculated using binary and multiple logistic regression; OR = Odds Ratio

Table 3 presents the association between periapical status at the end of root canal treatment and upon the follow-up consultation. The teeth with normal periodontium ligament on postoperative radiographs, 3 teeth with an initial diagnosis of necrosis (21.4%) developed

signs of apical periodontitis. Of the elements presenting apical periodontitis established in the postoperative radiography, 7 (19.4%) presented healing at follow-up, 25 (69.4%) continued with periapical changes, and 4 (11.1%) presented treatment failure.

Table 3 - Association of status periapical of treatment final with to the x-rays in follow-up (n = 60).

Condition initialperiapical (N= 60)		1-2 years			> 2 years		Valuein P
	Repair complete	Repair Incomplete	Failure	Repair complete	Repair Incomplete	Failure	
Normal periodontium ligament (n= 14)	9 (64.2%)	0 (0%)	3 (21.4%)	2 (14.2%)	0 (0%)	0 (0%)	0.0172*
Periodontalligament thickening (n= 10)	8 (80%)	1 (10%)	0 (0%)	1 (10%)	0 (0%)	0 (0%)	
Lesion ≤ 5mm(n=18)	2 (11.1%)	8 (44.4%)	2 (11.1%)	2 (11.1%)	3 (16.6%)	1 (5.5%)	0.3580
Lesion 5-10 mm(n=13)	3 (23%)	8 (61.5%)	1 (7.7%)	0 (0%)	1 (7.7%)	0 (0%)	0.7617
Lesion >10 mm(n=5)	0 (0%)	2 (40%)	0 (0%)	0 (0%)	3 (60%)	0 (0%)	>0.999

CI = 95%; P significant <0.05; *<0.05; P calculated through logistic regression.

When initial periapical conditions were evaluated, periodontal ligament thickening presented a significant correlation to treatment success ($P = 0.0172$). Teeth with an absence of periapical thickening tended to present greater treatment success (Figures 1B and 1C).

Table 4 - Association of clinical and radiographic conditions of follow-up

Radiographic condition				
Clinical condition	Complete repair (n=27)	Incomplete repair (n=26)	Failure (n=7)	P value
Vertical percussion	9 (33.3%)	2 (7.6%)	3 (42.8%)	0.0106*
Being Absent	18 (66.6%)	24 (92.3%)	4 (57.1%)	
Horizontal percussion	9 (33.3%)	2 (7.6%)	3 (42.8%)	0.0446*
Being Absent	18 (66.6%)	24 (92.3%)	4 (57.1%)	
Chewing	1 (3.7%)	2 (7.6%)	1 (14.2%)	0.1570
Being Absent	26 (96.3%)	24 (92.3%)	6 (85.7%)	
Palpation	0 (0%)	0 (0%)	0 (0%)	-
Spontaneous	0 (0%)	0 (0%)	0 (0%)	-
Edema	0 (0%)	1 (3.7%)	0 (0%)	0.5468
Being Absent	27 (100%)	25 (96.2%)	7 (100%)	
Fistula	0 (0%)	2 (7.4%)	0 (0%)	0.0313*
Being Absent	27 (100%)	24 (92.5%)	7 (100%)	
Mobility	1 (3.7%)	1 (3.7%)	0 (0%)	0.4995
Being Absent	26 (96.2%)	25 (96.2%)	7 (100%)	
Coronary structure				
Definitive restoration (n = 45)	22 (48.8%)	19 (42.2%)	4 (8.8%)	0.0443*
Temporary Restoration (n=13)	5 (38.4%)	6 (46.1%)	2 (15.3%)	
Fixed prosthesis (n=2)	0 (0%)	1 (50%)	1 (50%)	

Table 4 presents the association of the clinical condition at follow-up with the apical control. We observe that teeth with treatment gaps presented more pain on percussion (42.8%) and during chewing (14.2%) when compared to teeth with complete or incomplete healing. Teeth that presented oedema (n=1) and fistula (n=2) presented incomplete healing as their periapical status. None of the failed teeth presented oedema, fistula, loosening, or pain on palpation. As to coronary conditions, we observed that teeth presenting complete healing were (largely) definitively restored. Teeth with provisional restoration presented 15.3% failure.

Analysing Table 4, we can see that the variables of vertical percussion ($P=0.01$), horizontal percussion ($P=0.04$), fistula ($P=0.03$) and coronary structure ($P=0.04$) present significant correlations with treatment success. In the trend curves, it is evident that a greater tendency towards success occurred in cases absent of pain (Figure 1D) and in cases involving definitive coronal restoration (Figure 1 AND).

Binary and multivariate regression logistics analyses (between root canal treatment success and other variables) are presented in Table 5. In the multivariate model, patient gender, type of restoration, periodontal ligament thickening, and presence of injury or pain all had significant influence on treatment success. In the binary model, the type of restoration, periodontal ligament thickening, and pain presented marked influences. Of the analysed variables, only age and quality of filling presented no association with treatment success, although, in the trend curves, it is observed that patients younger than 40 years who received satisfactory obturation also trended towards treatment success (Figures 1A and 1F).

Table 5 – Analysis in regression logistics binary it is multivariate in between success endodontic it is others variables

Variable	P	binary OR	P	multiple OR
Age (<40 years old / >40 years old)	0.3890	0.5833	0.0805	30.95
Sex (Male/Female)	0.1210	0.9000	0.0190*	0.02849
Restoration (Definitive/Temporary)	0.0443*	2.167	0.0106*	78.77
Periodontal ligament thickening (Yes/No)	0.0172*	0.9000	0.0416*	0.0002412
Presence of lesion (Present/Absent)	0.5291	1.111	0.0242*	6.7919
Obturation quality (satisfactory/unsatisfactory)	0.0803	2.167	0.8432	1.379
Pain (Present/Absent)	<0.0001**	2,800	0.0055**	0.0006731

CI = 95%; P significant <0.05; *<0.05; **<0.01; P calculated through binary logistic regression and multiple; OR = Odds Ratio.

4 DISCUSSION

The success of root canal therapy can be influenced by factors ranging from the clinical presentation of the patient, adequate disinfection of the root canals, the quality of the obturation, adequate coronal sealing, and even operator experience.¹⁴⁻¹⁵ Our study aimed to evaluate clinical and radiographic results of root canal treatments performed by undergraduate students. A failure rate of 11.6% was found. This corroborates other findings in the literature, which report a failure rate incidence of between 10 and 15%.¹⁶⁻¹⁷

In this study, radiographic criteria were used to consider treatment failure, that is, teeth with increased or unchanged periapical lesions or those presenting increased periodontal ligament space. The multivariate logistic regression identified only five significant variables for treatment success: gender, periodontal ligament thickening, injury, pain, and type of restoration.

Age did not present a significant difference in treatment success. For gender, being female significantly positively impacted root canal treatment success. Some studies have presented similar results.¹⁸⁻¹⁹

By tooth group, the anterior teeth (n=5) presented more failures than premolars (n=2). This diverges from certain studies that presented a 96% success rate for anterior teeth (evaluating all tooth groups) and an error frequency of only 19.2%.^{17-20,21} In addition, all of the failures occurred in teeth in the upper arch, similar to the results of Eusayde et al., finding that 62.7% of inadequate treatments occurred in the maxilla.²² The maxillary location requires greater operator dexterity, both for viewing and handling endodontic instruments; it is thus

more susceptible to errors, especially when treated by undergraduate students.²³⁻²⁴

In this study, iatrogenic mistakes presented a rate of 5% for instrument fractures and 1.6% for root perforation. Studies report the incidence of instrument fracture in the undergraduate clinic at from 1% to 9.2% and for perforation at 17.6%.^{25-26, 27, 28}

Iatrogeny may occur due to procedural failures or inappropriate use of an endodontic instrument.⁸ Procedural errors may impede control and prevention of intra-canal infection and can thus result in root canal failure.²⁹⁻³⁰ Of the 4 complications reported, 3 were instrument fractures, which led to 1 failure (33.3%) and 1 perforation (which did not lead to failure). The error detected presented pain on percussion and palpation, with the formation of a periapical lesion. In such cases, there is an unfavourable prognosis, principally if no one manages to remove the fragment and prevent RC infection. This leads to treatment failure. Successful root perforation treatments depend upon immediate treatment of the defect, relative ease of access, and the use of suitable repair material.²⁹

Proper disinfection of root canals can be challenging, especially when dealing with necrotic teeth with apical periodontitis (AP) appearing prior to treatment; the nature and extent of the infection is much greater than healthy teeth.³¹ In the present study, thickening of the periodontal ligament and periapical lesion had a significant influence on treatment success. It was observed that all teeth with failures presented periapical alterations, similar to other studies.^{13-32,33}

Numerous bacterial species have been detected in infected root canals, and elimination is difficult. This results in persistent root canal infection and therapy failure.⁸ In this study, 21.4% of the teeth presenting normal periodontal conditions upon initial radiography presented periapical changes at follow-up. We believe that aseptic failure during the treatment stages or deficiency in chemical-mechanical preparation and canal sealing culminated in the development of apical periodontitis.

Another factor relevant to treatment success is the apical obturation limit, which, as a prerequisite for maintaining periapical health and successful root canal treatment, must be between 0.5 to 1.5 mm short of the apical foramen.³⁴⁻³⁵ In this study, there was a higher failure rate for teeth that were either incompletely filled (23%) or overfilled (11.1%). Other studies have also reported these findings.³⁶⁻³⁷

In view of this, inadequate root canal filling generally presents a lower healing rate,³⁸ because when below the ideal limit, apical sealing is more likely to be affected by microorganisms, and consequently, biological healing conditions become unfavourable. Further, if obturation is performed beyond this limit, the obturation materials can act as a foreign body, inducing inflammatory reactions.^{13-39,40}

The absence of pain was a significant variable for root canal treatment success in both the binary and multivariate tests. In relation to the pain type, pain upon percussion was found in 18 teeth (28%), with only 3 cases of failure. Teeth presenting sensitivity to percussion without other signs/symptoms, periapical radiolucency, or incomplete healing were not considered "failures". Percussion sensitivity is not a pathognomonic sign of apical periodontitis since it can often be associated with traumatic occlusion or periodontal illness.³⁹⁻⁴¹ The presence of oedema and fistula after treatment reveals the infectious process, and according to the American Association of Endodontics (AAE),¹⁰ (1987), is one of the factors that leads to treatment failure.¹⁰

As for the type of coronal sealing, the quality of the restoration directly affects root canal treatment success.⁴²⁻⁴⁴ In our study, the presence of a definitive restoration was relevant to treatment success since most of the teeth that presented complete healing were definitively restored. Of teeth with provisional restorations, more than 60% presented permanent damage. Maslamani, Khalaf, Mitra³⁷ (2017) report that inadequate coronal sealing is associated with a higher prevalence of periapical lesion.³⁷ Failures involving definitively restored treatments can be explained by inefficiencies in cleaning, shaping, or conduit filling.¹⁹

A limitation of this study was the length of follow-up, which was from 1 year to 3 years and 2 months, with an average of 1.6 years. To determine treatment failure, the European Society of Endodontology⁵ (2006) recommends a follow-up time of up to 4 years for cases of incomplete healing.⁵ In this study, incomplete healing was observed more often in teeth with an established periapical lesion and in cases evaluated within the 2-year follow-up period.

Another limitation of the study was the use of conventional radiography to assess treatment success. Due to the two-dimensional nature of the image, the accuracy of this examination is affected, and it may present overlapping and geometric distortion.⁴⁵ In addition, the lack of standardisation in the execution of the treatments evaluated must be taken into account. Even though there is an established university protocol for performing root canal treatment, the students, in addition to being guided by different professors, presented different levels of skill and clinical training.¹⁹

Our study evaluated root canal treatment success using both clinical and radiographic evaluation during check-ups. This allowed for treatment success evaluations in accordance with pre-established European Society of Endodontology⁵ (2006) criteria. The criteria include the absence of painful symptomatology with palpation and percussion, the absence of a fistula, the absence of oedema and infection signals, normal periodontal ligament space, and the elimination of periradicular bone rarefaction. Compared to other studies found in the literature, which performed only radiographic evaluation^{5,46-48}, this represents an advantage.

Finally, we emphasise that follow-up of patients after treatment is extremely important to assess both periapical health and the patient's clinical conditions. This makes it possible to identify if there is a need or not to intervene. In addition, during these queries, it is possible to assess oral health while allowing both adaptations and instructions concerning improved oral hygiene. During the data collection for this study, evaluations were performed, and patients were forwarded to the school clinic to realise further procedures in accordance with their needs. Follow-up enables teachers to analyse results and develop new teaching methods, thus improving the teaching-learning process.

5 CONCLUSION

In conclusion, we observed a root canal treatment failure rate of 11.6% when performed in an undergraduate clinic. It is extremely important to perform case follow-ups to evaluate the quality of the treatment and the patient's periapical health and improve the teaching-learning process.

Factors determining treatment success, sex, periapical status, pain, and coronal condition, were also considered. However, given our limitations, we suggest implementing new studies using a longer time period to monitor and better standardise the assessment criteria.

REFERENCES

1. Polyzos NK, Sarris KG, Pita AI, et al. Quality of Root Canal Fillings Performed by Undergraduate Students and the Related Factors on the Treatment Outcome: A 2- to 5- Year Follow-Up. *Eur Endod J*. 2018; 3(3):179-185. doi: 10.14744/eej.2018.69077.
2. Leonardo RT, Leonardo MR. Aspectos atuais do tratamento da infecção endodôntica. *Revista da Associação Paulista de Cirurgiões Dentista*. 2012; 66(3): 174-180. Disponível em: http://revodonto.bvsalud.org/scielo.php?script=sci_arttext&pid=S0004-52762012000300002.
3. Silva BSF, Bueno MR, Yamamoto-Silva FP, et al. Differential diagnosis and clinical management of periapical radiopaque/hyperdense jaw lesions. *Braz Oral Res*. 2017;31: e.52. doi: 10.1590/1807-3107BOR-2017
4. Galler KM, Weber M, Korkmaz Y, et al. Inflammatory Response Mechanisms of the Dentine-Pulp Complex and the Periapical Tissues. *Int J Mol Sci*. 2021;22(3):1480. doi: 10.3390/ijms22031480.
5. European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *Int Endod J*. 2006;39(12):921-930. doi: 10.1111/j.1365-2591.2006.01180.x.
6. Holland R, Gomes JE Filho, Cintra LTA, Queiroz ÍOA, Estrela C. Factors affecting the periapical healing process of endodontically treated teeth. *J Appl Oral Sci*. 2017 Sep-Oct;25(5):465-476. doi: 10.1590/1678-7757-2016-0464.
7. Paz, Luiza Riomar. Avaliação da taxa de sucesso do tratamento endodôntico de dentes com periodontite apical utilizando procedimento complementares de desinfecção: estudo clínico prospectivo. São Paulo, 2018. Originalmente apresentada como dissertação de mestrado, Universidade de São Paulo, 2018. Disponível em: <https://www.teses.usp.br/teses/disponiveis/23/23156/tde-30042019-161335/publico/LuizaRiomarPazVersaoCorrigida.pdf>

8. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. *Eur J Dent.* 2016;10(1):144-147. doi: 10.4103/1305-7456.175682.
9. Werlang AL, Baldissareli F, Werlang FA, et al. Insucesso no tratamento endodôntico: uma revisão de literatura. *Revista Tecnológica.* 2016; 5(2): 31-47. ISSN 2358-9221. Disponível em: <https://uceff.edu.br/revista/index.php/revista/article/view/146>.
10. American association of endodontists. Quality assurance guidelines. Chicago: American Association of Endodontists; 1987. Disponível em: <https://www.aae.org/specialty/clinical-resources/guidelines-position-statements/>
11. Pietrzycka K, Radwanski M, Hardan L, et al. The Assessment of Quality of the Root Canal Filling and the Number of Visits Needed for Completing Primary Root Canal Treatment by Operators with Different Experience. *Bioengineering (Basel).* 2022; 9(9): 468. doi: 10.3390/bioengineering9090468.
12. Canto D, Hernandez BN; Victorino FR. Avaliação de tratamentos endodônticos realizados por alunos de graduação com proervação de um ano. *Full dent sci.* 2018; 9(36): 130-5. Doi: <https://doi.org/10.24077/2018;936-130135>.
13. NG YL, Mann VM, Rahbaran S, et al. "Outcome of primary root canal treatment: systematic review of the literature- Part 2. Influence of clinical factors". *International endodontic jornal.* 2008; 41(1): 6-31. doi: 10.1111/j.1365-2591.2007.01323.x.
14. Luckmann G, Dorneles LC, Grando CP. Etiologia dos insucessos dos tratamentos endodônticos. *Vivências.* 2013; 9(16): 133-139. Disponível em: http://www2.reitoria.uri.br/~vivencias/Numero_016/artigos/pdf/Artigo_14.pdf.
15. Pasquale M, Bavaresco CS, Pelegrine G, et al. Comparison of compressive strength between temporary restorative materials in endodontics: an in vitro study. *Revista Odontológica do Brasil Central.* 2018; 27(83): 229-233. <https://doi.org/10.36065/robrac.v27i83.1284>.
16. Benvenuti A, Scalvi M, Rodrigues Junior SA, et al. Clinical and radiographic assessment of root canal treatments performed by dental students. *Revista Sul Brasileira de Odontologia.* 2016; 13(1): 11-7. Disponível em: <https://www.redalyc.org/pdf/1530/153046961003.pdf>.
17. Mustafa NS, Kashmoola MA, Majeed KRA, et al. Assessment of the success rate of endodontically treated patients attending outpatient polyclinic. *Eur J Dent.* 2018;12(4):540-545. doi: 10.4103/ejd.ejd_377_17.
18. Azim AA, Griggs JA, Huang GT. The Tennessee study: factors affecting treatment outcome and healing time following nonsurgical root canal treatment. *Int Endod J.* 2016;49(1):6-16. doi: 10.1111/iej.12429.
19. da Rocha JG, Lena IM, Trindade JL, et al. Outcome of endodontic treatments performed by Brazilian undergraduate students: 3- to 8-year follow up. *Restor Dent Endod.* 2022;47(3):e34. doi: 10.5395/rde.2022.47.e34.
20. Peak JD, Hayes SJ, Bryant ST, et al. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). *Br Dent J.* 2001;190(3):140-144. doi: 10.1038/sj.bdj.4800907.
21. AlRahabi MK. Evaluation of complications of root canal treatment performed by undergraduate dental students. *Libyan J Med.* 2017; 12(1): e.1345582. doi: 10.1080/19932820.2017.1345582.
22. Elsayed RO, Abu-Bakr NH, Ibrahim YE. Quality of endodontic treatment performed by dental students at the University of Khartoum, Sudan. *Aust Endod J.* 2011;37(2):56-60. doi: 10.1111/j.1747-4477.2010.00273.x.
23. Donnelly A, Coffey D, Duncan HF. A re-audit of the technical quality of undergraduate endodontic treatment after the introduction of new technologies and teaching practices. *Int Endod J.* 2017;50(10):941-950. doi: 10.1111/iej.12727.
24. Ribeiro DM, Réus JC, Felipe WT, et al. Technical quality of root canal treatment performed by undergraduate students using hand instrumentation: a meta-analysis. *Int Endod J.* 2018;51(3):269-283. doi: 10.1111/iej.12853.
25. Haji-Hassani N, Bakhshi M, Shahabi S. Frequency of Iatrogenic Errors through Root Canal Treatment Procedure in 1335 Charts of Dental Patients. *J Int Oral Health.* 2015;7(1):14-17. PMID: 26225098; PMID: PMC4516079.
26. AlRahabi MK. Evaluation of complications of root canal treatment performed by undergraduate dental students. *Libyan J Med.* 2017;12(1): e.1345582. doi: 10.1080/19932820.2017.1345582.
27. Saatchi M, Mohammadi G, Vali Sichani A, Moshkforoush S. Technical Quality of Root Canal Treatment Performed by Undergraduate Clinical Students of Isfahan Dental School. *Iran Endod J.* 2018;13(1):88-93. doi: 10.22037/iej.v13i1.18517.
28. Al Shehadat S, El-Kishawi M, Almudalal A, et al. An Audit of the Technical Quality and Iatrogenic Errors of Root Canal Treatment by Undergraduate Dental Students at the University of Sharjah. *European journal of dentistry.* 2022 Feb;17(1):191-199. doi: 10.1055/s-0042-1743150.
29. Imura N, Pinheiro ET, Gomes BP, et al. The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist. *J Endod.* 2007;33(11):1278-1282. doi: 10.1016/j.joen.2007.07.018.
30. Campos FL, Guimarães LC, Almeida GC, et al. Causas de insucessos no tratamento endodôntico – análise dos casos de retratamento atendidos no projeto de extensão da Faculdade de Odontologia da UFMG. *Arquivos em Odontologia.* 2017; 53(1): 1-8. Doi: 10.7308/aodontol/2017.53.e20.
31. Bergenholtz G. Assessment of treatment failure in endodontic therapy. *Journal of oral rehabilitation.* 2016; 43(10): 753–758. doi: 10.1111/joor.12423.
32. Santos-Junior AO, De Castro Pinto L, Mateo-Castillo JF, et al. Success or failure of endodontic treatments: A retrospective study. *J Conserv Dent.* 2019;22(2):129-132. doi: 10.4103/JCD.JCD_507_18.
33. Burns LE, Kim J, Wu Y, Alzwaideh R, McGowan R, Sigurdsson A. Outcomes of primary root canal therapy: An updated systematic review of longitudinal clinical studies published between 2003 and 2020. *Int Endod J.* 2022 Jul;55(7):714-731. doi: 10.1111/iej.13736.
34. Lopes H, Siqueira Jr JF. *Endodontia: biologia e técnica.* 4. ed. Rio de Janeiro: Elsevier, 2015.
35. Ricucci D, Pascon EA, Siqueira Jr JF. A Complexidade da Anatomia Apical. In: Versiani M, Basrani, B, Sousa-Neto, M. *A anatomia do canal radicular na dentição permanente.* Springer, Cham, 2018: 241-254. Doi: 10.1007/978-3-319-73444-6_8.
36. Pedro FM, Marques A, Pereira TM, Bandeca MC, Lima S, Kuga MC, Tonetto MR, Semenoff-Segundo A, Borges AH. Status of Endodontic Treatment and the Correlations to the Quality of Root Canal Filling and Coronal Restoration. *J Contemp Dent Pract.* 2016 Oct 1;17(10):830-836. doi: 10.5005/jp-journals-10024-1939.
37. Maslamani M, Khalaf M, Mitra AK. Association of Quality of Coronal Filling with the Outcome of Endodontic Treatment: A Follow-up Study. *Dent J (Basel).* 2017 Jan 11;5(1): 0-5. doi: 10.3390/dj5010005.

38. Balto H, Al Khalifah Sh, Al Mugairin S, et al. Technical quality of root fillings performed by undergraduate students in Saudi Arabia. *Int Endod J.* 2010;43(4):292-300. doi: 10.1111/j.1365-2591.2009.01679.x.
39. Polyzos NK, Sarris KG, Pita AI, Mikrogeorgis GV, Lyroudia KM. Factors Affecting the Outcome of Non-Surgical Endodontic Treatments Performed by Undergraduate Students in a Greek Dental School. *Eur Endod J.* 2018 Jul 19;3(2):93-100. doi: 10.14744/eej.2018.18291.
40. Malagnino VA, Pappalardo A, Plotino G, Carlesi T. The fate of over-filling in root canal treatments with long-term follow-up: a case series. *Restor Dent Endod.* 2021 Apr 29;46(2): e.27. doi: 10.5395/rde.2021.46.e27.
41. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: the Toronto Study. Phase 1: initial treatment. *J Endod.* 2003 Dec;29(12): 787-93. doi: 10.1097/00004770-200312000-00001.
42. Gillen BM, Looney SW, Gu LS, Loushine BA, Weller RN, Loushine RJ, Pashley DH, Tay FR. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. *J Endod.* 2011 Jul;37(7):895-902. doi: 10.1016/j.joen.2011.04.002.
43. Gonçalves EMB, Silva SJA, Araújo RPC. Avaliação da eficácia obturadora do Coltosol® e do IRM® no selamento provisório de dentes sob intervenção endodôntica. *Revista De Ciências Médicas E Biológicas,* 2012;11(2):154–158. <https://doi.org/10.9771/cmbio.v11i2.6676>.
44. Bendocchi Alves GB, Sampaio MSP, Araújo RPC. Avaliação in vitro da infiltração de dois materiais restauradores provisórios utilizados em endodontia. *Revista De Ciências Médicas E Biológicas,* 2014;12(4), 427–432. Disponível em: https://repositorio.ufba.br/bitstream/ri/23108/1/4_v.12_esp..pdf
45. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lemberg K. Cone beam computed tomography in Endodontics - a review. *Int Endod J.* 2015; 48(1):3-15. doi: 10.1111/iej.12270.
46. Zoti M, Hartmann M. Avaliação de tratamentos endodônticos realizados por alunos de graduação da Escola de Odontologia da IMED. *Journal Oral Investigation.* 2016; 5(1): 4- 12.
DOI: 10.18256/2238-510X/j.oralinvestigations.v5n1p4-12.
47. Silva PAO, Lima SMF, Freire MS, Murad AM, Franco OL, Rezende TMB. Proteomic analysis of human dental pulp in different clinical diagnosis. *Clin Oral Investig.* 2021 May;25(5):3285-3295. doi: 10.1007/s00784-020-03660-3.
48. Travassos RM, Zimmerie CM, Falcão MM, et al. Evaluation of endodontic treatments performed by hiring student. *Research, Society and Development.* 2022; 11(3): e.16711326336. Doi: <https://doi.org/10.33448/rsd-v11i3.26336>.

Submetido em 29/01/2025

Aceito em 27/03/2025