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Research Article

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Outcome of endodontic treatments performed by Brazilian undergraduate students: 3- to 8-year follow up

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No potential conflict of interest relevant to this article was reported.

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Conceptualization: Lena IM, Morgental RD, Bier CAS. Data curation: da Rocha JG, Lena IM. Formal analysis: Lena IM, Liedke GS. Methodology: Lena IM, da Rocha JG, Trindade JL, Liedke GS, Morgental RD, Bier CAS. Project administration: Bier CAS. Writing - original draft: da Rocha JG. Writing - review & editing: da Rocha JG, Lena IM, Trindade JL, Liedke GS, Morgental RD.

ABSTRACT

Objectives: This study aimed to evaluate the success rate of endodontic treatments performed by undergraduate students and the factors associated with the outcome.
Materials and Methods: A follow-up of 3 to 8 years after root canal filling was carried out in 91 patients. At the follow-up visits, medical and dental history questionnaires were applied along with clinical and radiographic examinations. Data collected in the clinical exam included: the presence of pain, swelling, sinus tract, mobility, tenderness to palpation and percussion, periodontal probing profile, and type/quality of coronal restoration. Postoperative and follow-up radiographs were digitalized and analyzed by 2 trained and calibrated examiners to assess periapical healing. The treatment outcome was based on strict clinical and radiographic criteria and classified as success (absence of any clinical and radiographic sign of apical periodontitis) or failure (other combination). Logistic regression was used to investigate the impact of clinical and radiographic variables on endodontic treatment outcomes at a 5% significance level.
Results: The success rate of endodontic treatments was 60.7%. The only risk factor significantly associated with failure was the presence of a periapical lesion on the postoperative radiograph (odds ratio, 3.35; 95% confidence interval, 1.17–9.54).
Conclusions: The success rate of endodontic treatments performed by undergraduate students was low and was jeopardized by the presence of a periapical lesion on the postoperative radiograph.

Keywords: Endodontics; Educational measurement; Treatment outcome

INTRODUCTION

Endodontic treatment combines mechanical instrumentation, chemical disinfection, and sealing of the root canal system (RCS) with biocompatible materials [1,2]. In teeth with pulp necrosis and apical periodontitis (AP), endodontic treatment aims to restore the health of periapical tissues, allowing bone neoformation in that region [1,3].

AP is the main disease that affects the root apex [3]. It is characterized by an inflammatory process caused by the progression of pulp necrosis towards periapical tissues due to the

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invasion of microorganisms in the RCS [4]. In the radiographic examination, AP may present no alteration in the bone pattern, a widened periodontal ligament space, or bone resorption in more advanced cases [4]. Correct diagnosis and careful treatment are crucial since it is a very prevalent disease worldwide, and the presence of larger lesions causes a reduction in the success rates of endodontic treatment [5].

In addition to AP, other systemic and clinical variables influence the outcome of an endodontically treated tooth. For example, the patient's biological characteristics, systemic deficiencies, and daily habits, such as diabetes and smoking, can affect the ability of tissues to repair and impair the outcome of endodontic treatment [6-9]. The presence of satisfactory coronal restorations also has an important role in root canal treatment, improving periapical healing [1,10]. Likewise, pain symptoms after the end of treatment can impair the periapical healing process [10].

Thus, clinical and radiographic follow-up of the patient for at least 1 year after the endodontic intervention is essential [3]. In cases of persistent AP, or if the lesion has only decreased in size, it is advised to follow up with the patient for a minimum of 4 years [3]. The absence of clinical signs and symptoms, bone healing, and the normality of lamina dura and periodontal ligament space are considered indicatives of periapical tissue healing and endodontic treatment success [11-13]. However, the maintenance of AP 4 years after the root canal treatment is usually a sign of post-treatment disease and, when associated with clinical symptoms, the necessity of a retreatment approach should be considered [3].

The operator's clinical experience also affects the success rate of endodontic treatments. According to the literature, root canal treatments performed by professionals with specialty training present a higher success rate than treatments performed by undergraduate students [14,15]. Dental schools should form a general practitioner capable of working with diverse clinical tasks and in different levels of health care [16]. Therefore, evaluating the factors influencing the outcome of endodontic treatments performed by undergraduate students is essential to improve the training required to perform appropriate treatments. The present study aimed to evaluate the success rate of endodontic treatments performed by Federal University of Santa Maria (RS, Brazil) undergraduate students and the associated clinical and radiographic factors.

MATERIALS AND METHODS

Ethical aspects

The sample comprised 91 patients (91 teeth) with complete dental records, including clinical and radiographic data, who underwent root canal treatment between 2011 and 2015. When these patients returned for recall, they were invited to participate in the study and signed an informed consent form. The study was approved by the Research Ethics Committee of the Federal University of Santa Maria (RS, Brazil) (approval No. 54823016.0.0000.5346).

Root canal preparation protocol

All endodontic treatments were performed by undergraduate students, in multiple visits, by the crown-down technique. Gates-Glidden or Largo drills (Dentsply Sirona, Ballaigues, Switzerland) were used for cervical preflaring and stainless-steel hand instruments to prepare the RCS. Working length (WL) determination was performed by the radiographic method.

The WL was established 1- and 2-mm short of the radiographic apex in necrotic and vital teeth, respectively. During the entire endodontic procedure, the root canals were irrigated with 1% and 2.5% sodium hypochlorite (NaOCl) solution (Asfer Indústria Química Ltda, São Caetano do Sul, SP, Brazil) in vital and necrotic teeth, respectively. For teeth with AP, foraminal patency was maintained using sizes 08 to 15 stainless-steel hand K-files. Also, an intracanal medication based on calcium hydroxide (Calen or Calen-PMCC; SS White Dental, Rio de Janeiro, RJ, Brazil) was applied in all the cases for at least 14 days. Root filling was carried out by cold lateral condensation of gutta-percha (Dentsply Sirona) with zinc oxide and eugenol-based endodontic sealer (Endofill; Dentsply Sirona). A postoperative radiograph was taken after root filling and was used as the reference during the follow-up recalls. After the obturation session, the patients were referred to the operative dentistry clinics of the Federal University of Santa Maria, and the mean time for the final restoration was 30 days.

Clinical and radiographic examinations

At the follow-up visit, patients answered a questionnaire about medical history, general dental history, and specific dental history of the tooth submitted to endodontic treatment. In addition to the questionnaire, clinical and radiographic examinations were performed.

The clinical exam evaluated the presence of pain, swelling, sinus tract, mobility, tenderness to palpation and percussion, periodontal probing profile around the tooth, and type/quality of coronal restoration. The restoration quality was classified according to Dugas *et al.* [17], with minimal adaptations: the presence of open margins, overhangs/coronal margins discrepancy, fracture, or secondary caries were indicatives of inadequate coronal sealing. In addition, the type of restoration was categorized as permanent or temporary, being temporary restorations made with glass ionomer cements or zinc oxide and eugenol-based materials.

Periapical radiographs were performed using the paralleling technique with the aid of dental film holders (Indusbello, Londrina, PR, Brazil); in cases where it was impossible to use the positioning device, the examination was performed using the bisecting angle technique. In addition, radiographic film #2 (Carestream Health, Rochester, NY, USA), intraoral radiographic equipment (Timex 70E; Gnatus, São Paulo, SP, Brazil; 70 kVp, 7.0 mA, and 0.50 seconds), and time-temperature processing method, as recommended by the manufacturer of the radiographic film, were used.

X-ray digitalization

Postoperative and follow-up radiographs were digitalized for evaluation. The films were positioned on a lightbox, and a standardized device was used to stabilize and parallelize the digital camera (Sony Cyber-Shot DSC-W690; Sony, Tokyo, Japan) and the radiograph, as well as to standardize the distance. A black mask with a central hole of the size of the film was used, avoiding light dissipation. The photographs were always taken with the same adjustment and configuration. The images were saved in JPEG and transferred to a computer.

Image analysis

The digitized radiographs were organized in pairs (postoperative and follow-up radiographs) and presented in slides using PowerPoint software (Microsoft Corp., Redmont, WA, USA). The zoom, contrast, and brightness tools were available for the examiner's use.

Two trained and calibrated examiners (I.M.L. and J.G.R.) evaluated all the images on a computer screen (15.6") in a dark environment. Training consisted of an expository lecture

to standardize periapical status and periapical repair concepts. Calibration was performed by evaluating, in duplicate, 16 pairs of radiographs not included in this study sample. Inter- and intra-examiner agreement was calculated using Cohen's kappa coefficient. The intra-examiner kappa ranged from 0.76–0.89 (examiner 1) to 0.73–0.80 (examiner 2), and the inter-examiner kappa was 0.69.

The periapical status of the postoperative and follow-up radiographs was classified according to the 3 categories proposed by Ng *et al.* [10]: intact periodontal ligament, widened periodontal ligament (at least twice the normal width), or periapical lesion.

The periapical repair was also classified using the index proposed by Ng *et al.* [10], comparing the periapical status of the postoperative radiograph with the follow-up image. Four categories were used: complete repair, when the periodontal ligament space on the follow-up radiograph had an aspect of normality; incomplete repair, when there was a reduction in the size of the radiographic lesion, but the space of the periodontal ligament remained altered; uncertain repair, when it was radiographically impossible to make a final decision on the status of periapical healing; or treatment failure, when the pre-existing AP had increased or remained unchanged on the follow-up radiograph, or if the previously normal periodontal ligament space had become widened or an AP had developed.

The cases that presented divergence of assessment were referred to a third examiner, a specialist in endodontics (J.L.T.), for the final decision.

Statistical analysis

The data were expressed in frequencies. The treatment outcome was defined based on the association of clinical and radiographic findings. According to Lee *et al.* [8], it was successful when the patient had no clinical signs and symptoms and the radiographic analysis showed complete repair; all the other combinations, with changes in clinical and/or radiographic outcomes, were classified as a failure.

Logistic regression was used to investigate the impact of demographic, clinical, and radiographic variables on the outcome (success/failure of endodontic treatment). For the logistic regression, variables were dichotomized into age (≤ 45 years or > 45 years), sex (female or male), restoration (Adequate: Satisfactory restoration margin or Inadequate: Open margins, overhangs/coronal margins discrepancy, fracture or secondary caries), Systemic impairment (Present: Yes to diabetes, hypertension, smoking or continuous medication or Absent: No to all the conditions), root canal system (non-molars or molars), postoperative periapex (Normal: Intact periodontal ligament or Altered: Widened and periapical lesion), and postoperative pain (absent or present). Variables with statistical significance in the binary model ($p < 0.2$) were included in the multivariate model. In the multivariate model, the level of statistical significance was set at $p < 0.05$.

The data were analyzed using Microsoft Office Excel (Microsoft Corp., Redmond, WA, USA) and SPSS (SPSS Inc., Chicago, IL, USA) software.

RESULTS

At the follow-up visit, of the 91 analyzed patients, 7 teeth (7.7%) were missing and were excluded from the data analysis. The reasons for tooth loss were unknown since patients seek treatment outside the University. When clinical and radiographic outcomes were assessed, the success rate of endodontic treatments performed by undergraduate students was 60.7% (51 teeth). The sample size was based on a convenience sample and was not calculated for this study. Therefore, a post hoc achieved power was calculated, given that the logistic regression analysis R^2 is 0.171, that there are 7 predictors, a sample size of $n = 91$, and an alpha error probability of 0.05 resulting in a sample power of 95%.

Table 1 shows the demographic, systemic, clinical, and radiographic characteristics of the final sample ($n = 84$) and the proportion of failure in each category.

Table 2 presents the binary and the multivariate logistic regressions. From the multivariate model, the only risk factor significantly associated with endodontic treatment failure was the presence of a periapical lesion on the postoperative radiograph (odds ratio [OR], 3.35; 95% confidence interval [CI], 1.17–9.54). Nonetheless, in the binary model, molars had greater chances for endodontic treatment failure (OR, 2.71; 95% CI, 1.05–6.95).

Table 3 shows the association between periapical status at the end of endodontic treatment and at the follow-up visits. Of the teeth with normal periodontal ligament on the postoperative radiograph, 31 (88.6%) remained normal during the follow-up, but 4 (11.5%) developed signs of AP. Among the elements with AP on the postoperative radiography, 21 (56.8%) showed healing in the follow-up, while 16 (43.2%) remained with periapical changes.

Table 1. Characteristics of the endodontic treated elements and of those with failure

Variables	Endodontic treated patients ($n = 84$)	Endodontic treated patients with failure ($n = 33$)
Demographic evaluation		
Age		
≤ 45 years	41 (48.8)	16 (39.0)
> 45 years	43 (51.2)	17 (39.5)
Sex		
Female	57 (67.9)	22 (38.6)
Male	27 (32.1)	11 (40.7)
Systemic		
Hypertension		
Yes	28 (33.3)	10 (35.7)
No	56 (66.7)	23 (41.1)
Smoking		
Yes	4 (4.8)	0 (0.0)
No	58 (69.0)	25 (43.1)
Ex-smoker	22 (26.2)	8 (36.4)
Diabetes		
Yes	8 (9.5)	4 (50.0)
No	76 (90.5)	29 (38.2)
Continuous medication		
Yes	33 (39.3)	12 (36.4)
No	51 (60.7)	21 (41.2)

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Table 1. (Continued) Characteristics of the endodontic treated elements and of those with failure

Variables	Endodontic treated patients (*n* = 84)	Endodontic treated patients with failure (*n* = 33)
Clinical evaluation		
Tooth type		
Anterior	33 (33.3)	11 (33.3)
Premolar	19 (22.6)	6 (31.6)
Molar	32 (8.1)	16 (50.0)
Dental Arch		
Maxillary	50 (59.5)	19 (38.0)
Mandibular	34 (40.5)	14 (41.2)
Percussion		
Yes	11 (13.1)	7 (63.6)
No	72 (85.7)	25 (34.7)
WCD	1 (1.2)	1 (100.0)
Palpation		
Yes	3 (3.6)	3 (100.0)
No	80 (95.2)	29 (36.3)
WCD	1 (1.2)	1 (100.0)
Pain		
Yes	9 (10.7)	9 (100.0)
No	74 (88.1)	23 (31.1)
WCD	1 (1.2)	1 (100.0)
Crown structure		
Restored	65 (77.4)	25 (38.5)
Fractured	13 (15.5)	7 (53.8)
Carious	3 (3.6)	0 (0.0)
Fixed dental prostheses	1 (1.2)	0 (0.0)
WCD	2 (2.4)	1 (50.0)
Restoration condition		
Adequate	36 (42.9)	16 (44.4)
Inadequate	28 (33.3)	9 (32.1)
Fracture	1 (1.2)	1 (100.0)
Secondary caries	4 (4.8)	1 (25.0)
Inadequate and secondary caries	2 (2.4)	1 (50.0)
WCD	13 (15.5)	5 (38.5)
Radiographic evaluation		
Post-operative		
Normal	35 (41.7)	8 (22.9)
Widened PL	12 (14.3)	6 (50.0)
AP	37 (44.0)	19 (51.4)
Follow-up		
Normal	59 (70.2)	8 (13.6)
Widened PL	10 (11.9)	10 (100.0)
AP	15 (17.9)	15 (100.0)

Values are presented as number of elements (%).
WCD, without clinical data; PL, periodontal ligament; AP, apical periodontitis.

Table 4 shows the results of clinical examinations and their association with the radiographic findings. Even in those teeth that presented complete repair on the radiograph, patients reported a rate of 13.6% tenderness on percussion and 3.4% on palpation. On the other hand, the 9 cases classified radiographically as treatment failure showed no signs or symptoms. When the quality of the coronal restoration and longitudinal evaluation of the endodontic treatment were correlated, the results revealed that most (39.0%) of the treated teeth with complete repair showed the integrity of restoration margins. However, when endodontic treatment failed, most restorations also had intact margins (66.7%).

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Table 2. Binary and multivariate logistic regression analyzes between endodontic success and other variables

Variable	*p*	OR $_{binary}$ (95% CI)	*p*	OR $_{multivariate}$ (95% CI)
Age (< 50 years)				
> 50 years	0.491	1.41 (0.53–3.78)		
Sex (female)				
Male	0.851	1.09 (0.43–2.78)		
Restoration (adequate)				
Inadequate	0.382	0.65 (0.25–1.70)		
Systemic impairment (absent)				
SI	0.170	0.54 (0.22–1.30)	0.372	0.63 (0.23–1.73)
RCS (Single-rooted or premolar)				
Molar	0.038	2.71 (1.05–6.95)	0.182	2.05 (0.71–5.88)
Post-operative periapex (normal)				
Widened or AP lesion	0.011	3.52 (1.34–9.25)	0.024	3.35 (1.17–9.54)
Post-operative pain (absent)				
Present	0.146	3.07 (0.68–13.91)	0.175	3.21 (0.60–17.32)

p, OR, and 95% CI for independent variables (group in parentheses is reference group for logistic regression analysis); in bold, variables with statistical significance in the binary model ($p < 0.2$) and thus included in the multivariate model.
OR, odds ratio; CI, confidence interval; SI, positive for diabetes, hypertension, use of medication, or smoking; RCS, root canal system; AP, apical periodontitis.

Table 3. Association of the periapical status of the final treatment with the follow-up radiographs ($n = 84$)

Post-operative	Follow-up			
	Normal	Widened PL	AP	Total
Normal	31 (88.6)	1 (2.9)	3 (8.6)	35 (100.0)
Widened PL	7 (58.3)	4 (33.3)	1 (8.3)	12 (100.0)
AP	21 (56.8)	5 (13.5)	11 (29.7)	37 (100.0)
Total	59 (70.2)	10 (11.9)	15 (17.9)	84 (100.0)

Values are presented as number of elements (%).
PL, periodontal ligament; AP, apical periodontitis.

Table 4. Association of clinical data with radiographic longitudinal assessment

Clinical outcome	Radiographic outcome			
	Complete repair	Incomplete repair	Repair uncertain	Failure
Percussion				
Absent	51 (86.4)	6 (60.0)	6 (100.0)	9 (100.0)
Present	8 (13.6)	3 (30.0)	0 (0.0)	0 (0.0)
WCD	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)
Palpation				
Absent	57 (96.6)	8 (80.0)	6 (100.0)	9 (100.0)
Present	2 (3.4)	1 (10.0)	0 (0.0)	0 (0.0)
WCD	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)
Pain				
Absent	51 (86.4)	8 (80.0)	6 (100.0)	9 (100.0)
Provoked	6 (10.2)	2 (20.0)	0 (0.0)	0 (0.0)
Spontaneous	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)
WCD	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)
Crown structure				
Restored	46 (78.0)	8 (80.0)	4 (66.7)	7 (77.8)
Fractured	8 (13.6)	2 (20.0)	1 (16.7)	2 (22.2)
Carious	3 (5.1)	0 (0.0)	0 (0.0)	0 (0.0)
Fixed dental prostheses	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)
WCD	1 (1.7)	0 (0.0)	1 (16.7)	0 (0.0)
Restoration condition				
Adequate	23 (39.0)	5 (50.0)	2 (33.3)	6 (66.7)
Inadequate	22 (37.3)	2 (20.0)	2 (33.3)	2 (22.2)
Fracture	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)
Secondary caries	3 (5.1)	1 (10.0)	0 (0.0)	0 (0.0)
Inadequate and secondary caries	1 (1.7)	0 (0.0)	0 (0.0)	1 (11.1)
WCD	9 (15.3)	2 (20.0)	2 (33.3)	0 (0.0)

Values are presented as number of elements (%).
WCD, without clinical data.

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DISCUSSION

The outcome of endodontic treatment is multifactorial: it depends on systemic health, clinical and radiographic variables of the patient and the tooth, as well as the operator's clinical experience [1,2,10,14,15]. The present study evaluated endodontic treatments performed by Brazilian undergraduate students, finding a low success rate of 60.7%. Moreover, the results from a multivariate logistic regression model identified that the presence of a periapical lesion on the postoperative radiograph was a significant factor associated with increased chances of failure.

The complete cleaning and disinfection of root canals are challenging procedures in teeth with pre-established endodontic infection and AP since the microorganisms are observed throughout the RCS and in the apical external root surface [18,19]. According to the literature, teeth with pre-operative AP have more treatment failures [5]. A recent systematic review and meta-analyses suggest that teeth without previous AP have 2.75 more chances of success when compared to teeth without previous AP [2]. Similarly, dental elements without pulp vitality and with previous AP are 2.35 times less likely to be successful than vital teeth [1]. Some resources can be used to achieve more efficient cleaning and disinfection strategies to increase the success, such as instrumentation of the RCS up to the appropriate WL, use of ethylenediaminetetraacetic acid solution to remove debris generated during chemomechanical preparation, and application of a calcium hydroxide-based dressing for 14 days [1,10]. However, our findings show that 29.7% of the teeth with AP at the end of endodontic treatment remained affected during the follow-up period. More importantly, this study showed that teeth with persistent AP in the postoperative radiograph are 3.35 times more likely to fail.

Sex and age presented no association with treatment failure in the present study. Systemic impairment, postoperative pain, and RCS complexity, although not significantly associated with the outcome in the multivariate model, were potential risk factors according to the binary logistic regression analyzes. The influence of systemic diseases on treatment outcomes is still controversial in the literature, but systemic conditions can cause major changes in the healing process and are associated with impaired innate immune responses [20,21]. Some authors found an association between diabetic patients and reduced success rates of endodontic treatment; nevertheless, others have not found this association [21-25]. Hypertension also contributed to the decreased retention of endodontically treated teeth, but a cross-sectional study in hypertensive and controlled patients concluded that there was no association with endodontic variables [23,26]. Concerning smoking habits, there is still no consensus and sufficient scientific evidence addressing the relationship between smoking, AP, and the outcome of endodontic treatment [9]. However, it is known that smoking has direct consequences on the marginal periodontium, and it seems likely that this effect is systemic and impairs the healing response [9].

Regarding the type of tooth, molars had greater chances for endodontic treatment failure in the binary model. Similar results have been reported by other authors [8,14,17]. A possible explanation for this finding is related to the greater complexity of the RCS, which often presents narrow canals and severe root curvatures [27]. Furthermore, the position of the elements in the dental arch can affect the manual dexterity of students working with indirect vision and endodontic instruments, which can compromise the quality of endodontic treatment and favor the occurrence of operative accidents [27,28].

The condition of the coronal restoration did not show an association with the outcome of endodontic treatment in this study. However, according to the systematic review and meta-analysis by Gillen *et al.* [29], the quality of endodontic treatment and coronal restoration are equally important for endodontic success. In our study, most teeth (39.0%) with complete repair had the integrity of the restoration margins, and the majority (66.7%) of the failed treatments had the same restoration condition. The failure of these treatments with adequate coronal sealing would be explained by the inefficiency in cleaning, shaping, and filling the root canals.

Postoperative pain is related to mechanical and chemical aggressions resulting from endodontic procedures, and its leading cause is the extrusion of contaminated material during root canal instrumentation [30]. According to Ng *et al.* [10], extrusion can cause a foreign body reaction or transient periapical infection that could result in treatment failure. According to the same author, the presence of postoperative pain episodes significantly reduced the success rate of endodontic treatments, even though Sjögren *et al.* [31] did not find this association [10]. An interesting aspect observed in our study was that even in teeth with complete radiographic repair, patients reported tenderness on percussion and palpation. On the other hand, all teeth classified as a failure based only on the radiograph analysis were asymptomatic. Cone-beam computed tomography (CBCT) could be used as a resource for investigating these cases, as it is more sensitive in detecting AP and could be a complementary tool in clinical decision making [32]. Also, asymptomatic cases presenting partial healings on the radiograph could indicate the presence of scar tissue in the periapical area without any sign of inflammation [32].

It is essential to point out that this study adopted strict criteria for the classification of the endodontic treatment outcome: only the association between the complete absence of periapical radiolucency and the absence of clinical signs or symptoms was considered a successful treatment. If loose criteria were used, cases with incomplete healing would be considered successful, increasing the study's success rate [10]. However, some factors have to be considered that might justify the low success rate (60.7%), besides the strict criteria already enlightened. Endodontic treatment is a complex procedure that needs a solid knowledge of anatomy and continuous training to improve manual dexterity. A study found a success rate of 94% in treatments performed by specialists [14]. In this study, all treatments were carried out by undergraduate students attending the 3rd year of dental school, who still are on the learning curve, improving and acquiring technical competences [14,28]. Other authors evaluating endodontic treatments performed by undergraduate students found a success rate of 77.4% in the 1-year follow-up; although, in the 3-year follow-up, this rate decreased to 75.5% [15]. Therefore, the more extended follow-up period (3–8 years) could also explain the lower success rate of our study. Moreover, the lack of standardization during the execution of endodontic treatments was the main limitation of this study since the students had different levels of skill and clinical training, as well as assistance from different teachers and monitors with distinct teaching methodologies.

On the other hand, the strength of the present study is the use of clinical data. Most studies assessed the success rate of endodontic treatments only by radiographic examination, electronic dental databases, or dental records, without analyzing clinical signs and symptoms in a clinical follow-up exam [23,33-35]. Although radiographic evaluation is indispensable for determining the success or failure of root canal treatments, it should not be the only criterion considered. Thus, the association between clinical and radiographic data is essential for

the clinical decision-making process regarding endodontic retreatment [3]. The analysis of clinical data is also important to identify possible shortcomings, such as painful symptoms and lack of satisfactory coronal sealing [10]. In addition, all patients in this study were evaluated for a minimum period of 3 years after the endodontic treatment ended, as proposed by the systematic review of Ng *et al.* [36] and a maximum of 8 years (2018–2019), allowing for an adequate assessment of the periapical repair.

Finally, studies evaluating samples from a single institution are important for evaluating the local teaching-learning process. From these data, teachers will be able to analyze the results and promote changes in the teaching approach. According to the European Society of Endodontics, endodontic procedures must be based on the context of comprehensive patient care [37]. Thus, the follow-up appointments are fundamental for verifying the outcome of endodontic treatment and are also crucial for monitoring the maintenance of oral health and advising on changes in habits, if necessary, so the patient can maintain the functional dentition throughout life [2,3,38].

CONCLUSIONS

In conclusion, the success rate of endodontic treatments performed by undergraduate students was 60.7%. Failures were significantly associated with the presence of a periapical lesion on the postoperative radiograph. Additionally, longitudinal follow-up of patients with clinical and radiographic exams is essential after endodontic treatment to identify therapeutic failures and propose additional treatments whenever necessary.

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