

Root Canal Treatment Outcome and Restorative Condition of Teeth Treated by Undergraduates—A Clinical and Radiographic Evaluation

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Abstract

Background: The aim was to evaluate the nonsurgical Root Canal Treatment (nRCT) outcome, the restorative condition and the relationship between the coronal restoration quality and the outcome of teeth endodontically treated by undergraduates at the University of Caxias do Sul School of Dentistry (UCS-SD), Brazil, between 2019 and 2021. **Materials and Methods:** Data from the endodontically treated cases were retrieved, and the patients were recalled for a follow-up appointment at the university. The endodontic diagnosis, radiographs, and the presence of definitive restorations were analyzed in the clinical records. During the follow-up appointment, endodontically treated teeth were classified as present or absent. The nRCT was classified as successful (complete or incomplete healing) or failure (uncertain or unsatisfactory healing). Coronal restoration was classified as absent or present. When it was present, it was classified as permanent or temporary, and its quality as adequate or inadequate restoration. The results were presented as percentages. **Results:** A total of 257 teeth were endodontically treated. The most prevalent diagnosis was Chronic Apical Periodontitis (33.33%) and the most commonly treated teeth were premolars (46.15%). A total of 52 (21%) treated teeth were clinically and radiographically reexamined. The success rate for the nRCT was 98.08%. About 61.54% of this sample had a definitive composite resin restoration. **Conclusion:** The nRCT success rate was high. Special attention should be given to the presence and quality of the definitive restoration. **Clinical Implications:** There was no statistically significant impact between the coronal restoration and the nRCT success ($P > 0.05$).

Keywords

Periapical Periodontitis, Permanent Dental Restoration, Permanent Dental Filling Root Canal Obturation, Treatment Outcome

1. Introduction

Nonsurgical Root Canal Treatment (nRCT) follow-up is a vital part of the treatment plan. Despite limitations, radiographic examination is one of the most widely used methods for this purpose [1] [2].

The optimal scenario for successful endodontic therapy should successfully combine healing/prevention of disease (apical periodontitis) and functional retention of the tooth [2]. The success of a nRCT is conditioned on the following clinical evidence: absence of pain, thoroughly filled root canal space with no radiographic evidence of periapical inflammation, and a well-restored and functional tooth. Clinical and radiographic features conventionally associated with failure of endodontic therapy include pain, periapical radiolucent lesion, fistula, and edema [3].

The quality of the coronal restoration seems to have a greater impact on periapical status and success of the nRCT than the quality of the root filling [4]. This is because no root canal obturation technique provides a definitive coronary, lateral and apical sealing. Additionally, coronal infiltration and fracture can occur in any inadequately restored tooth [5]. Therefore, the restoration of endodontically treated teeth is an essential component of the treatment [6].

Since the study by Ray and Trope [4], it has become necessary to conduct similar clinical studies to confirm the validity of the results. In 2021, an 18-year follow-up study of endodontically treated teeth, found that clinically detectable not precise coronal margins predict the presence of any clinical complication with a hazard ratio almost seven times higher than endodontically treated teeth with a proper margin [7].

The findings emphasize the importance of ensuring ongoing follow-up for the nRCT and the definitive restoration of the dental element.

The objective of this study was to evaluate the proficiency of undergraduate students in performing endodontic procedures within their clinical practice, while also establishing the success rate of nRCT. This evaluation involved both radiographic and clinical assessments of the effectiveness of nRCT procedures carried out in the undergraduate clinic of the School of Dentistry at Caxias do Sul University between 2019 and 2021. It should be noted that this clinic extends its services to low-income patients, providing them with cost-free root canal treatments and subsequent coronal restorations. Furthermore, the potential influence of the quality of coronal restorations on the outcomes of endodontic treatments was also investigated in this study.

2. Materials and Methods

2.1. Sample

In this retrospective cohort study, a total of 53 teeth (from 37 adult patients) were included as a sample, out of a larger population of 257 teeth from 207 patients who underwent nRCT by undergraduates at the University of Caxias do Sul in Brazil, between 2019 and 2021. Written informed consent was obtained from all patients. This study was previously approved by the Ethics and Research Committee from University of Caxias do Sul, Caxias do Sul, RS, Brazil (CAAE 53033321.4.0000.5341).

The inclusion criteria were:

- 1) Nonsurgical Root Canal Treatment performed by undergraduate students under the same treatment protocol,
- 2) Endodontic cases of single- and multi-rooted permanent teeth treated with a non-surgical endodontic approach,
- 3) Fully detailed case history sheets accompanied by a full set of periapical radiographs of good diagnostic value (initial, working length, master cone, and post-obturation radiographs).

The exclusion criteria were:

- 4) Patients who failed to attend in the follow up appointment.

2.2. Root Canal Treatment Protocol

All of the non-surgical root canal treatments were performed by undergraduate students between 2019 and 2021 following the same treatment protocol under the supervision of a faculty member. Preoperative radiographs of the tooth in need of root canal treatment were obtained. All root canal procedures were performed under local anesthesia and rubber dam isolation. Radiographs were taken for endodontic diagnostic, working length measure, final root canal preparation, obturation before cutting the gutta-percha cones, and final obturation. The root canal preparation technique used was the crown-apex, performed manually. The canals were irrigated with 2.5% sodium hypochlorite (Asfer, São Caetano do Sul/SP, Brazil), and the smear layer was removed with 17% EDTA (K-dent/Quimidrol, Joinville/SC, Brazil). In vital pulp and necrosis cases, the chemical-mechanical preparation was carried out at a working length established 1- and 2-mm short of the radiographic vertex. The teeth diagnosed with Apical Periodontitis (AP), after complete chemical-mechanical preparation, had calcium hydroxide medication applied for a minimum of 14 days. Zinc oxide and eugenol (Endofill, Petrópolis/RJ, Brasil) and lateral condensation were the filling cement and obturation technique of choice, respectively. After completion of the nRCT, the subjects were assigned to their respective clinical classes for definitive restoration.

2.3. Clinical and Radiographic Evaluation

After collection of all the patients' information, they were recalled and invited to

participate in the study. Those who accepted returned to the University for follow-up appointment. Two examiners (G. T. B. B and D. M. R.) performed clinical and radiographic evaluation of the 53 endodontically treated teeth in 37 patients.

Radiographic examination was performed with Cone Indicators (Indusbelo, Londrina/Brazil), using the periapical radiographic technique with parallelism method.

Clinical/radiographic evaluation analyzed:

- nRCT outcome evaluation;
- Identify the presence, type and quality of coronal restoration.

An intraoral examination was performed with a #5 dental mirror and dental probe to identify the type and quality of coronal restoration.

Signs and symptoms of endodontic origin were assessed by palpation and percussion.

The nRCT outcomes were classified according to Polyzo *et al.* [8] criteria as follows:

1) Success:

Healed: absence of radiographic signs of apical periodontitis (PAI score < 3) and no clinical signs other than tenderness to percussion and no symptoms;

Incomplete healing: (for cases with <3 years of follow-up period), reduction of the size of the periapical lesion but not completely resolved (reduction of PAI score but still > 2) with no clinical signs other than tenderness to percussion and no symptoms.

2) Failure:

a) Uncertain healing: no radiographic sign of reduction of the size of the periapical lesion (follow-up PAI score remaining at pathological value similar to preoperative) with no clinical signs and symptoms.

b) Unsatisfactory healing: development of a new periapical lesion or increase in size of an existing periapical lesion (further increase of PAI score) or presence of clinical signs and symptoms. healthy/success (PAI 1 and PAI 2, no symptoms or clinical signs) or diseased/failure (PAI 3, 4, and 5, presence of symptoms and/or clinical signs).

The coronal restoration material was classified according to the criteria:

a) Temporary: tooth sealed with glass-ionomer cement or presence post and core crown cemented temporarily.

b) Permanent: tooth restored with composite resin, amalgam, or with a post (metallic or fiberglass) and core crown cemented definitively.

The quality of restorations was assessed according to modified criteria from Craveiro *et al* [9]. For this, the radiographic appearance of the restoration was considered. Thus, coronal restorations were clinically and radiographically classified as follows:

a) Adequate coronal restoration: a radiographic and clinical intact restoration, with good marginal fit, no fractures, cracks, or recurrent caries.

b) Inadequate coronal restoration: any restoration showing radiographic and clinical detectable signs of overhangs, fractures, cracks, poor marginal fit, or re-

current caries, or temporary crown over a post.

Fisher's Exact Test was performed to analyze the relationship between the success of nRCT and the restorative condition. The level of significance was set at 5% ($P < 0.05$).

3. Results

A total of 257 teeth were endodontically treated according to the Caxias do Sul University's data, 23 teeth from 15 patients were missing clinical records, so, the data of 234 teeth was analyzed regarding the diagnosis before nRCT and the group of teeth. The most commonly treated teeth were premolars (46.15%) (**Table 1**) and the most prevalent diagnosis was Chronic Apical Periodontitis (33.33%) (**Table 2**).

The phone numbers of 182 (88%) patients were obtained, out of a total of 207. After calling 47 patients, only 37 showed up for the follow-up appointment. Thus, we obtained a final sample of 53 endodontically treated teeth, or 21% of a

Table 1. Groups of teeth endodontically treated by students of UCS-SD between 2019 and 2021.

	Maxillary		Mandibular		Total	
	n	%	n	%	n	%
Incisors	37	16	4	2	41	18
Canine	19	8	9	4	28	12
Premolars	65	28	43	18	108	46
Molars	34	14	23	10	57	24
Total	155	66	79	34	234	100

Table 2. Diagnosis of pulpal/periapical condition of teeth treated endodontically by students of UCS-SD between 2019 and 2021.

	n	%
Vital Pulp	64	27
Normal Pulp	15	6
Symptomatic Pulpitis	41	18
Asymptomatic Pulpitis	8	3
Non-vital Pulp	170	73
Non-vital Pulp	65	28
Acute Apical Periodontitis	12	5
Acute Apical Abscess	3	1
Chronic Apical Periodontitis	78	33
Uncertain diagnosis of teeth that needed a re-treatment	12	5
Total	234	100

total of 257 nRCTs performed (Figure 1). The most prevalent diagnosis was Non-vital Pulp (32%), Table 3 outlines the diagnosis of the pulpal/periapical condition that has driven the teeth to endodontic treatments of the reexamined teeth, respectively.

Of the 37 patients, 59% were female and 54% were aged 36 - 59 years. 94% were Caxias do Sul residents and 100% were from the low-income group. Table 4 shows a descriptive socio-demographic analysis of the sample.

One of the 53 followed-up teeth was extracted after endodontic treatment, due to vertical root fracture.

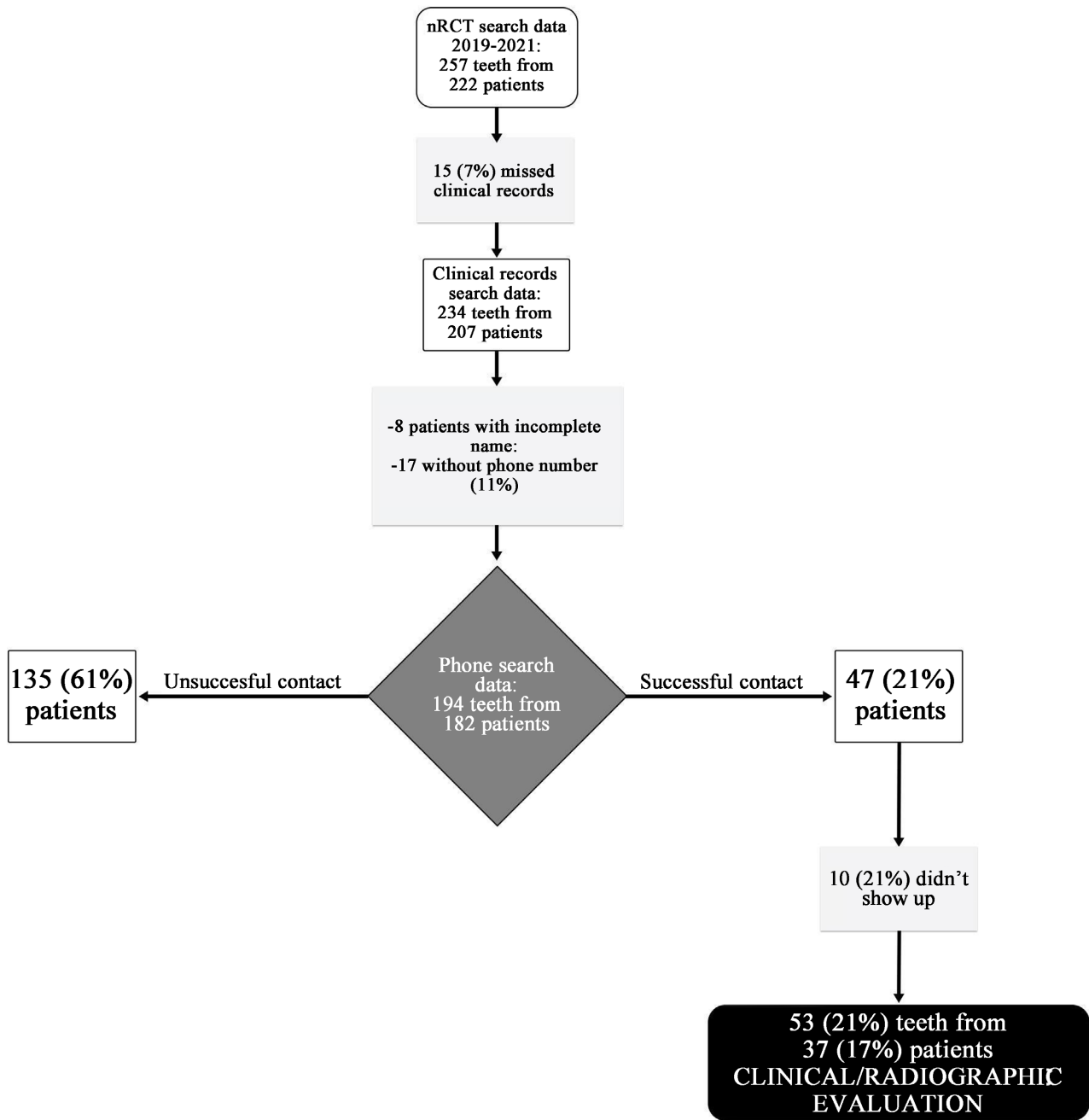


Figure 1. Flowchart representing the initial and final samples related to patients and teeth reexamined.

Table 3. Pulp/periapical diagnosis of the sample, teeth that were reexamined, before root canal treatment.

	n	%
Vital Pulp	16	30
Normal Pulp	5	9
Symptomatic Pulpitis	9	17
Asymptomatic Pulpitis	2	4
Non-vital Pulp	37	70
Non-vital Pulp	17	32
Acute Apical Periodontitis	3	6
Acute Apical Abscess	1	2
Chronic Apical Periodontitis	14	26
Uncertain diagnosis of teeth that needed a re-treatment.	2	4
Total	53	100

Table 4. Sociodemographic characteristics of the sample.

		n	%
Sex	Women	22	59
	Men	15	41
Age	10 - 18 years	1	3
	19 - 35 years	7	19
	36 - 59 years	20	54
	60 - 71 years	9	24
Socio-economic status	Low	37	100
Residence	Caxias do Sul	34	94
	Garibaldi	1	2
	Antônio Prado	1	2
	Nova Petrópolis	1	2

Table 5 shows the nRCT success rate of the 52 teeth reevaluated clinically and radiographically. The teeth classified as success, being healed (n = 44) and incomplete healing (n = 7) accounted for 98% of the analyzed sample. Elements with unsatisfactory healing, classified as failure (n = 1) represented 2% of the cases. **Figure 2** illustrates diagnostic periapical radiographs and the follow-up of several successful and unsuccessful cases documented in this study. Out of the 52 teeth examined, 51 (98%) achieved success, 85% deemed to be healed (**Figure 2(c)**, **Figure 2(d)**) and 13% incompletely healed (**Figure 2(a)**, **Figure 2(b)**, **Figure 2(e)**, **Figure 2(f)**). Only one tooth failed because of a large radiolucent lesion (**Figure 2(g)**, **Figure 2(h)**). This tooth had definitive Class II composite resin

Table 5. Root canal outcome classification according to POLYZO *et al.* (2018) criteria.

	n	%
Success (healed)	44	85
Success (incomplete healing)	7	13
Failure (uncertain healing)	0	-
Failure (unsatisfactory healing)	1	2
Total	52	100

Table 6. Restorative condition of teeth treated at UCS-SD between 2019 and 2021, of patients who attended the follow-up appointment.

	Restorative Condition					
	Adequate		Inadequate		Total	
	n	%	n	%	n	%
Composite restoration	21	66	11	34	32	100
GIC temporary restoration	5	42	7	58	12	100
Intracanal retention + temporary crown*	7	100	0	-	7	100
Without sealing**	0	-	1	100	1	100
Total	33	63	19	37	52	100

*Fiber and metallic posts. **Filling material exposed. GIC: Glass Ionomer Cement.

restoration with unsatisfactory adaptation and secondary caries lesion distally. This corresponded to a failure rate of 2%.

Three teeth displayed a periapical lesion healed without definitive restoration (**Figure 2(d)**). In these cases, all units had a Glass Ionomer Cement (GIC) restoration with satisfactory adaptation at the time of the follow-up visit.

Table 6 shows the sealing condition of the coronal restoration of the treated teeth at the follow-up visit. Among the 32 (62% of the 52 teeth evaluated) teeth definitively restored with composite resin, 11 (34% of the 32 restored teeth) exhibited inadequate marginal adaptation. Considering the seven cases with definitive cemented intra radicular posts as definitively restored, we can assume that 39 teeth (75%) were definitively restored (**Table 6**).

The nRCT outcomes were dichotomized. The results showed that 51 teeth were classified as successful, while only one tooth was categorized as a failure. The quality of coronal restoration was considered adequate for 33 teeth, and inadequate for 19 teeth. The Fisher Exact Test showed that there was no association between the outcome of endodontic treatment and the quality of the coronal restoration ($P = 0.365$) (**Table 7**).

4. Discussion

The objective of this retrospective study was to clinically and radiographically

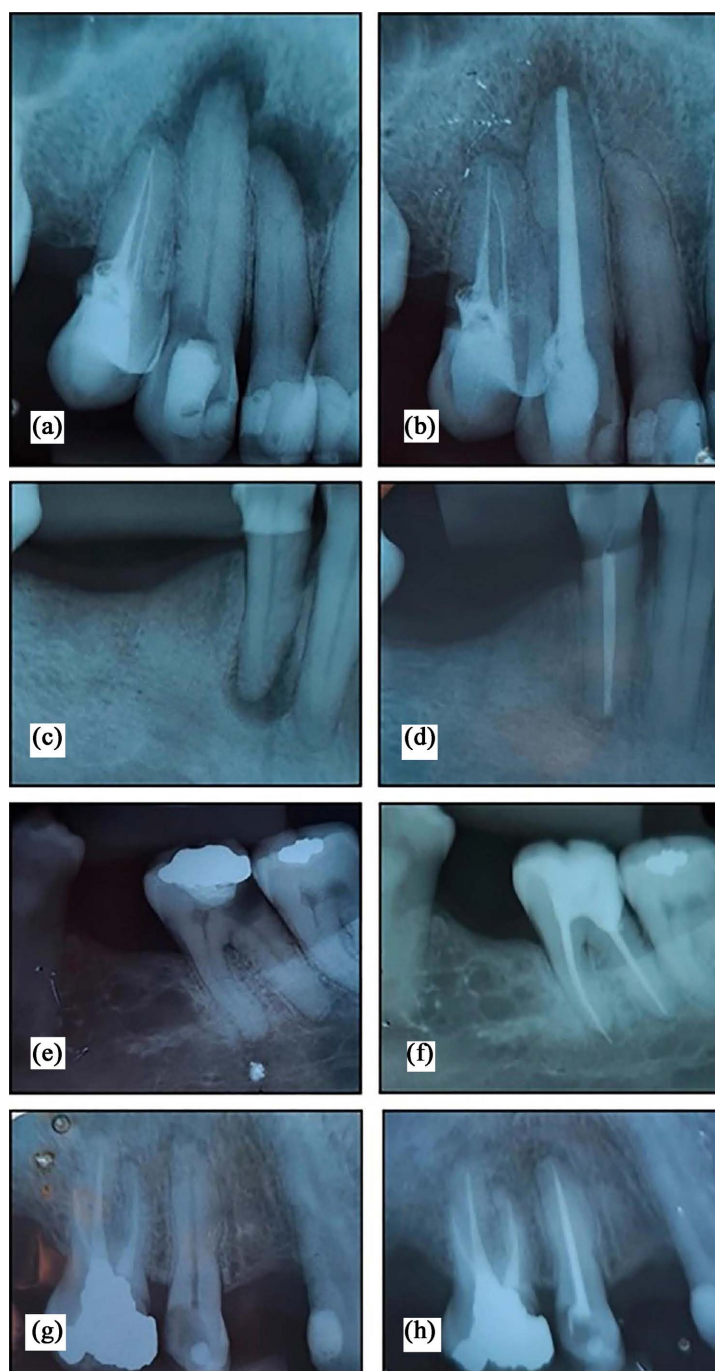


Figure 2. (a) Diagnostic radiography of element 13 with chronic apical periodontitis. Unit 12 reacted positively to the vitality test. (b) Follow-up radiograph 19 months after completion of nRCT demonstrating successful therapy with incomplete healing. (c) Diagnostic radiograph of unit 44 shows chronic apical periodontitis. (d) Follow-up radiograph 29 months after completion of the nRCT showed successful therapy and regression of the periapical lesion even with provisional GIC restoration. (e) Diagnostic radiograph of unit 36 shows chronic apical periodontitis. (f) Follow-up radiograph taken six months after completion of the nRCT showing root canal overfilling in the mesial root in a patient with lupus. (g) Diagnostic radiograph of unit 15 shows chronic apical periodontitis. (g) A 20-month follow-up radiograph after completion of the nRCT demonstrating the failure of therapy due to increased periapical lesion.

Table 7. Outcome of root canal treatment and quality of coronal restoration for re-examined teeth.

	Category	n	%	P
Quality of coronal restoration	Adequate	33	63	0.365
	Inadequate	19	37	
Outcome of Root Canal Treatment	Success	51	98	0.365
	Failure	1	2	
Total		52	100	

*Fisher's Exact Test, $P < 0.05$.

evaluate the outcome of endodontic treatments, the restoration condition and its correlation with the outcome in teeth that were endodontically treated by undergraduate students of the Dentistry course at SD-UCS.

In this follow-up cohort study, the most prevalent teeth that underwent the follow-up appointments were maxillary premolars ($n = 13$) (24.53%). Endodontic treatment was most frequent in maxillary teeth (60.38%) than in mandibular dental units (39.62%). The literature [10] [11] [12] has indicated that the mandibular first molar is the tooth most commonly treated endodontically. This is because it is the first permanent tooth to erupt without a deciduous predecessor. Our results diverged from the literature, as most students in the Disciplines of Endodontics were unable to perform nRCT on permanent molars.

Of the 52 teeth that underwent the follow-up appointments, 37 (70%) had a diagnosis of non-vital pulp. Some authors have already demonstrated that this diagnosis has a worse prognosis than when there is pulp vitality [13] [14]. According to SJOGREN *et al.* [15], teeth with periapical lesions present a success rate 20% lower than teeth without periapical lesions in the diagnostic radiograph. Furthermore, a better prognosis for endodontic therapy has been reported by STRINDBERG [16] for small lesions, up to 5 mm in diameter, compared to larger lesions. There seems to be a correlation between lesion size and the number of microorganisms in the root canal [17]. Another important consideration is that larger lesions also require a longer time for healing. In **Figure 2(a)** of this study, a large periapical lesion is observed, and in the follow-up radiograph (**Figure 2(b)**), taken 19 months after the completion of the endodontic therapy, incomplete healing is evident, demonstrating the need for longer follow-up periods for larger periapical lesions.

Non-vital pulp (32%) and Chronic Apical Periodontitis (26%) were the most prevalent pulpal/periapical condition diagnosis (**Table 3**). The records evaluated in this study indicated 14 teeth with a diagnosis of Chronic Apical Periodontitis. However, diagnostic radiographs revealed periapical lesions in 17 teeth, of which one tooth was diagnosed as Acute Apical Abscess and two teeth as Non-vital Pulp. There is a possibility that the case of acute apical abscess comes from a phoenix abscess and that the teeth with non-vital pulp were not correctly diag-

nosed. Phoenix abscess is a chronic apical periodontitis characterized by an acute exacerbation and appearance of clinical symptoms [18] [19].

The overall success rate of nRCT in this study (98%) (**Table 5**), was considered high when compared with similar studies [20]. The students were assisted by professors during the appointments, which ensured attention to biosafety protocols, as well as a better performance of each step of the root canal treatment (disinfection of the root canals, the use of intracanal medication, obturation and coronal sealing). This fact positively impacted the success rate as well as the short follow-up period, since longer periods could yield lower success rates, especially for those dental elements with restorative failures or which were temporarily sealed. Radiographic and clinical examination techniques evidenced periapical lesion and inadequate composite resin restoration in the only case of failure reported in this study. This finding supports the studies of Ray and Trope indicating that successful endodontic treatment is more often related to definitely restored teeth [4]. Chugal *et al.* [14] and Safavi *et al.* [21] also observed successful results more frequently for teeth with a permanent restoration (amalgam, composite, crown) than for teeth with a temporary restoration; however, the differences did not reach statistical significance, which is in agreement with the results of the present study.

In four teeth, the healing was incomplete, as the lesion did not fully regress. In these cases, the lesions had larger diameters and patients showed no clinical signs other than sensitivity to palpation. According to the European Society of Endodontology [22], these features define the success of endodontic therapy and indicate the need to maintain patient follow-up over the years. The follow-up time for all teeth was less than three years. In one out of four teeth, root canal overfilling was observed (**Figure 2(f)**). This endodontic failure prevents the lesion from healing. In this case, the patient was elderly and presented with Lupus, which are systemic factors that influence the healing process [11]. In two of the teeth, a six-month follow-up of the endodontic treatment was performed. One of them belonged to a young patient with no systemic conditions. Thus, the repair was favorable regardless of the established follow-up period for both teeth. These findings are aligned with the studies of HOLLAND *et al.* [23], LLENA [24] and SELTZER *et al.* [10]. The authors state that systemic factors related to the patient's health contributed to the outcome of the endodontic treatment. Our study corroborates the recommendations of the European Society of Endodontology [22] regarding a longer follow-up time of endodontic treatment for these cases.

This study relies on radiographic and clinical data, which presents limitations that should be considered when analyzing the results. One limitation was the evaluation of endodontic treatment success in the periapical region through periapical radiographs, instead of using CBCT, as proposed by ESTRELA *et al.* [2] [3]. The radiographic method was chosen for the following reasons: convenient and accessible, it is the main technique used by undergraduates at UCS-SD and matches the ALADA principle (as low as diagnostically acceptable) [25]. CBCT

should only be used when an accurate diagnosis cannot be achieved through a conventional radiographic study [26].

Another point was that the clinical sample evaluated was small (53 teeth) relating to the treated cases in the period (257 teeth), corresponding to 21% (Figure 1). Exhaustive efforts were made to contact all patients and encourage them to attend the follow-up appointment. The high proportion of dropouts, either for not showing up for the appointment (21%) or for not responding to the numerous phone calls and text messages (61%) were consistent with previous studies [13] [14]. In fact, most of the patients who attended the follow-up appointment reported other dental needs and interest in undergoing other procedures.

Our findings support the need for definitive restoration at the same appointment as root canal obturation and a long-term follow-up of endodontic treatment. The Fisher's Exact Test was unable to identify a statistical significance between the outcome of endodontic treatment and the quality of the coronal restoration ($P = 0.365$). This fact may be associated with the sample size and also the low failure rate of the endodontic treatment. Studies employing a larger sample size should be encouraged to provide a correlation between the success of endodontic treatment and the restorative condition of the dental element. The main objective of the present study was to assess the performance of undergraduate students in endodontics during their clinical practice at UCS-SD. The overall percentage of nRCT success was 98%.

5. Conclusions

- The success rate of endodontic treatment performed by UCS-SD undergraduates was high (98%);
- Among the restored endodontically treated teeth (62%), 34% showed unsatisfactory marginal adaptation;
- Methodologies using a larger sample size are encouraged to analyze the correlation between the quality of the restorative condition and the success of endodontic treatment.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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