RETROSPECTIVE STUDY ON THE EVOLUTION OF TEETH WITH ENDODONTIC TREATMENT IN A GROUP OF PATIENTS FROM CRAIOVA – ROMANIA

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ABSTRACT

The importance of preserving dental tissues together with the evolution of dental techniques and materials has led to advances in the field of endodontics and new principles in tooth restoration. Endodontically treated teeth are more prone to fracture and endodontically treated abutment teeth have a lower survival rate compared to vital abutment teeth. **The aim** of this study was to establish the evolution of teeth with endodontic treatment in a group of patients from Craiova, the frequency of various forms of failure of endodontic treatment and to identify the factors that contributed to the failure or success of endodontic treatment. **Materials and Methods:** This study was carried out based on the clinical and radiological examination and the consultation of the treatment sheets of some patients who came for treatment in the Dental Prosthetics Clinic of the Faculty of Dental Medicine of the University of Medicine and Pharmacy Craiova. The general technical quality of the endodontic treatment was evaluated based on the guidelines published by the European Society of Endodontology, following the radiological appearance of the root canal obturation as well as the presence of periapical lesions. The periapical index (PAI) proposed by Orstavik et al. was used to assess the periapical condition of teeth with root canal fillings. **Results:** The most common indications for endodontic treatment were irreversible pulpitis (64.05%) and endodontic treatment for prosthetic purposes (23.72%). Periapical lesions were observed in 33.4% of all endodontically treated teeth. Periapical lesions were observed in 35.2% of endodontically treated abutment teeth compared to 7.1% of vital abutment teeth. **Conclusions:** The most common indications for endodontic treatment were irreversible pulpitis and endodontic treatment for prosthetic purposes. Endodontic treatments for prosthetic purpose were very frequent although there are clear recommendations against it. Periapical complications were recorded in a higher proportion in case of abutment teeth**.**

Keywords: endodontic treatment; abutment teeth; coronary restoration; statistical study.

INTRODUCTION

Oral health is a fundamental component of general health and "it is influenced by a person's changing experiences, perceptions, expectations and ability to adapt to circumstances" [1].

Tooth loss is a critical indicator of oral health status [2, 3] and quality of life [4-7]. New advances in science and technology have also been implemented in dentistry, making possible to retain on dental arches teeth that would have been sacrificed in the past.

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Over the years, the importance of preserving dental tissues along with the evolution of dental techniques and materials has led to advances in endodontics and new principles in tooth restoration [8,9].

Endodontics through endodontic treatment, retreatment and endodontic surgery aim to eradicate or prevent an infection in the endodontic system, as well as to eradicate an infection or prevent access of microorganisms or their metabolites into the periapical tissues [10]. The European Society of Endodontics proposed in 2006 that the following should be considered as failures of endodontic treatment: presence of clinical signs and symptoms; appearance of radiological signs of apical periodontitis after endodontic treatment; the increase in size of a pre-existing apical periodontitis lesion/ the pre-existing periapical lesion has remained at the same size or only decreased in size over four years; the presence of root resorption [11]. Clinically, the outcome of endodontic treatment is judged by the functional survival of the tooth on the arch after endodontic treatment, without causing discomfort or functional disorders to the patient [12]. According to these criteria, several cross-sectional studies have shown, however, that a large proportion of endodontically treated teeth have AP, between 41,3%, [13] and 52% [14] or 25%-50% [15].

For endodontic treatment failures, preoperative factors, factors that may intervene during treatment, and post-treatment factors were considered. Preoperative causes influencing the outcome of endodontic treatment include misdiagnosis, errors in treatment planning, wrong case selection or treatment of a tooth with a poor prognosis [16]. Operative causes influencing the prognosis of endodontic treatment are thought to be mechanical and biological. Mechanical factors include access cavity preparation, root canal cleaning and shaping, instrument fracture, canal perforation or omission [17], and quality of root canal filling (incomplete/overfilled) [16,18]. Biological factors involve removal or reduction of existing and potential irritants in the pulp space, sealing of the endodontic space, microbial control, and management of periapical inflammation [19]. Postoperative factors that may compromise endodontic treatment include: late performed coronal filling; deficient coronal provisional filling; tooth fracture and root canal exposure prior to final restoration; final restoration, regardless of type or design, if fails to seal the root canal filling or has fractured; presence of recurrent caries at restoration margins [21,22].

Recent studies have shown that teeth with endodontic treatment are more prone to fracture due to changes in tooth tissue structure [23,24], higher risk of overloading [25] and decreased tooth strength.

The tooth tissue structure and strength are influenced by the access cavity preparation, root canal preparation and usage of lavage solutions [23,24,26].

The higher risk of overloading is due to the absence of the dental pulp which is a sensitive sensor. The reduction in the tooth sensitivity to an applied force after endodontic treatment increases the risk of overloading and fracture. [25]. It has also been noted that abutment teeth with endodontic treatment have a lower survival rate compared to vital abutment teeth [27,28].

The present study aimed to determine the evolution of endodontically treated teeth in a group of patients in Craiova, the

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frequency of various forms of endodontic treatment failure and to identify factors that contributed to endodontic treatment failure or success. To highlight the role of occlusal forces in the evolution of teeth with endodontic treatment, a comparison will be made between the frequency of failures in abutment teeth and non-abutment teeth.

MATERIALS AND METHODS

The present research is a retrospective cross-sectional study, which was conducted on 319 patients, who came to the Prosthodontics Department of the Faculty of Dental Medicine of the University of Medicine and Pharmacy Craiova for oral rehabilitation between October 2022 and February 2024. Patients were clinically examined, had an orthopantomography performed and their treatment records from the clinic database were consulted.

Inclusion criteria were: (1) patients' agreement to be included in the study based on informed consent; (2) patients who had been treated in the clinic in the past (who returned for treatment during the study) and for whom there was a treatment record in the clinic database; (3) patients with teeth presenting endodontic treatments.

Exclusion criteria were: (1) patients who did not give their consent to be included in the study; (2) patients with complete edentulism; (3) patients with incomplete data in the treatment record; (4) patients with mental or physical disabilities.

The clinical and radiological examination was performed by two examiners (two endodontists with radiologic expertise), independently. The recorded data were completed with those in the treatment record for teeth with endodontic treatment. The relevance of the recorded data was checked using Cohen's Kappa coefficient.

The following information were recorded: patient identity, age, gender, oral status, number of teeth present on the arch, teeth with endodontic treatment (tooth type), survival time on the arch after endodontic treatment, access cavity design, method of isolation, method of root canal preparation, use of a intracanal medicament, quality of root canal filling, presence of root canal posts, type of coronal restoration (coronal filling, crown), reason for endodontic treatment failure, periapical index.

The presence of a fractured instrument on the canal was recorded when the instrument was detected inside a root canal, or its tip was stuck in the periapical area.

The overall technical quality of endodontic treatment was assessed based on guidelines published by the European Society of Endodontics [11], looking on the radiological appearance of the root canal filling as well as the presence of periapical lesions. According to Liang et al. 2012, the correct (adequate) root canal filling should be homogeneous, sealed and performed up to 2 mm away from the radiological apex. Incorrect (inadequate) root canal filling has been defined as either short (>2 mm distance from radiological apex) or long (beyond radiological apex), homogeneous or inhomogeneous [29,30].

The periapical index (PAI) proposed by Orstavik et al. in 1986 was used to assess the periapical status of teeth with root canal fillings [31]. The PAI is a simple radiological assessment method of 5 categories numbered from 0 to 5. Apical periodontitis (AP) scores were divided so that 1 and 2 were grouped into "no AP" and 3, 4 and 5 "AP present". For pluriradicular teeth the root with the highest PAI score and the quality of the root canal filling on

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that root were considered [31]. The technical quality of root canal fillings was classified as adequate or inadequate according to the guidelines of the European Society of Endodontology.

Thus, success or failure of endodontic treatment was defined according to the presence/absence of AP lesions and the presence of teeth with treatment, as follows:

- Success - PAI 1/2 (no periapical lesion) and tooth present on arch.
- Failure - PAI 3/4/ 5 or tooth no longer present on the arch [32,33].

Statistical tests were performed using the SPSS (Statistical Package for Social Sciences) software, version 26 (SPSS Inc., Chicago, IL, USA). Continuous variables were defined as mean ± standard deviation (SD). Nominal and ordinal variables were described as frequency distributions and corresponding percentages. Normality distribution for continuous parameters was assessed using the Kolmogorov–Smirnov/Shapiro–Wilk test. The measure of inter-rater agreement for categorical scales was computed using the Cohen Kappa value. Comparisons between subgroups were performed with the Chi-Square test for categorical data and Mann-Whitney U for continuous data without a normal distribution. All p values < 0.05 reflected statistically significant results.

The study was approved by the Ethics Committee of the University of Medicine and Pharmacy Craiova. Patients gave their consent to participate in the study by signing the informed consent and the anonymity of the patients was respected (No. 212/10.11.2022).

RESULTS

Following the application of the inclusion and exclusion criteria out of 319 patients who presented to the clinic during the mentioned period, 122 patients were included in the study presenting a total of 3153 teeth on the arches. Thus, 548 teeth with endodontic treatment were studied of which 270 were abutment teeth.

Cohen's Kappa index was calculated to determine the index of agreement between the two examiners on the analysis of the PAI index and the dental fillings quality for a sample of 100 teeth.

Regarding the PAI index, the two examiners agreed on 55 patients with PAI 1/2 and 36 patients with PAI 3/4/5. However, examiner 1 rated 6 patients as having PAI 1/2 when examiner 2 rated them as having PAI 3/4/5 and examiner 1 rated 3 patients as having PAI 3/4/5 when examiner 2 rated them as having PAI 1/2. There was a very good level of agreement between the analysis of the two medical examiners, $\kappa = 0.813$ (95% CI, 0.697 - 0.928), $p < 0.0005$.

Regarding the quality of root canal fillings, the two examiners agreed on 57 patients with correct fillings and 38 patients with incorrect fillings. Thus, examiner 1 rated 3 patients as having correct fillings, while examiner 2 rated them as having incorrect fillings, and vice versa. There was a very good level of agreement between the two examiners' analysis, $\kappa = 0.896$ (95% CI, 0.807 - 0.984), $p < 0.0005$.

3.1. Study group characteristics

The study group comprised 122 patients, with ages between 14 and 70 years, and a mean age of 41.99±13.65 years, divided as following: 66 females (54.10%) and 56 males (45.90%) (Figure 1).

Table 1 contains the characteristics of the study group, based on the general and

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oral status.

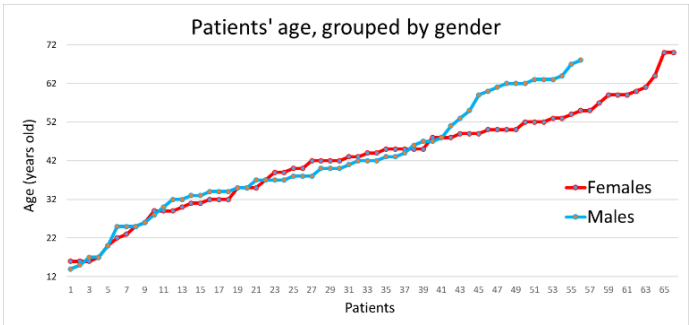


Figure 1. Patients' age, grouped by gender.

Table 1. General data.

Category	Parameter	Patients N (%)	Teeth n (%)	Abutment		p [1]
				Yes	No	
General status	Good	119 (97.54%)	525 (95.80%)	250 (92.60%)	275 (98.90%)	< 0.0005
	Poor	3 (2.46%)	23 (4.20%)	20 (7.40%)	3 (1.10%)	
Oral status	Good	40 (32.79%)	147 (26.82%)	51 (18.90%)	96 (34.50%)	< 0.0005
	Poor	82 (67.21%)	401 (73.18%)	219 (81.10%)	182 (65.50%)	

[1] Chi-square test.

3.2. Dental and endodontic status

The results for the assessment of dental status, endodontic status and factors that may influence tooth status are presented in the following paragraphs.

Correlated with dental and endodontic status, the indications for endodontic treatment for the 548 teeth taken in the study are presented in Table 2.

Table 2. Treatment indications and cavity access design.

Category	Parameter	Teeth n (%)	Abutment		p [1]
			Yes	No	
Treatment indications	Irreversible pulpitis	351 (64.05%)	111 (31.62%)	240 (68.38%)	< 0.000
	Endodontic treatment for prosthetic	130 (23.72%)	130 (100%)	0 (0%)	
	Necrosis	43 (7.85%)	19 (44.20%)	24 (55.80%)	
	Chronic apical periodontitis	24 (4.38%)	10 (41.70%)	14 (58.30%)	
Cavity access	Caries-driven	445 (81.20%)	219 (49.20%)	226 (50.80%)	0.027

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design	Traditional	86 (15.70%)	37 (43.00%)	49 (57.00%)
	Conservative	14 (2.55%)	12 (85.70%)	2 (14.30%)
	Restoration-driven	3 (0.55%)	2 (66.70%)	1 (33.30%)

[1] Fisher Exact test

Out of 130 teeth with endodontic treatment for prosthetic purposes, 63 teeth (48.4%) had cavities, 18 teeth (13.8%) had a horizontal change in the tooth position, 4 teeth (3%) had class I mobility, and 45 teeth (34.8%) had endodontic treatment without a medical recommendation, only to ensure the patient the absence of pain due to pulpitis. It should be noted that apart from these teeth with endodontic treatment for prosthetic purposes, 77 teeth had been previously treated for various pulpal diseases and were subsequently included in various fixed prosthetic restorations.

Regarding the *access cavity design*, 445 teeth (81.20%) of the total number of teeth with endodontic treatment had caries-driven access cavity, 86 teeth (15.69%) had traditional access cavity, 14 teeth (2.55%) had conservative access cavity, and 3 teeth (0.55%) had restorative-driven access cavity (Table 2, Figure 2). Analysis of access cavity design according to abutment /no abutment tooth status indicated that there were statistically significant differences between these two categories ($\chi^2(3) = 9.146$, $p = 0.027$).

The following aspects related to *endodontic treatment* were analyzed: tooth isolation, type of root canal preparation, application of intracanal medication, materials for root canal filling, quality of root canal filling and presence of root canal posts.

Regarding *tooth isolation*, the method with cotton rolls was used more frequently for abutment teeth and teeth restored with crowns - 216 teeth compared to teeth restored with fillings - 190 teeth, so the differences between these two groups of teeth are statistically significant, $\chi^2(1) = 9.691$, $p = 0.002$ (Figure 2a).

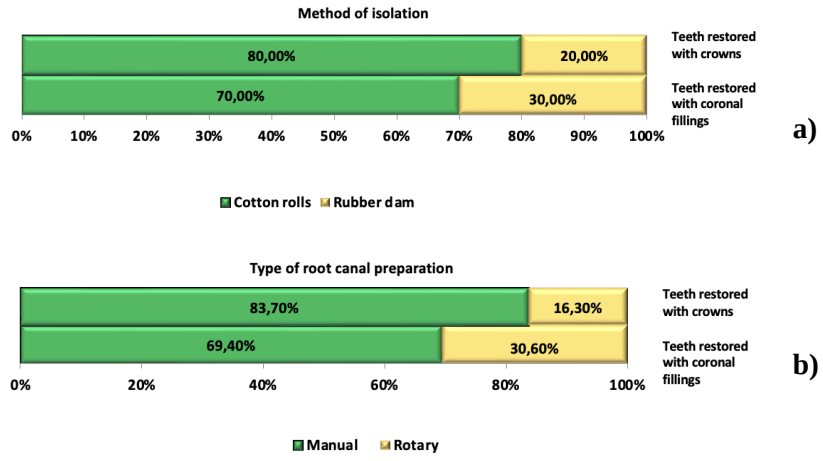


Figure 2. (a)Teeth isolation method; (b) Type of mechanical root canal treatment.

Regarding the *type of mechanical root canal treatment*, manual treatment was used more frequently for abutment teeth and teeth restored with crowns - 226 teeth (83.7%), compared to teeth restored with fillings - 193 teeth (69.4%), differences

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were statistically significant ($\chi^2(1)$ = 15.517, p < 0.0005) (Figure 2b, Table 3).

A statistically significant association was found between the type of mechanical root canal treatment and the method of tooth isolation. Thus, 372 teeth (91.6%) isolated with cotton rolls were manually instrumented, compared to teeth isolated with rubber dam where manual instrumentation was used for 47 teeth (33.1%), $\chi^2(1)$ = 200.218, p < 0.0005. Beside the manual instrumentation, the systems used were Protaper Gold (rotary motion) and Reciproc Blue (reciprocating motion), both with variable tapers.

The data recorded regarding application of intracanal medicament, quality of root canal filling and materials used for root canal filling are presented in Table 3.

Table 3. Endodontic treatment.

Category	Parameter	Teeth n (%)	Treatment		p [1]
			Crown	Fillings	
Isolation method	Cotton rolls	406 (74.09%)	216 (80.00%)	190 (68.30%)	0.002
	Rubber dam	142 (25.91%)	54 (20.00%)	88 (31.70%)	
Type of root canal preparation	Manual	419 (76.46%)	226 (83.70%)	193 (69.40%)	< 0.0005
	Rotary and reciprocating	129 (23.54%)	44 (16.30%)	85 (30.60%)	
Intracanal medication	No medication	389 (70.99%)	200 (74.10%)	189 (68.00%)	< 0.0005
	Calcium hydroxide	138 (25.18%)	53 (19.60%)	85 (30.60%)	
	Walkhoff	21 (3.83%)	17 (6.30%)	4 (1.40%)	
Quality of root canal obturation	Adequate	264 (48.18%)	121 (44.80%)	143 (51.40%)	0.121
	Inadequate	284 (51.82%)	149 (55.20%)	135 (48.60%)	
Materials for root canal obturation	Gutta-percha cone and sealapex	308 (56.20%)	147 (54.40%)	161 (57.90%)	0.121 [2]
	Gutta-percha cone and Ah plus	149 (27.19%)	57 (21.10%)	92 (33.10%)	
	Gutta-percha cone and endomethasone	76 (13.87%)	52 (19.30%)	24 (8.60%)	
	Gutta-percha cone and iodoformed paste	15 (2.74%)	14 (5.20%)	1 (0.40%)	

[1] Chi-square test. [2] Fisher Exact test.

3.3. Restorative modalities

Results on restorative modalities are revealed in the following paragraphs.

Regarding the presence of *root canal posts* in endodontically treated teeth, proportion was low, 26.28% (144 teeth), and among

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those restored with posts, the use of Cr-Ni alloy cast posts and screw-retained posts was approximately equal (Figure 3a).

Abutment teeth and teeth restored with crowns had a higher proportion of root canal posts - 107 teeth (39.6%), compared with teeth restored with fillings - 37 teeth (13.3%), reflecting statistically significant differences between these two categories, $\chi^2(1) = 51.360$, $p < 0.0005$.

In terms of types of *coronal restoration* of the 548 teeth with endodontic treatment, 278 teeth (50.73%) had various types of coronal fillings made by direct techniques and 270 teeth (49.27%) had full coverage crowns (aggregation element/single crown) (Figure 3b).

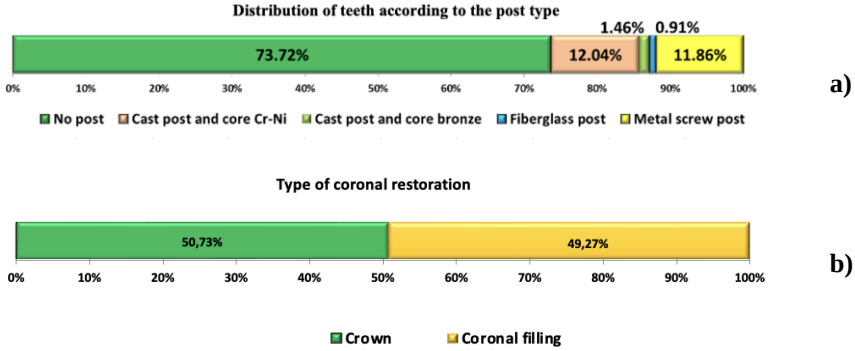


Figure 3. (a) Type of posts; (b) Coronal restoration.

3.4. Endodontic treatment

Analyzing *the endodontic treatment indications,* for the 548 teeth, results are presented in Table 4.

Table 4. Endodontic treatment indication.

Teeth restorations	Total	Endodontic treatment for prosthetic n (%)	Irreversible pulpitis n (%)	Necrosis n (%)	Chronic apical periodontitis n (%)	p [1]
Crowns	270	130 (48.10%)	111 (41.20%)	19 (7.00%)	10 (3.70%)	< 0.0005
Fillings	278	0 (0.0%)	240 (86.40%)	24 (8.60%)	14 (5.00%)	

[1] Chi-square test.

Regarding the *evolution of teeth with endodontic treatment*, it can be estimated that 365 teeth (66.6%) can be considered as successful (no radiologically visible periapical lesions - PAI 1/2) and 183 teeth (33.3%) as failure (PAI 3/4/5) (Figure 4).



Figure 4. Success/failure status.

Analyzing tooth evolution by oral status, 38 teeth (25.9%) of patients with

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good oral status developed PAI 3/4/5 compared with 145 teeth (36.2%) of patients with poor oral status. A chi-square test for association between oral status and presence of AP was performed. A weak ($\varphi = 0.097$, $p = 0.023$) but statistically significant association was found between oral status and AP, $\chi^2(1) = 5.140$, $p = 0.023$.

Regarding endodontic treatment *failures* that would require tooth extraction for teeth included in the study, crown-root fractures and periapical complications in which conservative treatment failed were considered.

Thus, of the total number of endodontically treated teeth, 23 presented fractures (Table 5).

Table 5. Endodontic treatment failures.

Category	Parameter	Fractures n (%)		p [1]	Periapical complications n (%)		p [1]
		Yes	No		Yes	No	
Total		23 (4.20%)	525 (95.80%)	-	54 (9.90%)	494 (90.10%)	-
Oral status	Good	21 (5.20%)	380 (94.80%)	0.045	40 (10.00%)	361 (90.00%)	0.875
	Poor	2 (1.40%)	145 (98.60%)		14 (9.50%)	133 (90.50%)	
Post	No post	17 (4.20%)	387 (95.80%)	0.442 [2]	35 (8.70%)	369 (91.30%)	0.408 [2]
	Cr-Ni cast post	2 (2.67%)	73 (97.33%)		9 (11.84%)	66 (86.84%)	
	Screwed metal post	3 (4.70%)	61 (95.30%)		10 (15.60%)	54 (84.40%)	
	Fiberglass post	1 (20.00%)	4 (80.00%)		0 (0%)	5 (100%)	
Coronal restoration	Provisional cement filling	11 (17.46%)	52 (82.54%)	< 0.0005 [2]	7 (11.11%)	56 (88.89%)	0.458 [2]
	Composite filling	6 (2.70%)	130 (97.30%)		21 (9.46%)	201 (90.54%)	
	Crowns	6 (2.28%)	257 (97.72%)		26 (9.89%)	237 (90.11%)	
Intracanal medication	Calcium hydroxide	6 (4.30%)	132 (95.70%)	0.059 [2]	31 (22.50%)	107 (77.50%)	< 0.0005 [2]
	No medication	14 (3.60%)	375 (96.40%)		16 (4.10%)	373 (95.90%)	
	Walkhoff	3 (14.30%)	18 (85.70%)		7 (33.330%)	14 (66.70%)	
Isolation method	Cotton rolls	17 (4.20%)	389 (95.80%)	0.984	44 (10.80%)	362 (89.20%)	0.192
	Rubber dam	6 (4.20%)	136 (95.80%)		10 (7.00%)	132 (93.00%)	
Material for root canal obturation	Gutta-percha cone and sealapex	14 (4.50%)	294 (95.50%)	-	24 (7.80%)	284 (92.20%)	-
	Gutta-percha cone and Ah plus	6 (4.00%)	143 (96.00%)		9 (6.00%)	140 (94.00%)	

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Gutta-percha cone and endomethasone	1 (1.32%)	75 (98.68%)	16 (21.05%)	60 (78.95%)
Gutta-percha cone and iodoformed paste	2 (13.30%)	13 (86.70%)	5 (33.33%)	10 (66.70%)

[1] Chi-square test. [2] Fisher Exact test.

Out of the total number of teeth included in the study, 183 teeth developed various forms of AP, 54 of them had periapical complications with extraction recommendation.

Periapical complications were studied in terms of oral status, coronal restoration, presence of a root canal post, isolation type, intracanal medicament administration and root canal filling material (Table 5).

Regarding oral status, 40 teeth (74%) belonged to patients with poor oral status and 14 teeth (26%) belonged to patients with good oral status. A chi-square test of association indicated that there was no statistically significant association between oral status and the occurrence of periapical complications, $\chi^2(1) = 0.025$, $p = 0.875$.

The Fisher Exact test indicated that there was a statistically significant association between the occurrence of complications and the application of intracanal medication, $\chi^2(2) = 52.167$, $p < 0.0005$. The association is relatively strong, Cramer's V = 0.304.

An association between root canal obturation materials and periapical complications was not established because some of the materials came into use more recently.

In order of better assessment of *endodontically treated teeth evolution* on arches and to appreciate the role of occlusal forces in the endodontic status, a comparison was made between endodontically treated abutment teeth (270 teeth) and abutment teeth without endodontic treatment (84 teeth) according to the presence of AP lesions.

Regarding the presence of AP lesions, an unbalanced distribution between vital and non-vital abutment teeth was found, with statistically significant differences. The proportion of teeth without endodontic treatment and without AP lesions - 78 teeth (92.90%) was higher compared to endodontically treated teeth without AP - 134 teeth (64.70%). AP lesions were present for 6 abutment teeth without endodontic treatment (7.10%) compared to 73 of the abutment teeth with endodontic treatment (35.20%). These differences were statistically significant $\chi^2(1) = 21.481$, $p < 0.0005$ (Figure 5).

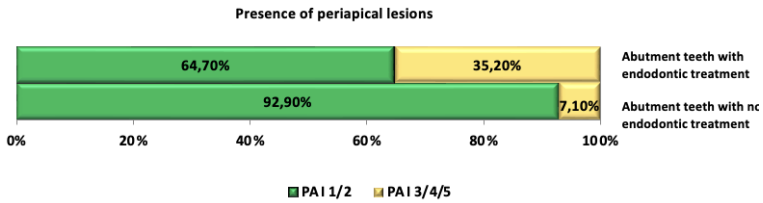


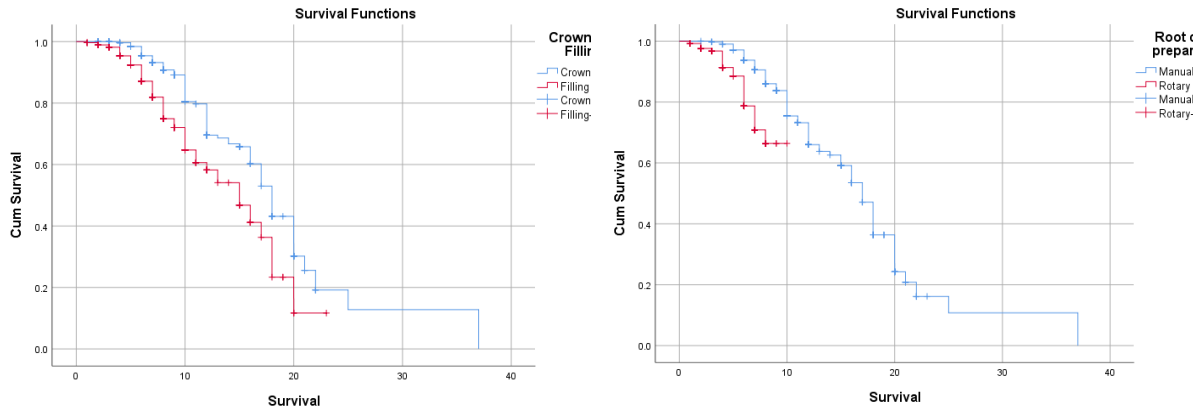
Figure 5. Distribution of periapical lesions on abutment teeth with and without endodontic treatment.

A Mann-Whitney U test revealed differences in the survival time of teeth on arches between teeth with PAI 1/2 and teeth with PAI 3/4/5. Distribution of survival duration for the two categories of teeth was similar, according to visual inspection. Median survival value for teeth with PAI 1/2 (8.00) and PAI 3/4/5

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(10.00) was statistically significantly different, U = 42.253.5, z = 5.082, p < 0.0005.

A similar Mann-Whitney U test revealed differences in tooth survival on arches in terms of restoration type (crowns vs fillings). The distribution of survival time for the two categories was similar, confirming visual inspection. Median survival value for teeth with crowns (10.00) was higher compared to teeth with fillings (8.00), being statistically significantly different, U = 26.133, z = -6.169, p < 0.0005. A Kaplan-Meier survival analysis was conducted to compare the two types of restorations for their effectiveness in preventing failures (Figure 6a). A similar percentage of censored cases was present in the crown (66.3%) and fillings (66.9%) groups. Patients with crowns had a median time to failure of 18.00 years (95% CI, 16.86 to 19.14) years. This was longer than for the group of patients with fillings, with a median time to failure of 15.00 years (95% CI, 12.72 to 17.28). A log rank test was conducted to determine if there were differences in the survival distributions for the different types of restorations. The survival distributions for the two techniques were statistically significantly different, $\chi^2(2) = 18.843$, p < 0.0005.



(**a**) (**b**)

Figure 6. Survival analysis: (a) Crowns and fillings; (b) Manual and rotary and reciprocating root canal preparation.

A similar Kaplan-Meier survival analysis was conducted to compare the two different methods for root canal preparation for their effectiveness in preventing failures (Figure 6b). The percentage of censored cases present in the manual (61.1%) and rotary and reciprocating techniques (84.5%) intervention groups was not similar. Patients that underwent manual technique had a median time to failure of 17.00 years (95% CI, 16.04 to 17.96) years. This was longer than for the group of patients who underwent the rotary technique, with a median time to failure of 8.50 years (95% CI, 8.01 to 9.10). A log rank test was conducted to determine if there were differences in the survival distributions for the different types of techniques. The survival distributions for the two techniques were statistically significantly different, $\chi^2(2) = 21.194$, p < 0.0005.

DISCUSSIONS

The present study aimed to determine the evolution of teeth with endodontic treatment in a group of patients in Craiova,

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as well as the frequency of various forms of endodontic treatment failures, and to identify the factors that contributed to the failure or success of endodontic treatment.

Epidemiological data recorded in this study on factors such as patient age and gender did not show a significant influence on the outcome of endodontic treatment. Some studies in the literature show that there are difficulties in endodontic treatment in the elderly patients, especially when the access cavity is made through a crown [34], compared to other studies which claim that there are no associations between older age of patients and endodontic treatment difficulties [35]. In young people, endodontic treatment can be difficult due to anxiety and other factors related to awareness of the importance of endodontic treatment [36].

The patient's immune response may have an important role in the progress of endodontic treatment in the young and elderly. Some of the variation in periapical healing outcomes can be attributed to differences in individual host responses [37].

Oral status was poor for most of the patients, an outcome that can be explained by patients' neglect of oral health and difficult access to oral care. In 2016, the International Dental Federation (FDI) redefined oral health comprehensively, recognizing that oral health is multifaceted and involves the ability to smell, touch, taste, chew, swallow, smile, speak and convey a range of emotions through facial expressions with confidence and without discomfort, pain and disease of the craniofacial region [1].

Poor oral hygiene has a significant impact on oral health and can generate several specific manifestations (periodontal disease, dental cavities and even tooth loss) [38]. Patients who had good oral hygiene, did not have missing teeth, did not present untreated cavities or periodontal disease were considered patients with a good oral status.

According to the present study, the most common indications for endodontic treatment were irreversible pulpitis and endodontic treatment for prosthetic purposes. Similar results have been obtained in other studies. In a study conducted in 2021 in Nepal, irreversible pulpitis was the most common indication for endodontic treatment - 59.30% [39]. Concerning the endodontic treatment for prosthetic purposes, the attitude has changed over time, so that endodontic treatment performed to prevent a potential pulpitis in the absence of the actual indication for this treatment (just to ensure the patient that he/she will not experience any pain) is totally contraindicated, being more a matter of ignorance [40-42]. The American Association of Endodontics has made the following recommendations for preprosthetic endodontic treatment: in overdentures, for teeth that will receive special systems, for malpositioned teeth and teeth to be hemisectioned; in fixed prosthodontics to ensure retention of restorations [43]. The recommendations of the European Society of Endodontics for elective devitalization are: to create space for a post, for teeth with questionable pulpal vitality, for malpositioned teeth whose preparation would expose the dental pulp and before apical resection or hemisection [11, 44]. The category of teeth with questionable health we considered that should include: teeth with voluminous fillings, possibly with relapse or secondary cavities and teeth that have been abutments before.

Regarding access cavity, the most

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important question about ultra-conservative access cavity design is whether it compromises root canal preparation, debridement and obturation [45], which has been addressed in laboratory studies [46].

Longer-term clinical studies could demonstrate improved periapical healing and dental survival. In the meantime, traditional access cavity and those through the caries-driven serve their purpose of facilitating root canal treatment without compromising periapical healing or survival outcomes [37].

An observational study related to root canal retreatment found a significantly higher periapical healing rate when rubber dam isolation was used compared to cotton rolls isolation [47].

In the study group, AP was present in a higher proportion in teeth isolated with cotton rolls compared to teeth isolated with rubber dam.

In contrast to this study, Gulabivala et al. 2023 consider that performing root canal treatment with or without dam isolation is unlikely to produce a significant difference in periapical healing. This is because the major influence on outcomes is conferred by the infection established at the apical level, which is unlikely to be altered by transitory salivary contamination [37].

Regarding the method of preparation of root canals in the study, the manual technique predominated. The explanation could be that many teeth were treated before the introduction of the rotary and reciprocating techniques and these techniques require a specific equipment that does not exist in all dental practices in Craiova.

Minimal root-canal preparation has been suggested to reduce the risk of root fracture, but as a result, satisfactory cleaning and shaping do not take place. Large-scale taper instrumentation can contribute to removing infected tissue; however, it may weaken the tooth structure [48].

A 2019 review by Mamani et al. analyzed the literature to highlight the advantages of each of the two root canal preparation methods. A total of 1104 publications were recorded, making it a topic of great interest to specialists in the field. According to this review, rotary and reciprocating techniques involve less working time, easier centering of the instrument in the canal, less change in the curvature of the canal than the manual technique. The manual technique showed better results in terms of smear layer removal, instrumented area and fewer dentin defects [49].

The two systems used were Protaper Gold (rotary motion) and Reciproc Blue (reciprocating motion). The flexibility and fatigue resistance of all Blue heat-treated and Gold instruments was found to be high as compared with the conventional NiTi instruments. All Gold and Blue heat-treated systems produce well-centered canal preparations in especially severely curved canals [50].

Due to various factors, such as the geometry, alloy, and movement of the instruments, as well as the characteristics of the canal (dentin hardness, canal curvature radius and angle, and complex anatomies) and operator experience [51], several incidents can occur during root canal preparation: loss of working length, apical blockages, threshold formation, apical transposition, perforations, apex widening, instrument fracture [52]. Combining manual and rotary /reciprocating techniques can lead to a reduction in the number of incidents.

In the present study, out of the total

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endodontically treated teeth, most teeth did not receive intracanal treatment and of those that did receive intracanal treatment, calcium hydroxide was the most applied. Calcium hydroxide was determined to be suitable for use as an intracanal medicament because it is stable for long periods, harmless to the body and bactericidal in a limited area. Endodontic treatment performed in a single session, where intracanal medicaments are not used, is currently indicated and various reports have shown that clinical outcomes between endodontic treatment performed in a single session and that performed in multiple visits are almost similar [53].

Analyzing the presence of AP according to the quality of the root canal filling, it was noted that it has a much higher frequency in inadequate root canal fillings. Some studies have reported even higher PA values in these cases [54, 55].

According to a study by Gheorghe et al. in 2019 [27], out of all teeth, 5% had adequate root canal fillings and AP, and 62% had inadequate root canal fillings and AP. In another study conducted in 2008, 16.5% of teeth with adequate endodontic treatment had AP and 66.3% of teeth with inadequate endodontic treatment had AP [56].

According to a study by Göransson et al. 2021 [23], the survival rate was higher for teeth with high quality root canal fillings. Similar results have been found in other studies [57, 58].

Regarding the influence of post types on PA, there was no statistically significant association between post type and PAI index. The results are consistent with the results of other studies [56].

Regarding the modality of coronal restoration of endodontically treated teeth, for many years the gold standard in case of extensive tooth structure loss has been the application of a crown with or without the presence of a post [59].

O'Sullivan has made it clear that post and core combined with a crown is recommended for front teeth when there is not enough tooth structure, or the dentine does not have the strength to retain a crown and a fracture may occur in the case of tissue loss. For lateral teeth, in the case of minimum dental tissue loss, restoration with a filling, in case of moderate dental tissue loss (one cuspid in premolar and two cuspids in molars present) post and filling is recommended and only in case of severe dental tissue loss post and crown is recommended [60].

According to the present study, approximately half of the teeth were restored with coronal fillings and half were restored with crowns, considering that a crown provides better marginal sealing of endodontic treatment, thus preventing periapical complications.

In a study by Mindiola in 2006, the absence of a permanent coronal restoration within 90 days after finishing the endodontic treatment was found to be the most significant factor associated with tooth extraction [61].

Several studies have reported tooth survival after root canal treatment in relation to restoration type. Although studies vary in design, follow-up time and region, results reveal a higher survival rate for teeth restored with an indirect restoration than those receiving a direct restoration [62-64]. The lowest survival rates were reported for teeth that did not receive a definitive restoration following root canal treatment [62, 65, 66]. In the present study, of the 77 teeth lost, 32 were coronally restored with crowns (41.5%) and 45 with coronal fillings (58.4%).

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Regarding endodontic treatment failures, out of all extracted teeth in the present study, approximately 30% were extracted due to coronal root fractures. The results are consistent with the results of other studies. A retrospective 10-year follow-up study found that the main reason for extraction of endodontically treated teeth was root fracture [64]. A retrospective study conducted in America found that tooth fracture was the most common reason for loss of endodontically treated teeth [65].

The increased susceptibility of dental fractures in endodontically treated teeth compared to vital teeth could be influenced by factors such as access cavity design, root canal preparation and use of endodontic lavage solutions. These procedures significantly reduce tooth strength through loss of tooth structure and increased dentin fragility [23, 24, 52].

Comparing abutment teeth with endodontic treatment to those without endodontic treatment, AP lesions were present more frequently for abutment teeth with endodontic treatment. This could be explained by the fact that regardless of the quality of endodontic treatment, AP may occur, therefore the recommendation is to preserve the vitality of abutment teeth. In a 2019 study, in abutment teeth, chronic periapical lesions were observed in 49.80% of endodontically treated abutment teeth compared to 34.15% in abutment teeth without endodontic treatment [27].

The strong points of the present study are represented by the evaluation of a significant number of teeth. Also, the use of treatment records from the clinic's database allowed the evaluation of factors that influenced the long-term development of the teeth.

The weak points of the present study are represented by the fact that OPG's were used to assess factors that led to root canal treatment failure. More conclusive results would have been obtained based on CBCT images. Radiographs of this type show two-dimensional images of three-dimensional structures and involve superimposition of adjacent anatomical structures.

In Romania as well as in other countries (Sweden [67], Korea [68], Finland [69]), orthopantomograms are widely used as routine radiographs and are based on ALARA radiation protection principles: they use an acceptable radiation dose compared to CBCT examination [70] and a series of periapical radiographs.

Regarding the performance of pulpotomies in irreversible pulpitis, the study specifically addresses abutment teeth, pulpotomies being totally contraindicated. The study is based on treatments carried out many years ago. In the literature, there are only recent data on the success of pulpotomies in irreversible pulpitis [71].

Regarding the low rate of use of rubber dam isolation, the article studies teeth that were treated 30 years ago, a time in which rubber dam isolation was not often practiced. Other studies report a similar frequency for the use of rubber dam isolation [72, 73].

Regarding the role of the study, we can say that at this moment, in Romania, many endodontic treatments are performed by dentists without a specialty in endodontics, especially in the countryside. The results can guide the clinicians for future treatments.

CONCLUSIONS

1. The most common indications for endodontic treatment were irreversible pulpitis and endodontic treatment for prosthetic purposes. Endodontic treatments for prosthetic purposes were very frequent although there are clear recommendations

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against it.

2. The most common designs of access cavity were caries-driven and traditional.

3. All abutment teeth had full-coverage crowns.

4. Dental fractures were mainly recorded in teeth of patients with poor oral status and periapical complications were mainly recorded in patients with poor oral status and in abutment teeth.

5. A very small number of teeth with apical periodontitis received endodontic treatment and were used as abutment teeth.

Author Contributions:

Conceptualization, V.M.,M.J.T. and M.R.B.; methodology, M.R.B, M.J.Ț., O.A.D.; software, M.I., P.C.M. and L.C.L.; validation, P.C.M., M.R.B. and L.C.L; formal analysis, O.A.D. and P.C.M.; investigation, M.R.B., P.C.M. and L.C.L..; resources, O.A.D.; data curation, M.I. and P.C.M.; writing—original draft preparation, M.R.B., P.C.M and L.C.L..; writing—review and editing, V.M., M.J.T. and O.A.D.; visualization, M.I.; supervision, V.M.; project administration, V.M. All authors have read and agreed to the published version of the manuscript.

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