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Post-treatment Apical Periodontitis in Primary Non-surgical Root Canal Treatment: A Multiple Correspondence Analysis

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Introduction: The presented study aimed to characterise periapical disease in teeth with primary non-surgical root canal treatment in persistent or emergent categories and their risk association. **Methods:** A retrospective observational study that evaluated permanent teeth with primary non-surgical root canal treatment, was conducted clinically and radiographically for over one year. The following variables were analysed: gender, age, type and location of tooth, previous diagnosis, treatment conditions, and type of coronal restoration. The supplementary variables included the perspectives of the treatment outcome, such as Remains normal, Improvement, and Failure. Statistical analysis was performed using a univariate analysis that estimated the average and proportion for each factor according to the result of the primary non-surgical root canal treatment. The multiple correspondence analysis identified the hierarchy between active variables and their association with the results. **Results:** A total of 232 teeth in 155 participants were analysed. A $\chi2$ value, (*P=0.023*) showed that the emergent disease is associated with patients around the age of 50. The multiple correspondence analysis identified a tendency of grouping between the emergent disease and the short filling category, followed by symptomatic pulpitis as a previous diagnosis. The persistent disease was associated with errors and overfillings. An inadequate root filling and taper density adversely impacted the treatment outcome. **Conclusions:** The length of obturation influenced the presence of failure. Short fillings were associated with emerging periapical disease. Errors and overfillings contributed to the persistent disease in the populations studied.

Keywords: Endodontics; Etiology; Periapical Disease; Root Canal Therapy; Treatment Outcomes

Introduction

Outcomes of non-surgical root canal procedures depend directly on the enlarging, shaping, cleaning and disinfection process, which can facilitate an adequate three-dimensional sealing of the root canal system [1, 2]. Within this perspective, treatment failure can often be correlated with the persistence of clinical and/or radiographic signs and symptoms, which determines the need for a second procedural intervention [1, 3]. Although clinical and experimental research in endodontics has advanced greatly in the last decade, the failure associated with primary non-surgical root canal treatment (PRCT) ranges from 7.7 to 11% [4, 5]. Recently, a comprehensive review article on cross-sectional studies illustrated that apical periodontitis (AP) is a prevalent disease in most populations, and the frequency of AP in root-filled teeth was 39% [6]. However, it is fundamental to recognise the confounding effect inherent to the heterogeneity of cross-sectional studies [7, 8]. From the clinical perspective of failure, it is common to see that results are impacted by the periapical status and the quality of the root filling [4, 9]. In 2011, Ng *et al.* [2] reported a 49% decrease in the success rate for cases with a prior diagnosis of AP. Regarding this, Tsesis *et al.* [10] confirmed that of all cases with AP before treatment, and only 79% resulted in healing. Analysing the evidence from clinical studies, the quality of the obturation becomes an indicator of the conditions in which endodontic treatment was performed [11]. Therefore, radiographically inadequate obturation promotes a risk of failure between 54 to 64.5% [4, 7], and the short length of filling (>2 mm from the radiographic apex) represents the highest percentage of failure [12].

With a cause-and-effect relation, the presence of AP on radiographic or tomographic images indicates microbial contamination inside the canal [13], and the failure of non-surgical root canal procedures has been identified as the presence of post-treatment periapical disease [14]. Friedman *et al.* [15] and Siqueira et al. [16] emphasise that after PRCT, this condition may not resolve or develop later, categorising endodontic failure as a persistent periapical disease (PPD) or emergent periapical disease (EPD) [16]. Both clinical circumstances, with notable microbiologic differences in the development and progression of disease, reveal association but not causation. Therefore, whether the bacterial organisation in biofilm precedes and is a prerequisite for AP to develop or is a later event [17], and whether an association with clinical factors could be estimated for each pathological condition remains unknown.

As such, the presented study aimed to characterise periapical disease in teeth with PRCT, in the persistent or emergent categories and their risk association.

Materials and Methods

A retrospective cohort observational study was performed. The Institutional Review Boards (IRB) Ethics Committee of the Universidad Nacional de Colombia School of Dentistry (CIEFO-261-16) approved this investigation.

Population and sample size

Data were collected from individuals with restored permanent teeth, with complete root formation, and PRCT, who attended follow-up appointments in the Graduate Program in Endodontics. Teeth with pre- and post-operative radiographic records identifying the periapical state before treatment and at the time of the follow-up were included. Teeth with a history of vertical root fracture, dento-alveolar trauma, current orthodontic treatment, and teeth where it was impossible to recover the initial periapical status prior to the PRCT were excluded.

The sample size was calculated based on a preliminary study in which the exposure factor of short obturation length estimated a 20% failure rate versus a 6.8% failure rate for teeth having flush obturation [18]. Therefore, with a confidence level of 95% and a power of 80%, a sample size of 243 teeth was estimated to be distributed in a ratio of 4:1 (teeth without the exposure factor:teeth that present it) [19]. A consecutive non-probabilistic selection of subjects who met the established eligibility criteria was designed to include the largest number of subjects.

Active variables

Demographics: Gender, age.

Dental features: Type of tooth and its location, diagnosis, and periapical status before PRCT (presence or absence of AP).

Quality of the root canal filling [11]: this variable was studied in terms of homogeneity, defined as presence or absence of spaces inside the root canal filling, as seen on a periapical radiograph [5]; Taper, defined as the continuous narrowing of the root canal in relationship with the transversal diameter [20]; Apical limit of the filling measured as the distance between the final extent of the sealing material and the radiographic apex. It was classified as short (>2 mm), flush (0-2 mm), or overfilling (<0 mm) [21].

Errors: Presence or absence of intra-operative alterations in the apical third, such as fractures of the intracanal files, the presence of ledges or blockage in the canal.

Type of Coronal Restoration: Direct or indirect; Role: Single tooth or abutment for a fixed partial denture; and Quality: Good or poor coronal seal, as determined subjectively.

Supplementary variable

The supplementary variable was analyzed according to the radiographic or clinical evaluation of the PRCT outcome regarding success and failure during the follow-up visits (greater than or equal to 1 year). Pre- and post-operative radiographic records allowed the classification of the periapical area as Presence of AP or Absence of AP. Additionally, the presence of one or more symptoms, such as pain or infection, during the postoperative phase was a failure indicator [21].

Four [4] categories describe the outcome of PRCT. Success, defined as the absence of symptoms [22] accompanied by normal periapical structures or small changes in bone structure (absence of AP) [23]. The Success category is further divided by two categories: The periapical condition remains normal, or the periapical condition shows improvement, as the resolution of apical periodontitis identified before endodontic treatment [24, 25]. On the other hand, Failure includes changes in bone structure with some mineral loss and the presence of AP with a well-defined radiolucent area [26, 27]. The Failure category is further divided by two categories: PPD after treatment, that indicates no resolution of the condition after treatment [16, 28]; or EPD which corresponds to the apical periodontitis that appears after having finished the endodontic treatment [16, 28] (Figure 1).

The reading of the radiographic images, which allowed the study of the periapical status, the quality of the root filling, and the presence of intra-operative errors, was performed out by two blinded evaluators (CD and SQ) whose inter-observer agreement concordance was considered good, Kappa Coefficient (ƙ):0.80, and with an almost perfect consistency ƙ: 1 for the intra-observer evaluation [29]. The radiographic images at the time of the control

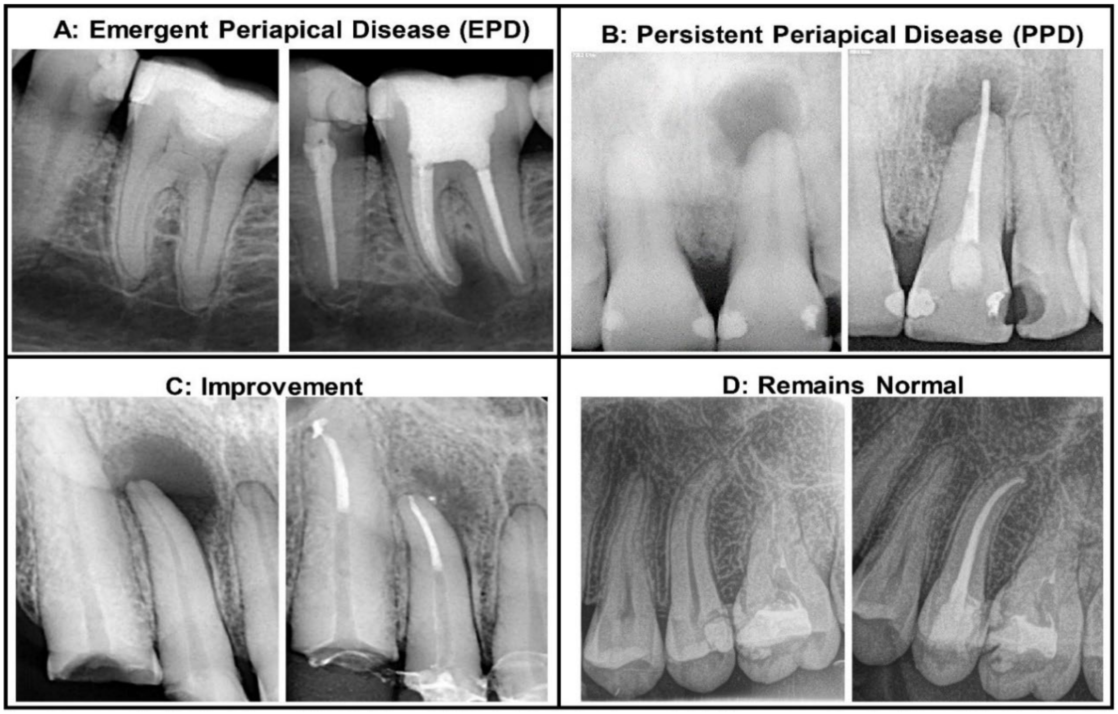

Figure 1. Supplementary Variables; *A)* Emergent Periapical Disease (EPD): Apical periodontitis at follow-up appointment or "novo"; *B)* Persistent Periapical Disease (PPD): Apical periodontitis unresolved after treatment; *C)* Improvement: Apical periodontitis that resolves or improves after carrying out the treatment; *D)* Remains normal: Absence of Apical Periodontitis (Normal periapical structures; or small changes in bone structure) before and after treatment

were taken by a Heliodent Sirona equipment (Heliodent 580921003350 Series 50602; Sirona Dental Systems, Bensheim, Germany) operated at 60-63 Kv, 8 mA and 0.25-0.32 sec of exposure, with a radiation dose of 0.033 mSv, depending on the type and location of the tooth. The parallelism technique was implemented using the XCP ring (Dentsply Rinn, Elgin, IL, USA). Observation was carried out under RVG (Radio Visio Graphy 5100 and Carestream Dental Imaging software, Rochester, NY, USA). The results were stored in digital files using Microsoft Excel 2007/12.0 (Microsoft Corp., Redmond, USA).

Statistical analysis

For continuous variables such as age, a univariate analysis determined ranges, percentiles, averages, and standard deviation. For discrete variables, a count established the proportion and the percentage frequency (n). To verify if there were significant differences between age and the outcomes of primary root canal procedures, a Kruskal-Wallis analysis was set at 95% confidence level. A multiple correspondence analysis established the similarity or proximity between the different factors, therefore, determining trends and rankings among them. The active variables (which participated in the construction of the factorial axes), and the supplementary or illustrative variables represented the categories of the result. The statistical analysis was performed using the statistical software R version 3.3.3 (GNOME Foundation TM, Orinda, CA, USA).

Results

A total of 232 teeth of 155 patients were studied (age range: 55.8±12.8 years, 59% females, 41% males). Failure rate for PRCT was 24% (PPD: 10.3%, EPD: 13.7%). Sixty one percent of teeth were followed over a period of less than 5 years, 24% were followed from 5 to 10 years, and 15% of them were followed over a period of more than 10 years (Table 1). The Kruskal-Wallis analysis (X^2=9.473 and a *P* value of 0.023) determined a statistically significant distribution between age and the primary treatment outcome categories. Therefore, it is possible to affirm that all 4 groups came from different distributions regarding age.

The active and supplementary variables were hierarchically distributed in the factorial planes regarding the multiple correspondence analysis. The active variables of gender, type and location of the tooth, presence or absence of a post-type restoration, and type and role of the restoration did not establish a concrete distribution in relation to the supplementary variables. Therefore, according to the mathematical principle of the analysis (Burt's matrix), it was assumed that variables with a very low cumulative percentage (<20%) were not representative of the primary treatment outcomes due to their low capacity to characterise a result, and consequently, they were excluded from the analysis.

Table 1. Distribution of the active variables in relation to the supplementary variables

Factors/N: 232	N (%)	Failure 56 (24%)				Success 176 (76%)			
		Emergent 32 (13.7 %)		Persistent 24 (10,3%)		Improvement 52 (22.5%)		Remains normal 124 (53.5%)	
Gender									
Male	96 (41)	15	(15,6)	8	(8.4)	22	(22.9)	51	(53.1)
Female	136 (59)	17	(12.5)	16	(11.8)	30	(22.1)	73	(53.7)
Tooth type									
Molar	102 (44)	22	(21.6)	11	(10.8)	20	(19,6)	49	(48)
Premolar	73 (31)	5	(6.8)	5	(6.8)	13	(17.8)	50	(68.5)
Anterior	57 (25)	5	(8.8)	8	(14)	19	(33.3)	25	(43.9)
Tooth localization									
Maxilary	136 (59)	19	(14.0)	17	(12,5)	28	(20,6)	72	(52.9)
Mandibulary	96 (41)	13	(13.5)	7	(7,3)	24	(25)	52	(54.2)
Initial pulpal diagnosis									
Pulp necrosis	80 (34)	0	(0,0)	24	(30)	47	(58.8)	9	(11.3)
Symptomatic irreversible pulpitis	71 (31)	15	(21.1)	0	(0)	1	(1.4)	55	(77.5)
Asymptomatic irreversible pulpitis	58 (25)	13	(22.4)	0	(0)	0	(0)	45	(77.6)
Normal pulp	23 (10)	4	(17.4)	0	(0)	4	(17.4)	15	(65.2)
Apical Periodontitis									
Present	76 (33)	0	(0.0)	24	(31.6)	52	(68.4)	0	(0)
Absent	156 (67)	32	(20.5)	0	(0)	0	(0)	124	(79.5)
Appointment									
1	140 (60)	31	(22.1)	0	(0)	0	(0)	109	(77.9)
2	90 (39)	1	(1.1)	22	(24.4)	52	(57.8)	15	(16.7)
3	2 (1)	0	(0.0)	2	(100)	0	(0)	0	(0)
Apical limit of the filling									
Short	46 (20)	25	(54.3)	9	(19.6)	4	(8.7)	8	(17.4)
Overfilling	13 (6)	1	(7.7)	3	(23.1)	3	(23.1)	6	(46.2)
Flush	173 (75)	6	(3.5)	12	(6,9)	45	(26)	110	(63.6)
Homogeneity of root filling									
Unacceptable	23 (10)	12	(52.2)	5	(21.7)	1	(4.3)	5	(21.7)
Acceptable	209 (90)	20	(9,6)	19	(9,1)	51	(24.4)	119	(56.9)
Taper of root filling									
Unacceptable	13 (6)	9	(69.2)	2	(15.4)	0	(0)	2	(15.4)
Acceptable	219 (94)	23	(10.5)	22	(10.0)	52	(23.7)	122	(55.7)
Ledge									
Yes	12 (5)	6	(50.0)	0	(0,0)	3	(25)	3	(25)
No	220 (95)	26	(11.8)	24	(10.9)	49	(22.3)	121	(55)
Instrument fracture									
Yes	21 (9)	2	(9.5)	5	(23.8)	2	(9.5)	12	(57.1)
No	211 (91)	30	(14.2)	19	(9.0)	50	(23.7)	112	(53.1)
Restoration type									
Direct	86 (37)	6	(7.0)	12	(14.0)	23	(26.7)	45	(52,3)
Indirect	146 (63)	26	(17.8)	12	(8.2)	29	(19.9)	79	(54,1)
Post									
Yes	124 (53)	21	(16.9)	11	(8.9)	21	(16,9)	71	(57.3)
No	108 (47)	11	(10.2)	13	(12.0)	31	(28,7)	53	(49.1)
Restoration role									
Denture abutments	21 (9)	5	(23.8)	1	(4.8)	6	(28.6)	9	(42.9)
Individual	211 (91)	27	(12.8)	23	(10.9)	46	(21.8)	115	(54.5)
Coronal restoration Seal									
Poor seal	17 (7)	5	(29.4)	3	(17.6)	2	(11.8)	7	(41.2)
Good seal	215 (93)	27	(12.6)	21	(9.8)	50	(23.3)	117	(54.4)
Control time									
<5 years	142 (61)	17	(12.0)	18	(12,7)	31	(21.8)	76	(53.5)
5– 10 years	56 (24)	10	(17.9)	5	(8.9)	11	(19.6)	30	(53. 6)
> 10 years	34 (15)	5	(14.7)	1	(2.9)	10	(29.4)	18	(52.9)

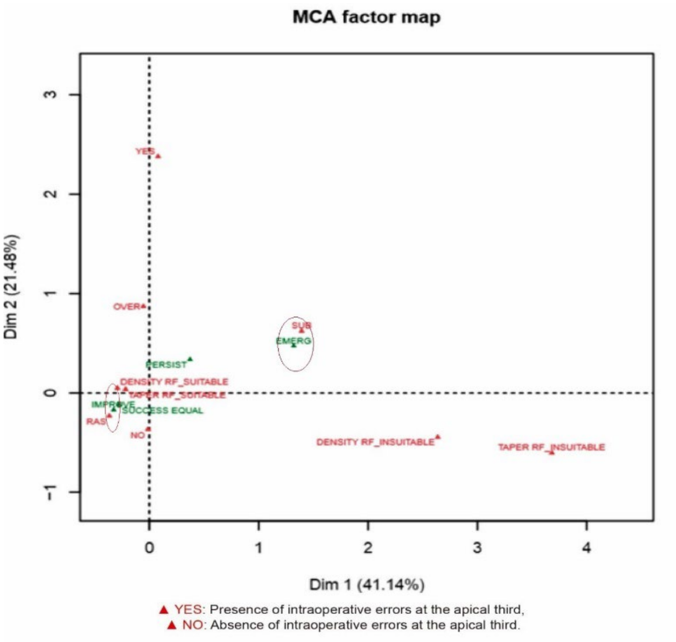

Figure 2. Multiple correspondence analysis that includes the active variables: Quality of the root canal filling (density, taper, and apical limit); Errors (present or absent)

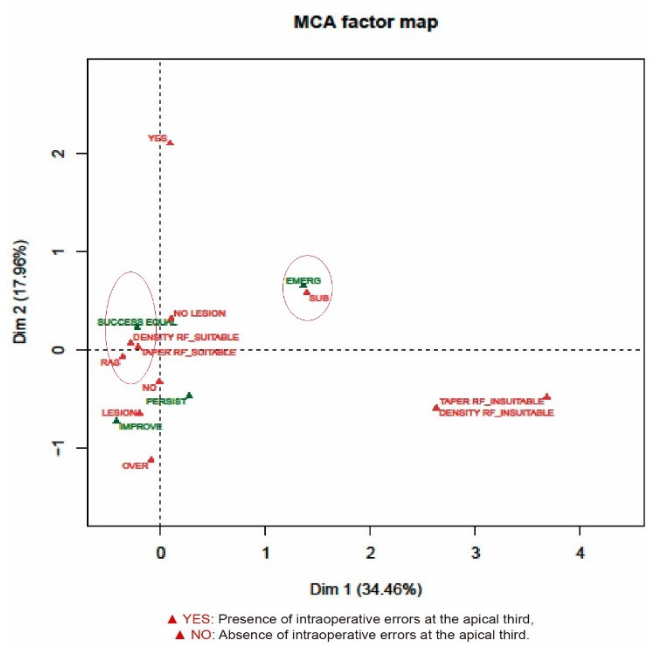

Figure 4. Multiple correspondence analysis that includes the active variables: Quality of the root canal filling (density, taper, and apical limit); Previous periapical status (lesion or no lesion); Errors (present or absent)

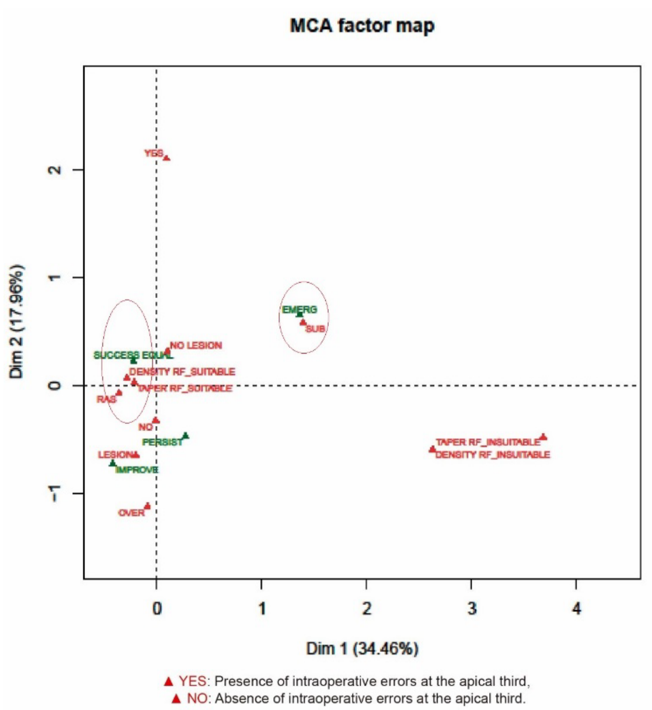

Figure 3. Multiple correspondence analysis that includes the active variables: Restoration quality; (poor or good seal); Restoration role (individual tooth or abutment for a fixed partial denture); Initial pulpal diagnosis (normal, necrosis, symptomatic or asymptomatic pulpitis); and Appointments (ordinal number)

Regarding, the mathematical weight of each active variable in relation to the supplementary one, 63%, 43% or 52% (Figures 2-4), the hierarchy for the factors such as pulpal diagnosis, presence or absence of AP, number of appointments, quality of root filling (apical limit, taper and homogeneity), presence or absence of errors (fracture of instrument or ledge), and quality of the filling was established. Variables were associated according to their spatial position in relation to the outcome categories, *i.e.*, Remains normal, Improvement, PPD, or EPD.

The abovementioned parameters and findings within this study determined that:

The association trend identified that the failure categories (PPD, EPD) are located in the same axis and the same coordinate, establishing a spatial closeness in a same plane, which implies a similarity between the distributions of the modalities they represent. Similar findings are seen within the success categories (Figures 2-4).

The sign of the coordinates was considered together with the representation given by the cosine-squared mathematical function. The points near the center of the plane indicate high frequencies. Conversely, points far from the plane represent unusual modalities.

Similar profiles in spatial distribution recognizable by the proximity between the factors and the supplementary variables established four outcome categories.

Group I: Failure-EPD: Characterized by a short length of filling, followed by previous pulpal diagnosis of inflammation, symptomatic irreversible pulpitis and asymptomatic irreversible pulpitis (Figures 2-4).

Group II: Failure-PPD: Characterized by a previous pulpal diagnosis of necrosis, presence of previous AP, occurrence of intra-operative errors in the apical third of the root, poor seal of the restoration, and overfilling (Figures 3 and 4).

Group III: Success-Improvement: Characterized by a flush length of root filling, absence of intra-operative errors at the apical third, completion of treatment in 2 appointments, and the presence of previous AP (Figures 2 and 3).

Group IV: Success-Remains normal: Characterized by a flush length of root filling, absence of intra-operative errors in the apical third, and an optimal sealing of the restoration (Figures 2 and 3).

Active variables of taper and homogeneity of the root filling were not considered common factors to categorize the outcome. Treatments in three appointments and the presence of intra-operative errors in the apical third represented infrequent modalities. In agreement with the distribution in the axes, it was possible to determine that the active variables that were located in regions opposed to the supplementary variables represented modalities with different and probably opposite distributions (Figures 2-4).

Discussion

A retrospective cohort observational study was conducted to categorise the failure of PRCT by analysing the clinical factors associated with it. A 24% failure rate was determined for 232 teeth with PRCT, followed from 1 to 16 years. The clinical conditions analysed before, and after the endodontic treatment determined two failure categories: PPD, and EPD. The application of the multiple correspondence analysis represented the interaction between intra-operative errors in the apical third and overfilling with PPD, and short filling and pulpitis with EPD, estimating a difference between the failure categories.

Longitudinal endodontic studies and clinical trials are the two main approaches of evaluating the results of PRCT. A 24% treatment failure should raise reflection to identify the dynamic nature of periapical healing and the effect of the endodontic intervention [27].

This failure rate, compared with other populations analysed (the 2006 Toronto Study-Phase III, (14%) [30], Ng *et al.* (32%) [31], and Da Silva *et al.* (21.4%) [32]), allows us to reflect on the difficulty of endodontic treatment for disease control and the causality that is established between clinical factors and treatment failure. Socio-demographic factors, age, sex, and tooth type did not significantly affect endodontic failure. These conclusions, confirmed by previous studies [27], identify the heterogeneous distribution of the population within oral health services, which prevents estimating associations inherent to the individual with the outcome.

These observations divert all attention to microbiological control and the operative clinical factors as specific risks for the appearance of the disease [33]. According to the results, the quality of filling in endodontically treated teeth, with radiographic evidence of length and density of root filling, could be used to assess the treatment outcome [33] .

Analysing the occurrence of post-treatment failure, it was compelling to observe a difference of 3.4% for the occurrence of EPD over PPD. In this regard, Siqueira *et al.* [16] showed that EPD is a secondary infection that appears after a treatment in a tooth that is expected to be free of bacterial contamination. In contrast, PPD confirms the resistance of the bacterial flora to treatment or failure to remove the aetiological factors during treatment. Both entities have been historically associated with poor root fillings and/or the occurrence of intra-operative errors during the mechanical manipulation of the root canal [34]. The present characterisation defined different routes for the emergence or persistence of such disease. As such, the spatial distribution of a short root filling associated with EPD in all possible scenarios constructed by the statistical analysis could determine that a short root filling can alter the prognosis, independently of the previous periapical diagnosis. Ricucci *et al.* [9] reported up to 66.7% failure rate for very short root treatments, confirming that the loss of length during endodontic obturation can be considered as a significant risk factor for the emergence of the disease [35, 36].

The opposite effect determined the flush filling category, which, in all models, is associated with the two success categories proposed in this study, confirming the role played by adequate mechanical and chemical conformation during primary endodontic treatment [9]. In addition, an apical limit of overfilling was spatially related to the persistence of periapical disease, once again confirming how the lack of an apical seal impacts the treatment outcome [36].

On the other hand, Hoskinson *et al.* [37] did not find significant differences between the remaining characteristics (taper and homogeneity) that define the quality of a root filling, which weakly characterise the result of the primary treatment, giving them a lower range of risk for failure compared to the effect that promotes the apical limit of filling [37]. The presence of a previous periapical lesion is considered a predictor of procedural failure. According to Ricucci *et al.* [9], the presence of previous periapical pathosis significantly reduces the success rate of treatment by 9%, and complex anatomical areas may serve as reservoirs of residual infection to cause persistent AP [9]. However, a dependency between bacterial infection before primary treatment and operative efficiency may affect the outcome [38]. Our findings confirm how the presence of AP impacts both the Failure-EPD category and the Success-Improvement category.

This principle further supports the recommendation that better working conditions promote successful procedures and that the presence of pre-operative infection as a potential factor for failure [38], can represent a minimal risk if controlled intracanal techniques are available. According to the results obtained, EPD depends directly on the control of intra-operative factors, mainly the apical limit of the obturation, which could increase the success rate of the PRCT by around 13%.

Emergent periapical disease is unrelated to the occurrence of intra-operative errors, fracture of instruments and the presence of steps. However, when there is evidence of AP before treatment, and an error occurs, the persistence of PPE becomes clear. This identifies an interaction between the presence of previous periapical pathosis and the occurrence of intra-operative errors in the apical third. Marquis *et al.* [30] associates the occurrence of intra-operative errors with the increased risk of treatment failure. However, the interaction that arises becomes evident by characterising the failure in EPE and PPE.

Lastly, a slight association between the quality of the coronal restoration and the outcome can be understood, considering that most of the studied populations (93%) presented an optimal sealing of the coronal restoration. However, a slight relationship between the persistence of the disease and a low-quality restoration was noted [39].

Conclusion

Failure of the PRCT can be characterised as EPD and PPD. Through the spatial associations observed in the distribution of the factors, an interaction between the presence of previous periapical pathosis and the occurrence of intra-operative errors in the apical third was established regarding the persistence of the disease. Additionally, short root fillings represented the greatest association with failure of the primary root treatment, even when there is no previous periapical pathology. Lastly, EPD should be considered as the true failure of PRCT.

Conflict of Interest: 'None declared'.

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