ORIGINAL RESEARCH
Endodontic Therapy

Factors related to apical periodontitis in a southern Brazilian population: a multilevel analysis

Monika Lamas FERREIRA[(a)]
Mônica Pagliarini BULIGON[(b)]
Camila Silveira SFREDDO[(c)]
Gabriela Salatino LIEDKE[(d)]
Renata Dornelles MORGENTAL[(d)]

[(a)]Universidade Federal de Pelotas – UFPel, Graduate Program in Dentistry, Pelotas, RS, Brazil.

[(b)]Universidade Federal de Santa Maria – UFSM, Graduate Program in Dental Sciences, Santa Maria, RS, Brazil.

[(c)]Universidade Federal de Pelotas - UFPel, School of Dentistry, Department of Semiology and Clinics, Pelotas, RS, Brazil

[(d)]Universidade Federal de Santa Maria – UFSM, School of Dentistry, Department of Stomatology, Santa Maria, RS, Brazil.

Abstract: The aim of this cross-sectional study was to evaluate the effects of individual-level and tooth-level factors on apical periodontitis (AP) in an urban population in southern Brazil. A random sample of digital panoramic radiographs (n = 545) from a dental school database was evaluated. The diagnosis of AP was determined by using a dichotomous scale (yes/no). AP was assessed according to gender, age, presence and quality of endodontic treatment (ET), presence of an intracanal post, coronal condition, and dental group. Data were analyzed descriptively and through multilevel Poisson regression analysis, considering teeth characteristics (level 1) nested in individuals (level 2). In this sample of 545 participants, the prevalence of AP was 49.5% (n =2 70) and ET was 43.5% (n = 237). Considering 13,595 teeth, AP was identified in 596 (4.4%) and ET in 617 (4.5%). Of the teeth with ET, 153 (24.8%) presented AP. Among individual-level factors, the disease was not significantly associated with gender or age. For tooth-level factors, AP was significantly associated with ET quality: teeth with short fillings (< 3 mm) and teeth with over-fillings had 2.77 (CI: 1.95–3.94, p < 0.001) and 1.08 (CI: 0.39–2.98, p < 0.001) higher prevalence of AP, respectively. There was no association between AP and age, gender, dental group, coronal condition, or the presence of an intracanal post. AP was highly prevalent in this population, and multilevel analysis indicated a significant association with ET quality.

Keywords: Periapical Periodontitis; Radiography, Panoramic; Endodontics; Observational Study.

Declaration of Interests: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

Corresponding Author:
Renata Dornelles Morgental
E-mail: remorgental@hotmail.com

https://doi.org/10.1590/1807-3107bor-2022.vol36.0112

Submitted: March 7, 2021
Accepted for publication: September 11, 2021
Last revision: May 25, 2022

Introduction

Apical periodontitis (AP) is an inflammatory condition that occurs in the presence of root canal infection at the apex of a tooth root.[1] The pathological process is dynamic and involves complex interactions between microbiological agents and the host immune response.[2] AP often develops asymptomatically and may lead to large areas of bone resorption; in addition, the prognosis is typically less favorable when late detected.[3]

A recent systematic review and meta-analysis of epidemiological studies performed in different countries showed that AP affects a large proportion of the world's population.[4] The prevalence of AP in cross-sectional studies is variable: 27% in a survey conducted in Finland,[5] 40%

in Belgium,[6] and 70% in Lithuania.[7] In Brazil, there are few studies on the epidemiology of endodontics, although there has been an increase in the volume of publications in this field in the last years.[8-14] These studies showed moderate to high frequencies of AP in different regions and populations when panoramic radiographs,[9] periapical radiographs,[10-13] and cone beam computed tomography (CBCT)[14] were used to detect the pathology.

The first therapeutic choice for AP is endodontic treatment (ET), defined as the chemo-mechanical preparation of the root canal system, followed by its filling with a biocompatible material.[9] However, this treatment is not flawless, mainly due to the difficulty of accessing the complex internal anatomy of the teeth and promoting proper disinfection.[15] Therefore, AP may persist after ET, and require complementary therapies.[16] In fact, the prevalence of AP is high in endodontically treated teeth,[9,12] especially in teeth with inadequate fillings concerning apical limits and mass homogeneity.[11,12]

Evidence from longitudinal studies points to the technical quality of ET as one of the main determinant factors for periapical health and tooth maintenance post-treatment.[3,4] However, the importance of coronal sealing has also been widely reported.[4,17] There is some controversy about the impact of the quality of coronal restoration on the success of ET. However, a systematic review demonstrated that the effect is comparable to the quality of ET.[17]

Epidemiological studies contribute to the understanding of the health-disease process of AP and provide valuable information for the development of preventive and therapeutic strategies.[8] Most of these studies used only bivariate analyses to assess the risk factors for AP.[5,6,9-14,17,18] Posterior teeth,[5,9,14,19] the presence of inadequate ET,[5,6,9,11-14,18] and deficient restoration[9,11,18] were factors that significantly correlated to the high prevalence of AP. Although tooth-level variables are very useful to understand the behavior of this disease, it is important to note that patient-level variables, such as age and sex, are confounding factors that should be considered and adjusted by a multivariate analysis.[20]

It is very common in epidemiological studies to analyze data at a single level; however, this approach may result in some valuable information being ignored. Exploring risk factors for AP, which only considers the tooth-level, assumes that this variable is totally independent. This approach ignores the fact that teeth are correlated to a patient with characteristics that can be confusing for the analysis.[21,22] Therefore, this cross-sectional study aimed to evaluate the effect of individual-level and tooth-level factors on AP in an urban population of southern Brazil, using multilevel modeling.

Methodology

Sample selection

This cross-sectional study consisted of 545 digital panoramic radiographs, obtained from patients that attended the Oral Radiology Service of the Federal University of Santa Maria, Santa Maria/RS, Brazil, from October 2013 to December 2017. Participants were referred from the clinics of that Institution or from primary health care units of Santa Maria. The sample size calculation was performed using Epiinfo™ software – version 7.1.5.2 (CDC – Center for Disease Control and Prevention, Atlanta, USA), considering the following parameters: 5957 population size (total number of panoramic radiographs performed during the mentioned period); "worst-case scenario" for the main outcome, apical periodontitis (i.e., 50% prevalence); 4% precision level; 1.0 design effect; and 95% confidence interval. Therefore, a sample size of 545 patients (panoramic radiographs) was established. This study was approved by the Institutional Research Ethics Committee (CAAE: 84181418.7.00005346).

The inclusion criteria were digital panoramic radiographs of good technical quality, taken from individuals aged 16 years or older. The radiographs were analyzed based on their quality by an experienced radiologist that considered patient positioning, head alignment, neck extension, tongue location, and framing. All radiographs were taken using the same unit (OP200D; Instrumentarium Dental, Tuusula, Finland) and the exposure parameters were adjusted to the gender and size of the patient. Radiographs of fully edentulous patients were excluded. Random sampling was performed using computer-generated random numbers (www.random.org/). Individual demographic data (gender and age) were obtained from the radiology service chart.

Radiographic evaluation

All images were assessed using the CliniView software (Instrumentarium Dental, Tuusula, Finland), in a dark room, on a 22-inch computer screen. Observers were free to apply zoom or any other image enhancement function to obtain the best possible interpretation.

Radiographic evaluation was performed by two independent, trained, and calibrated examiners. The training process was conducted under the supervision of a radiologist and consisted of the elucidation of concepts. For calibration, 55 randomly selected panoramic radiographs (10% of the sample) that were not included in the study were analyzed regarding all assessed variables. The evaluation was performed twice, one-week apart. Intra- and inter-examiner agreement was calculated using Cohen's kappa coefficient. Data from both examiners were also compared with those recorded by the reference examiner (radiologist). Substantial and almost perfect values were obtained for the variables assessed. The Kappa values for intra-rater and inter-rater reliability ranged from 0.61 to 0.76 for AP, 0.95 to 1.0 for ET, 0.81 to 0.93 for the ET quality, and 0.73 to 0.91 for coronal condition; for the presence of intracanal post, the value was 1.00. Detailed kappa values and their respective confidence intervals for all the variables assessed are presented in Table 1.

For each radiograph, teeth were classified as follows: absent/lost, present, root remnant, or impacted. Impacted teeth were not included in the evaluation. Present teeth and root remnants were categorized according to the dental group: incisors, canines, premolars, or molars.

Each included tooth was scored according to the criteria described by Huumonen et al.,[5] with minor adaptations. AP was classified as follows: absent, if the periapical structures were normal and with the periodontal ligament space preserved; and present, if there were changes in the normal tissues, such as an enlargement of the periodontal ligament space (twice the standard size) or a radiolucent area associated with the root apex. A multirooted tooth was registered with AP if any of the roots had the pathology.

ET was considered present when there was radiopaque material inside any of the root canals, and absent when no material was visible. Thus, root-filled teeth covered non-surgical and surgical root canal treatments. ET was classified as adequate if the root filling had an apical limit of 3 mm. The distance between the end of the filling and the root apex was measured using a specific software tool. Inadequate ET included short fillings (> 3 mm gap) and overfillings (gutta percha in the apical area).[5,23,24] Multirooted teeth were registered according to the most severe finding: for example, if any of the roots were short filled or overfilled, the treatment was classified as inadequate. If a multirooted tooth had different findings on their roots, the one that indicated

Table 1. Cohen's kappa values for intra and inter-rater reliability.

Variable	AP (95%CI)	ET (95%CI)	ET quality (95%CI)	Intracanal post (95%CI)	Coronal condition (95%CI)
E1	0.75 (0.62–0.87)	0.95 (0.90–1.00)	0.85 (0.72–0.98)	1.00	0.91 (0.86–0.96)
E2	0.61 (0.43–0.78)	0.95 (0.90–0.1.00)	0.93 (0.84–1.00)	1.00	0.90 (0.85–0.95)
E1-R	0.73 (0.60–0.86)	0.99 (0.96–1.00)	0.87 (0.76–0.99)	1.00	0.82 (0.75–0.88)
E2-R	0.76 (0.63–0.90)	1.00	0.81 (0.67–0.95)	1.00	0.73 (0.65–0.80)
E1-E2	0.65 (0.51–0.80)	0.99 (0.96–1.00)	0.93 (0.84–1.00)	1.00	0.81 (0.74–0.87)

E1: intra-examiner 1; E2: intra-examiner 2; E1-R: inter-examiner 1 and radiologist; E2-R: inter-examiner 2 and radiologist; E1-E2: inter-examiners 1 and 2; 95%CI: 95% confidence interval.

> 3 mm of filling material to the apex was classified as the most severe, followed by overfilling.[5,24] Intracanal post was recorded as present or absent.

The coronal aspect was evaluated according to the following scores: 0, healthy crown; 1, presence of restorations in good condition; 2, poor restoration/caries (crowns with open cavities, caries, restorations in bad condition or partially destroyed crowns); and 3, absence of crown (root remnants). In cases where a restoration in good condition was identified, but there was an open cavity or caries on another dental surface, the worst score was considered (score 2).

Statistical analysis

Data were analyzed using Stata (StataCorp. 2014. Stata Statistical Software: Release 14.1. StataCorp LP, College Station, USA). Descriptive statistics were used to describe the demographic and radiographic characteristics of the sample. Unadjusted analyses were conducted to provide summary statistics and preliminary assessments of the evaluated variables (gender, age, presence and quality of ET, presence of intracanal post, coronal condition, and dental group) and the outcome (AP). The models were fitted by multilevel Poisson regression analysis. In the multilevel structure, the teeth characteristics (level 1) were nested within patients (level 2). The multilevel model used the scheme of a fixed effect with random intercept. Results are presented as prevalence ratio (PR) and the corresponding 95% confidence interval (CI). Only variables that yielded a p-value < 0.20 in the unadjusted analyses were considered for the adjusted model. They were retained in the final model only if they had a p-value < 0.05 after adjustment. The quality of the fit of the model was evaluated using the deviance (–2 log likelihood) and the median incidence rate ratio (MIRR).

Results

Table 2 shows the individual and tooth characteristics of the sample. A total of 545 participants were

Table 2. Individual and tooth characteristics of the sample.

Variable	n (%)	AP n (%)
Individual (n = 545)		
Gender		
Female	352 (64.6)	176 (50.0)
Male	193 (35.4)	94 (48.7)
Age [mean (standard deviation)]	40.25 (16.6)	
Tooth (n = 13,595)		
Dental group		
Incisor	3,904 (28.7)	104 (2.6)
Canine	2,029 (14.9)	49 (2.4)
Premolar	3,524 (25.9)	139 (3.9)
Molar	4,138 (30.4)	304 (7.3)
Coronal condition		
Healthy/with adequate restoration	12,905 (94.9)	257 (2.0)
Unhealthy	690 (5.1)	339 (49.1)
Endodontic treatment		
Absent	12,978 (95.5)	443 (3.4)
Present	617 (4.5)	153 (24.8)
Endodontic treatment quality (n=617)		
Adequate	445 (72.1)	74 (16.6)
Short filling (< 3mm)	149 (24.1)	75 (50.3)
Overfilling	23 (3.7)	4 (17.4)
Intracanal post		
Absent	13,426 (98.7)	416 (3.1)
Present	169 (1.3)	42 (24.8)
Present in RFT (n = 617)	168 (27.2)	41 (24.4)

AP: apical periodontitis; RFT: root-filled teeth.

evaluated, with a majority of women (64.6%). The age of the participants ranged from 16 to 101 years old, with a mean of 40.25 [standard deviation (SD) = 16.61] years. The prevalence of AP was 49.5% (n = 270) with a mean of 1.09 (SD = 1.59) per individual, while ET was found in 43.5% (n = 237) of the sample with a mean of 1.13 (SD = 1.84) per individual. A total of 13,595 teeth were evaluated. Of these, 13,380 were classified as erupted teeth and the remainder as root remnants (n = 215). The average number of erupted teeth per subject was 24.94 (± 7.08; min. 1; max. 32). Of all evaluated teeth (n = 13,595), 4.4% had AP (n = 596) and 4.5% had ET (n = 617). AP was found in 3.4% of teeth without root filling (n = 443) and in 24.8% of root-filled teeth (n = 153). The root filling quality was considered adequate in 72.1% (n = 445) of the root-filled teeth. The presence of an intracanal post was identified in 169 teeth (1.3%), with one tooth having an intracanal post without ET. Furthermore, most coronal conditions were classified as healthy or with adequate restoration (94.3%).

The crude and adjusted multilevel Poisson regression models for the AP outcome are shown in Table 3. In the crude analysis, age was the individual-related variable associated with the prevalence of AP. In addition, the tooth-related variables ET quality, coronal condition, and dental group were also associated with the prevalence of AP. In the adjusted analysis, age was not associated with AP for individual-related variables ($p > 0.15$). For the tooth-related variables, only ET quality was associated with AP. The prevalence ratio (PR) of AP was 2.77 (CI: 1.95–3.94, $p < 0.001$) for teeth with short fillings (< 3 mm) and 1.08 (CI: 0.39–2.98, $P < 0.001$) for overfilled teeth. Poisson multilevel modeling showed a significant effect of the individual level: MIRR = 3.18.

Table 3. Crude and adjusted multilevel Poisson regression for apical periodontitis.

Variable	Crude		Adjusted*†	
	PR (95%CI)	p-value	PR (95%CI)	p-value
Individual (n = 545)				
Gender		0.21		
Female	1			
Male	1.21 (0.90–1.63)			
Age	1.04 (1.04–1.05)	< 0.01	1.01 (0.99–1.02)	0.15
Tooth (n = 13,595)				
Endodontic treatment quality		< 0.01		< 0.01
Adequate	1		1	
Short filling (< 3 mm)	3.03 (2.19–4.17)		2.77 (1.95–3.94)	
Overfilling	1.04 (0.38–2.86)		1.08 (0.39–2.98)	
Intracanal post		0.97		
Absent	1			
Present	1.00 (0.70–1.43)			
Coronal condition		< 0.01		0.36
Healthy/adequate restoration	1		1	
Unhealthy	9.19 (8.08–10.44)		1.09 (0.89–1.34)	
Dental group		< 0.01		0.17
Incisor	1		1	
Canine	0.87 (0.62–1.23)		1.31 (0.70–2.46)	
Premolar	1.56 (1.21–2.01)		1.24 (0.78–1.96)	
Molar	3.28 (2.59–4.08)		1.44 (0.88–2.36)	

95%CI: 95% confidence interval; PR: prevalence ratio. *Deviance (-2log l).

Discussion

The aim of this study was to investigate the effect of individual-level and tooth-level factors on AP in a sample from an urban population of southern Brazil, using multilevel modeling. The prevalence of AP identified in this sample (49.5%) is consistent with similar studies conducted in Brazil[10,12,14] and with the world prevalence, where AP was observed in 52% of the patients.[4] A survey conducted on a representative sample of the Finnish population found an AP prevalence of only 27%.[5] However, the relatively low prevalence of the disease in the former investigation may be associated with the high socioeconomic status of Scandinavian countries, which explains the low incidence of caries and subsequent AP in that population. Concerning ET, 43.5% of the sample evaluated in this study presented at least one root-filled tooth. These findings agree with studies from different geographical locations,[17,19,25] in which the prevalence of ET has been described between 40.6% and 61.2%.

When teeth were the unit of analysis, the prevalence of AP was 4.4%, similar to other studies (1.4 to 12.1%).[6,12,14] ET was observed in 4.5% of the teeth, a relatively lower value when compared with the results of Fernandes et al. (7.4%),[14] Terças et al. (11%),[10] and Oginni et al. (12.2%).[25] However, it is considered high when compared to the prevalence of 2.1% in the Spanish population evaluated by Jiménez-Pinzón et al.[19]

This study sample revealed more women (64.6%) than men (35.4%). Previous studies have presented similar results, emphasizing that this gender discrepancy in the search for dental services is due to the fact that women express more concern about their oral health, appearance, and general well-being.[9,13,19] However, no significant association between AP and gender was verified, corroborating other epidemiological studies.[7,9,19] Age was also not significant, which contradicts with other authors.[9,10,14,18,19]

The results of the adjusted multilevel analysis showed that the quality of ET was the only variable significantly related to AP. The prevalence of inadequate ET in epidemiological studies worldwide is quite variable and can be as high as 70% of the sample.[4,11,12,14] In this study, 27.9% of teeth with ET had inadequate root fillings. The lower prevalence may be related to the criteria used, since a gap of 3 mm probably underestimates the presence of an inadequate filling.[5] However, in an epidemiological context, using panoramic radiographs, this criterion is reliable.[5] Teeth with short fillings (PR = 3.03) had higher prevalence rates of AP than overfilled teeth (PR = 1.04). Although extrusion of non-biocompatible materials could cause foreign body reactions and persistent local inflammation, the lack of cleaning and disinfection in the apical portion of the root canal, which is usually associated with incomplete treatments, has been shown to be more detrimental to periapical health than extravasation of obturator material.[3,23] Regardless of some studies highlighting that the coronal condition[17] and the dental group[5,18] may be related to the prevalence of AP, this study did not find such associations.

The panoramic radiograph is considered the most practical exam for initial evaluation because it is fast, inexpensive, produces low radiation, and is already widely used, especially in the public sector.[5,9,18] Other techniques, such as periapical radiography and CBCT,[26] are more sensitive for detecting AP, but require more time for image acquisition, produce higher radiation dose for the patient, and also have more restricted indications, not fitting the objective of this study to investigate AP via a triage service database. Moreover, the higher sensitivity of CBCT was also related to a higher rate of false-positive results.[27] In view of this, despite being the lowest sensitivity technique among the three aforementioned, the panoramic radiograph is sufficiently sensitive to identify AP and ET[5,6,9,18,28] and is considered adequate for this study design.

A limitation of this study is related to the evaluation of a convenience sample that consisted mainly of young adults. This finding can be explained by the fact that many students attend dental care at the university and are referred to the Oral Radiology Service for further examinations. Therefore, the application of our results to the general population is limited and should be done with caution. Nevertheless, the use of convenience samples, especially from universities, is frequent among endodontic epidemiology studies.[6,14,19,25] In addition, cross-sectional studies are limited in nature, and the significant associations demonstrated here, as in any other cross-sectional study, do not indicate a cause-effect relationship. It is impossible to identify whether ET preceded the alleged AP, and whether it was a chronic lesion, a healing lesion, or a scar tissue.[27] Only the patient's dental history or longitudinal studies could provide this information.

The small number of predictors selected in our study should also be emphasized. Other individual-level and tooth-level variables may be associated with AP, such as socioeconomic status and systematic diseases.[4] This limitation is related to the use of secondary data. The number of variables affects the regression model results and, if a more complete picture of the individual and tooth's conditions were included, the association data could change. Moreover, the evaluation of coronal conditions using just radiographic images could underestimate results because radiographic examination may not detect minor defects such as microleakage in occlusal margins, cracks, and perforations, which should be seen during clinical assessment.[29]

On the other hand, the strength of the current study was the ability to consider the cross-sectional data in light of multilevel modeling, considering the patient and the teeth as different, but interconnected, units. Most studies conducted with Brazilian populations used less complex statistical tests, such as chi-square and bivariate regression, and thus may have misidentified some associations.[9,10,11,12,13,14] While bivariate analysis highlights the individual contribution of factors, multilevel analysis reveals valuable information hidden in the observations.[30] Age, dental group, and coronal condition, which were previously demonstrated to be individually related to the outcome,[5,9-14,18,19,25] had no significant association in the present study. This emphasizes that the analysis of variables at a single level presupposes that each tooth or individual is independent, when in fact they are nested and correlated, assigning different weights to each variable that operate differently at each level (tooth/patient).

Conclusion

AP was highly prevalent in this population and multilevel analysis indicated a significant association with ET quality. The multilevel analysis strengthens the body of evidence relating the ET quality to the AP outcome. The findings of this study may help identify the factors that influence treatment success and plan oral health policies for improving access to endodontic treatment.

References

1. Abbott PV. Classification, diagnosis and clinical manifestations of apical periodontitis. Endod Topics. 2004 July; 8(1):36-54, 2004. https://doi.org/10.1111/j.1601-1546.2004.00098.x
2. Siqueira Junior JF, Rôças IN. Bacterial pathogenesis and mediators in apical periodontitis. Braz Dent J. 2007;18(4):267-80. https://doi.org/10.1590/S0103-64402007000400001
3. Ricucci D, Russo J, Rutberg M, Burleson JA, Spångberg LS. A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011 Dec;112(6):825-42. https://doi.org/10.1016/j.tripleo.2011.08.003
4. Tibúrcio-Machado CS, Michelon C, Zanatta FB, Gomes MS, Marin JA, Bier CA. The global prevalence of apical periodontitis: a systematic review and meta-analysis. Int Endod J. 2021 May;54(5):712-35. https://doi.org/10.1111/iej.13467
5. Huumonen S, Suominen AL, Vehkalahti MM. Prevalence of apical periodontitis in root filled teeth: findings from a nationwide survey in Finland. Int Endod J. 2017 Mar;50(3):229-36. https://doi.org/10.1111/iej.12625
6. De Moor RJ, Hommez GM, De Boever JG, Delmé KI, Martens GE. Periapical health related to the quality of root canal treatment in a Belgian population. Int Endod J. 2000 Mar;33(2):113-20. https://doi.org/10.1046/j.1365-2591.2000.00295.x
7. Aleksejuniene J, Eriksen HM, Sidaravicius B, Haapasalo M. Apical periodontitis and related factors in an adult Lithuanian population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000 Jul;90(1):95-101. https://doi.org/10.1067/moe.2000.107059
8. Bueno MR, Estrela C. Prevalence of endodontic treatment and apical periodontitis in several populations of world, detected by panoramic and periapical radiography and cone beam computed tomography. ROBRAC. 2008;17(43):79-90.

9. Pedro FM, Marques A, Pereira TM, Bandeca MC, Lima S, Kuga MC, et al. Status of endodontic treatment and the correlations to the quality of root canal filling and coronal restoration. J Contemp Dent Pract. 2016 Oct;17(10):830-6. https://doi.org/10.5005/jp-journals-10024-1939
10. Terças AG, Oliveira AE, Lopes FF, Maia Filho EM. Radiographic study of the prevalence of apical periodontitis and endodontic treatment in the adult population of São Luís, MA, Brazil. J Appl Oral Sci. 2006 Jun;14(3):183-7. https://doi.org/10.1590/S1678-77572006000300007
11. Estrela C, Leles CR, Hollanda AC, Moura MS, Pécora JD. Prevalence and risk factors of apical periodontitis in endodontically treated teeth in a selected population of Brazilian adults. Braz Dent J. 2008;19(1):34-9. https://doi.org/10.1590/S0103-64402008000100006
12. Hebling E, Coutinho LA, Ferraz CC, Cunha FL, Queluz DP. Periapical status and prevalence of endodontic treatment in institutionalized elderly. Braz Dent J. 2014;25(2):123-8. https://doi.org/10.1590/0103-6440201302348
13. Berlink T, Tinoco JM, Carvalho FL, Sassone LM, Tinoco EM. Epidemiological evaluation of apical periodontitis prevalence in an urban Brazilian population. Braz Oral Res. 2015 Feb;29(1):1-7. https://doi.org/10.1590/1807-3107BOR-2015.vol29.0051
14. Fernandes LMPSR, Duarte MAH, Alvares Capelozza AL. Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation. Dentomaxillofac Radiol. 2013 Jan;42(1):1-6. https://doi.org/10.1259/dmfr/80179163
15. Wu MK, Dummer PM, Wesselink PR. Consequences of and strategies to deal with residual post-treatment root canal infection. Int Endod J. 2006 May;39(5):343-56. https://doi.org/10.1111/j.1365-2591.2006.01092.x
16. Friedman S. Considerations and concepts of case selection in the management of post-treatment endodontic disease (treatment failure). Endod Topics. 2002 Nov;1(1):54-78. https://doi.org/10.1034/j.1601-1546.2002.10105.x
17. Gillen BM, Looney SW, Gu LS, Loushine BA, Weller RN, Loushine RJ, et al. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. J Endod. 2011 Jul;37(7):895-902. https://doi.org/10.1016/j.joen.2011.04.002
18. Vengerfeldt V, Mändar R, Nguyen MS, Saukas S, Saag M. Apical periodontitis in southern Estonian population: prevalence and associations with quality of root canal fillings and coronal restorations. BMC Oral Health. 2017 Dec;17(1):147. https://doi.org/10.1186/s12903-017-0429-7
19. Jiménez-Pinzón A, Segura-Egea JJ, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV. Prevalence of apical periodontitis and frequency of root-filled teeth in an adult Spanish population. Int Endod J. 2004 Mar;37(3):167-73. https://doi.org/10.1111/j.0143-2885.2004.00759.x
20. Kirkevang LL, Vaeth M, Hörsted-Bindslev P, Bahrami G, Wenzel A. Risk factors for developing apical periodontitis in a general population. Int Endod J. 2007 Apr;40(4):290-9. https://doi.org/10.1111/j.1365-2591.2007.01224.x
21. Gilthorpe MS, Griffiths GS, Maddick IH, Zamzuri AT. The application of multilevel modelling to periodontal research data. Community Dent Health. 2000 Dec;17(4):227-35.
22. Hussein FE, Liew AK, Ramlee RA, Abdullah D, Chong BS. Factors associated with apical periodontitis: a multilevel analysis. J Endod. 2016 Oct;42(10):1441-5. https://doi.org/10.1016/j.joen.2016.07.009
23. Kirkevang LL, Hörsted-Bindslev P, Ørstavik D, Wenzel A. A comparison of the quality of root canal treatment in two Danish subpopulations examined 1974-75 and 1997-98. Int Endod J. 2001 Dec;34(8):607-12. https://doi.org/10.1046/j.1365-2591.2001.00436.x
24. Chugal NM, Clive JM, Spångberg LS. Endodontic infection: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003 Jul;96(1):81-90. https://doi.org/10.1016/S1079-2104(02)91703-8
25. Oginni AO, Adeleke AA, Chandler NP. Root canal treatment and prevalence of apical periodontitis in a nigerian adult subpopulation: a radiographic study. Oral Health Prev Dent. 2015;13(1):85-90. https://doi.org/10.3290/j.ohpd.a31661
26. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod. 2008 Mar;34(3):273-9. https://doi.org/10.1016/j.joen.2007.11.023
27. Kruse C, Spin-Neto R, Evar Kraft DC, Vaeth M, Kirkevang LL. Diagnostic accuracy of cone beam computed tomography used for assessment of apical periodontitis: an ex vivo histopathological study on human cadavers. Int Endod J. 2019 Apr;52(4):439-50. https://doi.org/10.1111/iej.13020
28. Molander B, Ahlqwist M, Gröndahl HG, Hollender L. Comparison of panoramic and intraoral radiography for the diagnosis of caries and periapical pathology. Dentomaxillofac Radiol. 1993 Feb;22(1):28-32. https://doi.org/10.1259/dmfr.22.1.8508938
29. Craveiro MA, Fontana CE, de Martin AS, Bueno CE. Influence of coronal restoration and root canal filling quality on periapical status: clinical and radiographic evaluation. J Endod. 2015 Jun;41(6):836-40. https://doi.org/10.1016/j.joen.2015.02.017
30. Aarts E, Verhage M, Veenvliet JV, Dolan CV, van der Sluis S. A solution to dependency: using multilevel analysis to accommodate nested data. Nat Neurosci. 2014 Apr;17(4):491-6. https://doi.org/10.1038/nn.3648