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RESEARCH

Apical periodontitis and associated factors in a rural population of southern Brazil: a multilevel analysis

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Abstract

Objectives This study aims to evaluate the association between apical periodontitis (AP) and sociodemographic/clinical factors in a probability sample of individuals living in a rural area of southern Brazilian.

Materials and methods A cross-sectional study was conducted involving 584 non-edentulous adult individuals who had undergone a full-mouth radiographic survey. Periapical status was analysed using the periapical index (PAI). Endodontic status was evaluated considering the occurrence of voids in the filling material and the root filling length. Crown status was classified based on the presence of caries, restorations, and prosthetic crowns. Sociodemographic variables, frequency of dental care, and periodontal disease were also registered. The data were analysed using hierarchical multilevel Poisson regression analysis. The multilevel structure was composed of three models: sociodemographic variables, clinical variables, and clinical variables adjusted by sociodemographic variables ($\alpha = 5\%$).

Results The prevalence of AP in the sample was 60.45%. AP was significantly associated with age, skin colour, schooling, periodontal disease, and frequency of dental care ($P < 0.005$). Among the 10,396 teeth evaluated, 868 (8.35%) had AP, which was significantly associated with tooth group, dental arch, crown status, and endodontic treatment ($P < 0.005$).

Conclusions The prevalence of AP was high in the population studied. An older age, black/brown skin colour, low level of schooling, infrequent dental care, severe periodontal disease, mandibular teeth, posterior teeth, inadequate crown status, and having undergone endodontic treatment were significantly associated with the outcome.

Clinical relevance

This study about a rural probability sample reinforces that AP is still a recurrent oral health problem.

Keywords Apical periodontitis · Prevalence · Endodontics · Rural population

Introduction

Apical periodontitis (AP) is a chronic inflammatory condition that occurs as a dynamic host defence response to microbial infection in the root canal system [1]. This disease has been associated with individual factors, such as age, sex, systemic health, and socioeconomic status [2–4]. A recent systematic review and meta-analysis of 114 epidemiological studies demonstrated that half of the global population has at least one tooth with AP [5].

Endodontic treatment (ET) is the therapy of choice for teeth with AP [6]. The goal is to ensure a reduction in the intracanal microbiota to enable the healing of the periapical tissues [7]. It is well-known that endodontic infection and reinfection are correlated with ET failure and persistent AP

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[1, 8, 9]. Microorganisms can remain in areas of restricted access within the root canal system or penetrate the root canals due to a failure of a coronal restoration [10].

Most studies on the prevalence and risk factors/indicators of AP have been conducted using convenience samples at universities, hospitals, or private practices in urban areas of different countries [5]. In Brazil, approximately 15% of the population lives in rural areas [11]. Rural populations are more likely to have poor social indicators, high frequencies of chronic diseases, and worse quality of life [12, 13]. Most rural areas do not have specialized health care services, mainly due to difficulties related to access, precarious transportation services, and distances between properties [14, 15]. Such aspects may also be one of the reasons for the scarcity of endodontic studies involving rural populations [16].

Cross-sectional studies have inherent limitations but assist in understanding the current context of a specific population [17, 18]. Data from a probability sample, as reported by Huumonen et al. [19], provide relevant information on the living conditions of the population, the prevalence of diseases, and the efficacy of health care services [17]. Moreover, the findings can be used in the planning, evaluation, and monitoring of oral health interventions.

Most epidemiological studies employ bivariate analysis to evaluate risk factors/indicators of AP [6, 19–22]. In this type of analysis, each variable is seen as independent. In reality, however, variables are actually nested and correlated [23]. So, if we are evaluating AP assuming that each tooth is an independent unity, we ignore the clustering effects of teeth within individuals. Multilevel analysis reveals that risk factors/indicators behave differently on each level and may function as confounders that should be identified and controlled [24–26].

Therefore, the aim of the present study was to evaluate possible associations between AP and sociodemographic/clinical factors in a probability sample composed of individuals from a rural population in southern Brazil using multilevel analysis.

Materials and methods

This study received approval from the Research Ethics Committee at the Federal University of Santa Maria (certificate number: 37862414.5.0000.5346) in the city of Santa Maria, Brazil, and was conducted in accordance with the ethical precepts of the Declaration of Helsinki. Volunteers who agreed to participate signed an informed consent form. All participants received a written report with details on their oral health status and were referred for dental treatment whenever necessary. The present observational study was reported following the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) Checklist and Statement [27].

Subjects

This study is part of a population-based, cross-sectional survey conducted in the city of Rosário do Sul, located in the state of Rio Grande do Sul in southern Brazil. The city has approximately 40,000 residents, 4776 of whom live in rural areas [11]. The research was funded by the Federal University of Santa Maria and Rosário do Sul City Hall.

The data were collected between March 2015 and May 2016. Detailed information on data collection procedures and sample size calculation can be found elsewhere [28, 29]. A representative sample of individuals residing in rural areas was obtained using a multistage probability sampling method. Among the 1087 individuals recruited, 688 agreed to participate and 584 met the eligibility criteria. The inclusion criteria were individuals aged 18 years or older who had at least one natural tooth, submitted to clinical examination and full-mouth periapical radiographic survey. The exclusion criteria were subjects with invalid radiographic exams (incomplete images of dental or support structures and images of insufficient quality) (Fig. 1).

Sociodemographic characteristics were collected using specific questionnaires addressing sex, age, skin colour, schooling, income, and oral health behaviours. Skin colour was dichotomised as "white" or "black/brown" [11]. Schooling was dichotomised as ≤ or > 8 years of formal education (which corresponds to primary school in Brazil). Household income was based on the median of the sample and was recorded in Brazilian currency (R$).

A complete periodontal examination (visible plaque index, retentive plaque factors, gingival bleeding index, pocket probing depth, bleeding on probing, suppuration on probing, clinical attachment loss, and furcation involvement) was performed at six sites per tooth. Intra-examiner and inter-examiner agreement for pocket probing depth and clinical attachment loss was determined using the intraclass correlation coefficient (ICC). ICC/Kappa > 0.80 was considered indicative of satisfactory reproducibility [28]. The criteria proposed by Eke et al. [30] were considered for the diagnosis of periodontal disease. The authors proposed the inclusion of the definition of mild periodontitis considering clinical attachment loss and pocket probing depth as a complement to assist in determining the prevalence of periodontitis.

Radiographic examination

A mobile unit consisting of a trailer equipped with a complete dental unit (dental chair, artificial light, compressor, dental x-ray machine, and other basic amenities) was used

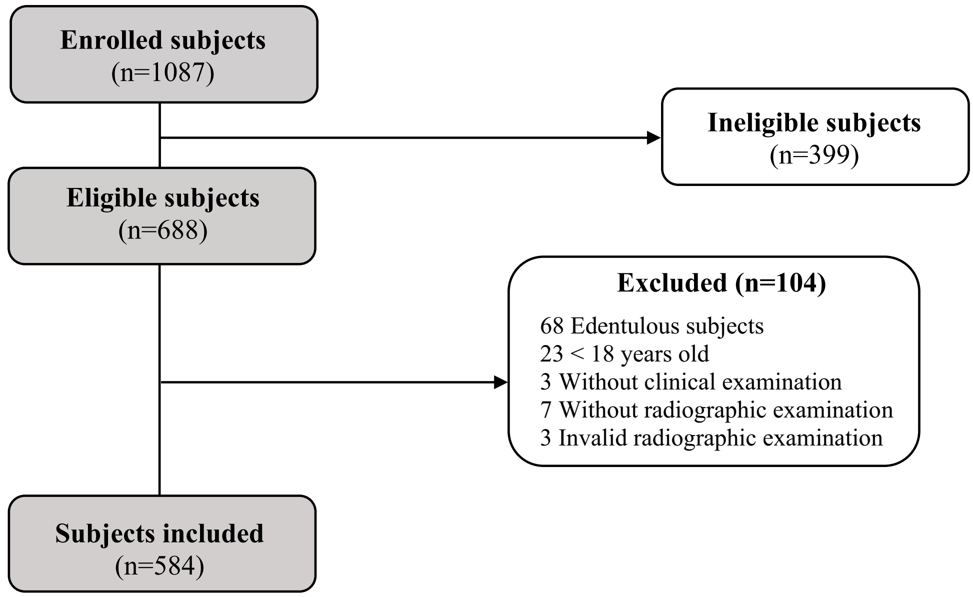

Fig. 1 Flowchart (subjects included in study)

for clinical and radiographic examinations, following radioprotection and biosafety principles.

A full-mouth radiographic examination was performed using an intraoral digital x-ray sensor (RVG 5100/#1; Carestream Dental, Atlanta, GA, USA), intraoral sensor holders (XCP-DS; DENTSPLY Rinn), and an x-ray unit (ProDental, São Paulo, SP, Brazil; 70 kVp, 10 mA, 0.5-s exposure time). Third molars were excluded from the examination.

The Kodak Dental Imaging Software version 6 (Carestream Dental, Atlanta, GA, USA) was used to view the radiographic images on a computer with a 20-inch screen, 1600 × 900-pixel resolution, and 60 Hz (AOC, Manaus, AM, Brazil). The observers were free to apply any image enhancement function (sharpness, brightness, contrast, negative, and colour changes) to obtain the best possible assessment, as described by Huumonen et al. [19].

Radiographic analysis

Apical periodontitis

The periapical index (PAI) was used for the determination of AP [30]. Teeth with PAI 1 or 2 were considered healthy, and those classified with PAI ≥ 3 were deemed to be diseased [20]. For multirooted teeth, the root with the worst score was used to represent the PAI index of the entire tooth. Cases of root remnants were also recorded. Teeth with no visible apical structure in the radiographic image were excluded from the analysis.

Endodontic treatment and crown status

Endodontic treatment (ET) and crown status were assessed using the parameters displayed in Table 1, which were adapted from Kirkevang et al. [20]. Root filling length was determined by measuring the distance from the end of the root filling to the radiographic apex using a Kodak Dental Imaging measurement tool. Endodontic variables were dichotomized as adequate or inadequate for statistical analysis. The following parameters were evaluated: lateral seal of root filling — code 0 was considered adequate and codes 1 to 3 were considered inadequate; length of root filling — codes 0 and 2 were considered adequate and all other codes were considered inadequate. ET was rated adequate only when both lateral sealing and length of root filling were adequate. For the evaluation of ET quality in multirooted teeth, the score of the root with the "worst scenario" was selected. The presence of an intracanal post was recorded. Crown status was also dichotomized: codes 0, 1, and 5 were considered adequate, whereas codes 2, 3, 4, 6, 7, and 8 were considered inadequate (Table 1).

Training and calibration of observers

Two observers underwent training and calibration exercises for the radiographic evaluation under the supervision of a single radiologist. One observer was responsible for determining AP and the other assessed endodontic and

Table 1 Parameters, registrations, and codes related to endodontic and crown status

Parameters		Registrations and codes
Endodontic status	Endodontic treatment	0 = absent 1= present
	Lateral seal of root filling (adequate = no voids)	0 = adequate 1/2 coronal and adequate 1/2 apical 1 = adequate 1/2 coronal and inadequate 1/2 apical 2 = inadequate 1/2 coronal and adequate 1/2 apical 3 = inadequate 1/2 coronal and inadequate 1/2 apical
	Length of root filling	0 = adequate ≤ 2 mm from radiographic apex 1 = inadequate > 2mm from radiographic apex 2 = *flush*, root filling ending at the radiographic apex 3 = overfilling, root filling material in periapical area 4 = pulpotomy, material seen only in pulp chamber
	Intracanal post	0 = absent 1 = present
Crown status		0 = healthy 1 = adequate radiopaque restoration 2 = inadequate radiopaque restoration (overhangs) 3 = inadequate radiopaque restoration (open margins) 4 = caries/open cavity/radiolucent restoration 5 = adapted prosthetic crown 6 = non-adapted prosthetic crown 7 = root remnant 8 = non-carious lesions
Periapical index (Ørstavik et al. 1986)		1 = normal periapical structures 2 = small changes in bone structures 3 = changes in bone structures with some mineral loss 4 = periodontitis with well-defined radiolucent area 5 = severe periodontitis with exacerbating features

Adapted from Kirkevang et al. (2001)

crown status. Calibration consisted of assessing 30 randomly selected periapical radiographs (www.randomizer.com) twice with a 1-week interval between assessments. Intra-examiner and inter-examiner *Kappa* coefficients for AP were 0.70 and 0.80, respectively. For the other variables, *Kappa* coefficients were as follows: 0.68 (intra) and 0.83 (inter) for lateral seal of root filling; 0.90 (intra) and 0.88 (inter) for length of root filling; 1.00 (intra) and 1.00 (inter) for presence of intracanal post; 0.83 (intra) and 0.70 (inter) for crown status (SPSS Statistics v. 24 software; IBM SPSS Inc., Chicago, IL, USA).

Statistical analysis

Data were analysed using the Stata Statistical Software (Release 14.1; StataCorp LLC, College Station, TX, USA). Descriptive statistics were used to report the sociodemographic and clinical characteristics of the sample. Unadjusted analyses were conducted to provide summary statistics and preliminary assessments of associations between the variables of interest (sex, age, skin colour, schooling, household income, tooth brushing frequency, visits to a dentist, number of teeth, dental arch, tooth group, crown status, presence and quality of ET, presence of intracanal post, periodontal disease) and the outcome (AP). Only variables that generated a *P*-value <0.20 in the unadjusted analyses were incorporated into the adjusted model and only those with a *P*-value <0.05 after adjustment were retained in the final models. The models were fitted using hierarchical multilevel Poisson regression analysis to assess associations between AP and sociodemographic/clinical variables. In the multilevel framework, the adjusted table was composed of three models: Model 1 — only sociodemographic variables (sex, age, skin colour, schooling); Model 2 — only clinical variables (dental visits, periodontal disease, dental arch, tooth group, crown status, ET quality, presence of intracanal post); Model 3 — clinical variables adjusted by sociodemographic variables (Fig. 2). The multilevel model involved a fixed-effects approach with a random intercept. The results are presented as prevalence ratios (PR) and respective 95% confidence intervals (CI). The goodness of fit of the model was evaluated using deviance (−2 log-likelihood). Significant changes in the fit of the models were assessed using the likelihood ratio test.

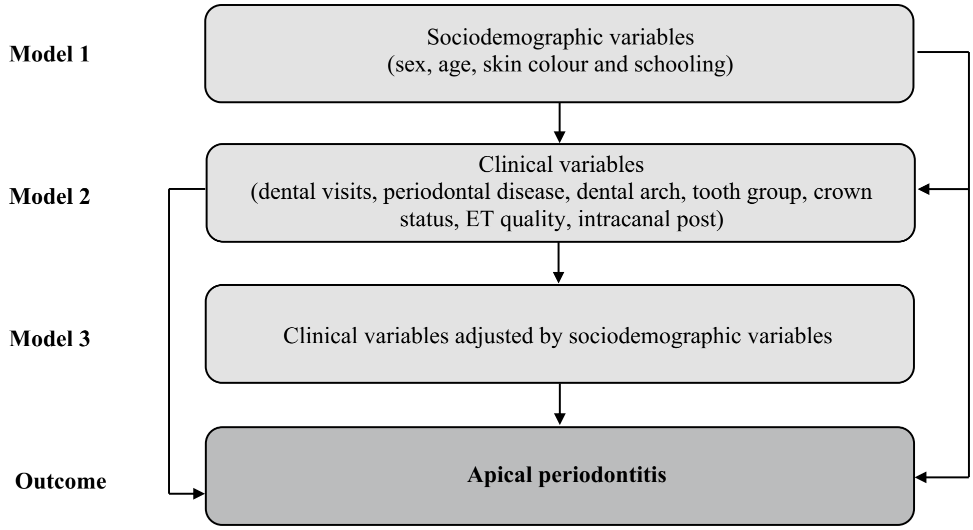

Fig. 2 Conceptual model for analysis of the association between independent variables and outcome (apical periodontitis)

Results

A total of 584 individuals were evaluated. The characteristics of the participants are displayed in Table 2.. Men comprised 50.51% of the sample. Age ranged from 18 to 93 years, with a mean of 47.23 years (SD: ± 15.39). The sample was predominantly composed of white individuals (68.49%), with ≤ eight years of schooling (77.91%), and an income above R$ 1,125 (62.76%). More than half of sample visited the dentist less than once per year (56.34%). Although 94.18% reported brushing their teeth more than twice per day, 84.31% were diagnosed with severe periodontal disease.

The prevalence of individuals with diagnostic of AP in this rural population was 60.45% ($n = 353$). The number of lesions per individual ranged from 0 to 12 (mean: 1.52, SD: ± 1.82). The prevalence of individuals who had ET was 20.72% ($n = 121$). The minimum and maximum number of ETs per patient were 0 and 8, respectively (mean: 0.36, SD: ± 0.81).

A total of 10,396 teeth were examined, 281 (2.70%) of which were classified as root remnants. The mean number of teeth per individual was 17.80 ± 6.76 (range: 1 to 28). A total of 868 teeth exhibited AP (8.35%) and 211 had a history of ET (2.03%). Crown status was classified as adequate for most teeth (77.55%).

Table 3 shows the results of the unadjusted analysis of associations between AP and sociodemographic/clinical factors. Among the sociodemographic variables, sex, age, and schooling were associated with AP. Among the clinical variables, ET quality and tooth brushing frequency were not associated with the outcome.

The multilevel Poisson regression models are displayed in Table 4. Sociodemographic variables composed Model 1, in which an older age, black/brown skin colour, and having less than eight years of schooling were associated with AP. Clinical variables composed Model 2, in which less than one visit to a dentist per year, severe periodontal disease, mandibular teeth, posterior teeth, inadequate crown status, and a history of ET were associated with AP. In model 3, the sociodemographic variables were incorporated to adjust the clinical variables. In this final model, an older age, black/brown skin colour, less than 8 years of schooling, less than one visit to a dentist per year, severe periodontal disease, mandibular teeth, posterior teeth, inadequate crown status, and a history of ET were significantly associated with AP.

Discussion

The prevalence of AP was high in this Brazilian rural population (60.45%), suggesting high caries experience and a lack of access to specialized dental centres [31]. This prevalence was similar to that reported in studies conducted in different geographic locations [6, 21, 32] but higher than that reported in investigations conducted in Scandinavian countries [19, 33], which have a better socioeconomic status. However, the findings of these studies should be compared with caution due to differences in sampling procedures, selection of participants, examination methods, and criteria for diagnosing dental diseases [34].

The sociodemographic variables provide an overall picture of the individuals in this rural population. AP was not significantly associated with sex, which is in agreement with data described by Chala et al. [34] and Moreno et al. [35]. However, a significant association was found between AP and age, as individuals between 41 and 93 years of age had a greater prevalence of AP compared to the youngest individuals. These results suggest an increase in the prevalence of AP with age, as proposed by other authors [17, 20, 36]. Black/brown skin colour and ≤ 8 years of schooling were

Table 2. Characteristics of the sample

Variable	*N*	%
Subjects (n = 584)		
Sex		
Female	289	49.49
Male	295	50.51
Age (tercile)		
18–40	199	34.08
41–54	197	33.73
55–93	188	32.19
Skin colour		
White	400	68.49
Black/brown	184	31.51
Schooling		
> 8 years	129	22.09
≤ 8 years	455	77.91
Income in R$* (median)		
≤ 1125	216	37.24
> 1125	364	62.76
Visit to dentist		
1 or more times per year	255	43.66
< once per year	329	56.34
Tooth brushing frequency		
2 or more times per day	550	94.18
< twice per day	34	5.82
Periodontal disease		
Not severe	91	15.69
Severe	489	84.31
Tooth (n = 10,396)		
Dental arch		
Maxillary	4915	47.28
Mandibular	5481	52.72
Tooth group		
Incisor	3464	33.32
Canine	1839	17.69
Premolar	3317	31.91
Molar	1776	17.08
Crown status		
Adequate	8062	77.55
Inadequate	2334	22.45
Endodontic treatment (ET)		
Absent	10,185	97.97
Present	211	2.03
Intracanal post		
Absent	10,335	99.41
Present	61	0.59
ET quality (n = 211)		
Lateral seal of root filling - voids		
Adequate	100	47.39
Inadequate	111	52.61
Length of root filling		
Adequate	121	57.35
Inadequate	90	42.65
Lateral seal + length of root filling		
Adequate	60	28.44
Inadequate	151	71.56

*R$, Real (US$ 1.0 was equivalent to R$ 3.34 when data were collected)

also significantly associated with AP. Although Bukmir et al. [37] found that dental variables are more strongly associated with AP, the results of this study demonstrated that socioeconomic variables could indirectly affect the occurrence of AP and, thus, the possibility of treatment and maintenance of the teeth. Individuals with fewer years of education have a greater frequency of caries [37], which is the main aetiological factor of AP. Moreover, many health indicators, access to care, and health care quality are worse among racial minorities [38].

The frequency of visits to a dentist was associated with AP. Individuals who visited a dentist less than once a year had a greater prevalence of AP. Irregular dental visits may lead to poorer dental health and, consequently, the development of periapical disease [39]. AP is often asymptomatic and identified by radiographic examinations. Therefore, the disease remains undiagnosed (and untreated) if dental visits are not a habit. One should bear in mind, however, that this variable was collected during the application of a questionnaire, which could be affected by recall bias or the individual's desire to please the interviewer.

It is well known that pulp disease can cause an inflammatory response in the periodontal ligament near the apical foramen, lateral canals, and other ramifications [40]. However, the opposite (periodontal disease affecting the pulp tissue) is a controversial subject in the literature [41–43]. Czernecki and Schilder [44] suggested that the pulp suffers harm only when periodontal disease involves the root apex. In contrast, other studies propose that the pulp can undergo changes, from calcifications, fibrosis, collagen resorption, reduction in volume until the loss of vitality and necrosis, when periodontal disease is established, without needing to invade the apex [42, 43, 45, 46]. Furthermore, bacterial studies have found common microorganisms to the root canal and the periodontal pocket, which suggests that the periodontal pocket could be a source for endodontic infection [47, 48]. Confirming this endo-periodontal interaction, individuals with a diagnosis of severe periodontal disease in this study had a greater prevalence of AP. Patients with severe periodontal disease, a long-term chronic infection, have high index values for pocket probing depth and clinical

Table 3 Unadjusted association between apical periodontitis and sociodemographic/clinical variables determined using multilevel Poisson regression

Variable	PR (CI 95%)	*P*-value
Sociodemographic characteristics		
Sex		0.03
Female	1	
Male	1.28 (1.02–1.60)	
Age (tercile)		<0.01
18–40	1	
41–54	1.99 (1.53–2.58)	
55–93	2.48 (1.90–3.24)	
Skin colour		0.07
White	1	
Black/brown	1.25 (0.98–1.58)	
Schooling		<0.01
> 8 years	1	
≤ 8 years	1.65 (1.25–2.18)	
Income in R$* (median)		0.46
≤ 1125	1	
> 1125	1.08 (0.87–1.36)	
Clinical characteristics		
Visit to dentist		<0.01
1 or more times per year	1	
< once per year	1.74 (1.39–2.18)	
Tooth brushing frequency		0.43
2 or more times per day	1	
< twice per day	1.20 (0.76–1.89)	
Periodontal disease		<0.01
Not severe	1	
Severe	3.11 (2.19–4.42)	
Dental arch		<0.01
Maxillary	1	
Mandibular	0.46 (0.39–0.53)	
Tooth group		<0.01
Incisor	1	
Canine	0.41 (0.32–0.54)	
Premolar	0.94 (0.80–1.11)	
Molar	1.42 (1.18–1.70)	
Crown status		<0.01
Adequate	1	
Inadequate	9.47 (8.07–11.11)	
Endodontic treatment (ET)		<0.01
Absent	1	
Present	8.99 (7.10–11.37)	
ET quality (lateral seal + length) (n=211)		0.67
Adequate	1	
Inadequate	1.09 (0.73–1.64)	
Intracanal post		<0.01
Absent	1	
Present	9.77 (6.78–14.08)	

PR Prevalence ratio, *CI* Confidence interval

*R$, Real (US$ 1.0 was equivalent to R$ 3.34 when data were collected)

attachment loss, which may result in the dissolution of dentinal tubules and help the microorganisms to invade the root canal area [49].

Posterior teeth were at a significantly greater prevalence of AP, especially molars. The results revealed a severity gradient, as reported elsewhere [19, 20, 50], that may be related to the complex anatomy of these teeth, which contributes to a greater chance of dental caries due to the accumulation of plaque. Moreover, the position of these teeth in the arch seems to lead to greater difficulty in performing effective dental hygiene [19, 22]. Previous studies reported no difference between the arches or higher prevalence of AP in maxillary teeth [6, 21, 22, 26, 32]. Agreeing with the studies that found a higher prevalence in the upper arch [6, 22, 32], in this investigation, the mandible had lower prevalence of AP. The spongy nature of the maxillary bone, which favours the faster development of a periapical lesion, could explain this difference [3].

A significant association was found between AP and a history of ET, as previously described [39]. Although studies have reported high frequencies of periradicular lesions in poorly filled root canals [20, 35, 36, 51], no significant association was found between AP and ET quality in the present investigation. This may be explained by the small number of endodontic treatments detected in this population, leading to a lower statistical power to reveal a significant difference. Moreover, radiographic images do not enable the determination of how endodontic procedures were conducted, such as the disinfection of the root canal system [52], which exerts a major influence on the outcome of ET [53]. The presence of an intracanal post was also not associated with AP, which is in agreement with findings described elsewhere [21, 35, 50].

Different studies have investigated the influence of ET quality and crown status on post-treatment periapical disease reporting contradictory results. Several authors found that ET quality had a greater effect on periapical health [34, 35, 39]. However, Ray and Trope [54] revealed that coronal restoration quality had a greater impact on periapical status than ET quality, justifying that even with an adequate ET, bacteria, and their toxic products in the crown may reach the root apex, stimulating an inflammatory response. The data presented by these authors challenged the rationale of endodontics and stimulated intense discussions in the scientific community [55, 56]. Based on a meta-analysis performed by Gillen et al. [57], it is reasonable to say that endodontic and crown status are equally important for periapical health. In the present investigation, a significant association was found between the prevalence of AP and crown status when all teeth were considered, as teeth with an inadequate crown had a greater prevalence of AP. Hommez et al. [50] and Moreno et al. [35] reported similar findings.

Cross-sectional studies have weak causal inference but strong external validity [17]. As the data are collected and analysed at a

Table 4 Adjusted association between apical periodontitis and sociodemographic/clinical variables determined using multilevel Poisson regression

Variable	Model 1[a] PR (CI 95%)	Model 2[b] PR (CI 95%)	Model 3[c] PR (CI 95%)
Sex			**
Female	1		
Male	1.16 (0.94–1.44)		
Age (tercile)			
18–40	1		1
41–54	1.96 (1.50–2.55)*		1.96 (1.50–2.55)*
55–93	2.27 (1.72–3.00)*		2.27 (1.72–3.00)*
Skin colour			
White	1		1
Black/brown	1.29 (1.03–1.62)*		1.29 (1.03–1.62)*
Schooling			
> 8 years	1		1
≤ 8 years	1.31 (1.00–1.72)*		1.31 (1.00–1.72)*
Visit to dentist			
1 or more times per year		1	1
< once per year		1.30 (1.08–1.57)*	1.31 (1.09–1.58)*
Periodontal disease			
Not severe		1	1
Severe		1.56 (1.17–2.08)*	1.56 (1.17–2.08)*
Dental arch			
Maxillary		1	1
Mandibular		0.54 (0.47–0.63)*	0.55 (0.47–0.64)*
Tooth group			
Incisor		1	1
Canine		0.54 (0.42–0.71)*	0.54 (0.42–0.70)*
Premolar		1.39 (1.17–1.65)*	1.38 (1.17–1.63)*
Molar		1.85 (1.53–2.24)*	1.82 (1.51–2.21)*
Crown status			
Adequate		1	1
Inadequate		7.05 (5.96-–8.34)*	7.12 (6.02–8.43)*
Endodontic treatment (ET)			
Absent		1	1
Present		4.62 (3.51–6.07)*	4.90 (3.87–6.21)*
Intracanal post			**
Absent		1	
Present		1.15 (0.77–1.73)	

PR prevalence ratio, *CI* confidence interval

[a]Model 1: Sociodemographic variables

[b]Model 2: Clinical variables

[c]Model 3: Sociodemographic variables adjusting clinical variables

*Significant at *P* <0.05 level

**Variables not included in final multiple model after adjustment

single point in time, the results are subject to interpretation bias. Moreover, this study was based on radiographic exams. Thus, it is impossible to distinguish whether a radiolucent image is genuine AP, a case in the healing process or scar tissue [58]. Only a clinical examination, dental history, or longitudinal study could provide such information [19]. Nevertheless, the method of choice for endodontic assessment remains the periapical radiograph [59] and most epidemiological studies use this method for evaluating AP, ET, and crown restoration quality [20, 35–37, 50].

The strength of this study was the multilevel analysis applied to a probability sample of a rural population. Hierarchical linear modelling considers the patient and tooth as different but interconnected and can therefore identify predictors of AP, distinguishing these predictors from confounding factors [24, 26]. Most epidemiological studies in endodontics use less complex statistical tests, such as the chi-square or bivariate regression, and may have misinterpreted some associations. When the analysis of variables is performed on a single level, it presupposes that each tooth or individual is independent, but, in reality, these aspects are correlated [25]. The adoption of the multilevel approach enables new perceptions in the epidemiology of AP [26].

To the best of the authors' knowledge, this cross-sectional study is the first epidemiological survey to assess AP and other oral health conditions in a probability sample of a rural population. The investigation of these conditions in rural inhabitants is necessary, especially when considering their difficult access to medical and oral care [60]. The improvement of oral health is strongly associated with better coverage of health care services [31]. Additionally, research with a representative population-based sample is rare in endodontics [17, 19]. The data collected herein reinforce the body of evidence on the prevalence of AP and associated factors, which can be helpful in the planning and improvement of oral health policies.

Conclusions

The present study revealed that the prevalence of apical periodontitis was high in the Brazilian rural population studied (60.45%). Age, skin colour, schooling, frequency of visits to a dentist, periodontal disease, dental arch, tooth group, crown status, and a history of endodontic treatment were significantly associated with apical periodontitis.

Author's contributions Dr. Mônica Pagliarini Buligon, Dr. Janice Almerinda Marin, and Dr. Carlos Frederico Brilhante Wolle were responsible for the radiographic evaluations and subsequent analyses; Dr. Gabriela Salatino Liedke and Renata Dornelles Morgental were the supervisors of the radiographic procedures; Dr. Camila Silveira Sfreddo was responsible for the statistical analysis; Dr. Carlos Alexandre Souza Bier and Dr. Carlos Heitor Cunha Moreira were the supervisors of the epidemiologic survey. All authors revised and approved the manuscript.

Declarations

Ethics approval This study received approval from the Research Ethics Committee at the Federal University of Santa Maria (certificate number: 37862414.5.0000.5346) in the city of Santa Maria, Brazil, and was conducted in accordance with the ethical precepts of the Declaration of Helsinki.

Informed consent All volunteers who agreed to participate in the survey signed an informed consent form.

Conflict of interest The authors declare no competing interests.

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