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SYSTEMATIC REVIEW

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Prevalence of periodontitis in dentate people between 2011 and 2020: A systematic review and meta-analysis of epidemiological studies

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Abstract

Aim: The aim of the study was to evaluate the prevalence of periodontitis in dentate people between 2011 and 2020.

Materials and Methods: PUBMED, Web of Science, and LILACS were searched up to and including December 2021. Epidemiological studies reporting the prevalence of periodontitis conducted between 2011 and 2020 were eligible for inclusion in this review. Studies were grouped according to the case definition of confidence as confident (Centers for Disease Control [CDC] AAP 2012; CDC/AAP 2007; and Armitage 1999) and non-confident (community periodontal index of 3 or 4, periodontal pocket depth >4 mm, and clinical attachment level ≥1 mm). Random effects meta-analyses with double arcsine transformation were conducted. Sensitivity subgroup and meta-regression analyses explored the effect of confounding variables on the overall estimates.

Results: A total 55 studies were included. The results showed a significant difference, with confident case definitions (61.6%) reporting nearly twice the prevalence as non-confident classifications (38.5%). Estimates using confident periodontal case definitions showed a pooled prevalence of periodontitis of 61.6%, comprising 17 different countries. Estimates reporting using the CDC/AAP 2012 case definition presented the highest estimate (68.1%) and the CDC/AAP 2007 presented the lowest (48.8%). Age was a relevant confounding variable, as older participants (≥65 years) had the highest pooled estimate (79.3%).

Conclusion: Between 2011 and 2020, periodontitis in dentate adults was estimated to be around 62% and severe periodontitis 23.6%. These results show an unusually high prevalence of periodontitis compared to the previous estimates from 1990 to 2010.

KEYWORDS
periodontal disease, periodontitis, prevalence, systematic review

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Clinical Relevance

Scientific rationale for study: To comprehensively estimate the prevalence of periodontitis reported in studies between 2011 and 2020 sourced from epidemiological data.

Principal findings: During this period, periodontitis was collectively estimated to be around 63% and severe periodontitis 24.2%. Pooled estimates from confident case definitions presented almost two-fold prevalence.

Practical implications: These results highlight the need for strengthening the surveillance of periodontitis and informing global health stakeholders to devise and better manage public periodontal health strategies.

1 | INTRODUCTION

Periodontitis is a public health problem whose high prevalence contributes to the global burden of chronic non-communicable diseases (Petersen, 2009; Tonetti et al., 2017; Caton et al., 2018; Tonetti et al., 2018). According to the Global Burden of Disease (GBD), periodontitis was ranked as one of the most prevalent conditions of humankind between 1990 to 2010 (Marcenes et al., 2013; Kassebaum et al., 2014), and a recent update until 2019 confirmed that this prevalence is still substantial and worrisome (Wu et al., 2022).

Periodontitis had a significant socio-economic impact in the United States and Europe in 2018 of around $154 billion and €159 billion, respectively (Botelho et al., 2022). Also, its impact on patients' quality of life and systemic health has been extensively verified over the last decades (Buset et al., 2016; Botelho et al., 2020, 2022).

The prevalence of periodontitis has been reported using different and highly heterogeneous approaches. On one hand, prevalence data provided by the GBD resort to arithmetic extrapolations based on miscellaneous periodontal classifications (Schwendicke et al., 2018; GBD 2017 Oral Disorders Collaborators et al., 2020; Botelho et al., 2022; Wei et al., 2021; Wu et al., 2022), whose reliability is under debate due to the variety of case definitions (Marcenes et al., 2013; Kassebaum et al., 2017; GBD 2017 Oral Disorders Collaborators et al., 2020). On the other hand, methodological heterogeneity hampers a traceable comparison over time (Frencken et al., 2017). Thus, it is imperative to carry out continuous studies of estimates, such as summary measures of population health (e.g., disability-adjusted life years), or through meta-analysis.

Considering the challenges with current measurement methodologies for periodontitis, measurable specific estimates based on epidemiological studies are warranted to advance global public health (Kassebaum et al., 2017). Therefore, this systematic review aims to comprehensively estimate the prevalence of periodontitis reported in studies between 2011 and 2020 sourced from epidemiological data. Our secondary objectives are (i) to evaluate the prevalence geographically, (ii) to compare estimates from confident and non-confident case definitions, and (iii) to explore other confounding variables. The following focused PECO question was addressed: "What is the pooled prevalence estimate of periodontitis in epidemiological studies carried out between 2011 and 2020?" (Population: among dentate adults assessed in an epidemiological survey; Exposure: periodontitis; Comparison: periodontal status assessed; Outcome: prevalence).

2 | METHODS

This systematic review protocol was previously set by all the authors and was registered in the National Institute for Health Research PROSPERO, the International Prospective Register of Systematic Reviews (http://www.crd.york.ac.uk/PROSPERO, ID Number: CRD42021231357). The review design followed the Cochrane Handbook of Systematic Reviews of Interventions (Higgins et al., 2019) and was reported according to the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (M. J. Page et al., 2021). The PRISMA checklist is provided as Supplementary File 1.

2.1 | Type of studies, type of intervention, and inclusion criteria

The eligibility criteria were as follows: observational epidemiological studies (cross-sectional and cohort studies) reporting the prevalence of periodontitis in adults (18 years old or older) between 2011 and 2020. Cross-sectional and cohort studies (data were gathered from baseline reports) represent epidemiological studies in nature and provided prevalence traits important for the aims of this systematic review. Case–control studies were not considered because of the the associated inconvenience in sampling cases and controls (Belbasis & Bellou, 2018). In line with this, intervention studies (both randomized and non-randomized) were considered only if they had a baseline inclusion of participants with an epidemiological approach.

In contrast, studies reporting the prevalence of periodontitis of a specific population (e.g., pregnant women, people with a particular underlying disease, etc.), studies based on self-reported case definitions of periodontitis, and pre-clinical studies were excluded.

In cases where additional clarifications were required, the corresponding author of the included study was contacted via e-mail, and, in case of no response, again 1 week later.

2.2 | Primary and secondary outcomes

The primary outcome of this systematic review was the prevalence of periodontitis reported in epidemiological studies, either national or regional. We further explored the distribution of periodontitis per

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continent, based on the case definition, according to established age intervals, as well as the severity of periodontitis.

2.3 | Information sources search

The search strategy sought to identify all studies reporting the prevalence of periodontitis conducted between January 2011 and December 2020. We defined this year interval, based on the recent estimates by Kassebaum et al. (2017) for the period between 1990 and 2010.

Detailed search strategies were used, without language restrictions, on the following electronic databases: PubMed, Web of Science, and LILACS (Latin-American Scientific Literature in Health Sciences). The search algorithm, developed using keywords and the Medical Subject Headings (MeSHs), was as follows: "(periodont* OR 'chronic periodontitis' OR (periodontal diseases [MeSH]) OR 'attachment loss' OR pocket*) AND (prevalence [MeSH] OR epidemiology [MeSH])".

For the remaining databases, the search was adapted accordingly.

2.4 | Study selection

Two researchers (D.T. and R.C.) independently selected the relevant articles by screening the titles and abstracts, excluding the non-relevant studies. Any paper classified as potentially eligible by either reviewer was appraised by a full-text reading and the reasons for exclusion were fully detailed. Any disagreement was resolved through discussion with a third reviewer (J.B.) and a decision arrived at by consensus.

2.5 | Data extraction process and data items

The studies that fulfilled the inclusion criteria were organized into evidence tables describing the characteristics and results of each study, including the following: study identification (i.e., first author's name and publication year), time period of the study, continent, country of origin of the research, country coordinates, funding information, inclusion and exclusion criteria, periodontal case definition, characteristics and number of participants, and outcome measures. We later added the methodological risk of bias of the study (detailed in Section 2.6). All disagreements were resolved through discussion with a third reviewer (J.B.). Because of the known impact of case definitions in prevalence estimates (Holtfreter et al., 2015), we categorized case definitions following the strategy used by Muñoz Aguilera et al. (2020) as confident and non-confident, as explained below.

2.5.1 | Confident case definition of periodontitis

The following case definitions were considered as confident:

- Interdental clinical attachment loss (CAL) in ≥2 non-adjacent teeth, or buccal or oral CAL ≥3 mm with periodontal pocket depth (PPD) >3 mm detectable at ≥2 teeth (American Academy of Periodontology [AAP]/European Federation of Periodontology [EFP]; Tonetti et al., 2018);
- Two or more inter-proximal sites with CAL ≥3 mm and two or more inter-proximal sites with PPD ≥4 mm (not on the same tooth) or one site with PPD ≥5 mm (Centers for Diseases Control [CDC]/AAP, 2012; Eke et al., 2012);
- At least two sites on different teeth with clinical attachment level (CAL) 6 mm and at least one site with PPD 4 mm (CDC/AAP 2007; R. C. Page & Eke, 2007);
- Generalized chronic periodontitis (at least 30% sites with CAL ≥4 mm; CDC 1999; Armitage, 1999).

2.5.2 | Non-confident case definition of periodontitis

The following reported criteria were considered as a non-confident case definition: the (WHO) CPI score 3/4 in at least one quadrant; at least one site with PPD >4 mm; CAL ≥1 mm.

2.6 | Risk-of-bias assessment

The methodological quality of the included studies was carried out by two independent reviewers (D.T. and R.C.) using the "Assessing risk of bias in population-based prevalence studies" tool (Hoy et al., 2012). Any disagreement was resolved through discussion with a third reviewer (J.B.).

The tool consists of 10 items addressing external validity (items 1–4, accounting for the selection and non-response bias domains) and internal validity (items 5–10, accounting for the measurement bias and bias related to the analysis domains). Each item was rated as having either "yes" (low) or "no" (high) risk of bias. Items with insufficient information to properly meet the requirements were classified as "no" (i.e., high risk of bias; Hoy et al., 2012). Following Hoy et al., the overall risk of bias of each study was decided on the basis of agreement between all authors. Therefore, each article's overall risk of bias was evaluated as "High" (i.e., if only 0–3 items were responded with yes, having an important impact on our confidence in the estimate, and will likely change the estimate), "Moderate" (if 4–8 items were responded with yes), and "Low" (if 9 or more items were responded with yes, indicating that further research is very unlikely to change our confidence in the estimate).

2.7 | Statistical analysis

Extracted data were organized into evidence tables. Because of the existence of multiple categories of prevalence for periodontitis in the literature, and the possible imbalance in weight of the studies affecting the meta-analysis, we implemented a double arcsine transformation meta-analysis (Barendregt et al., 2013). Considering the

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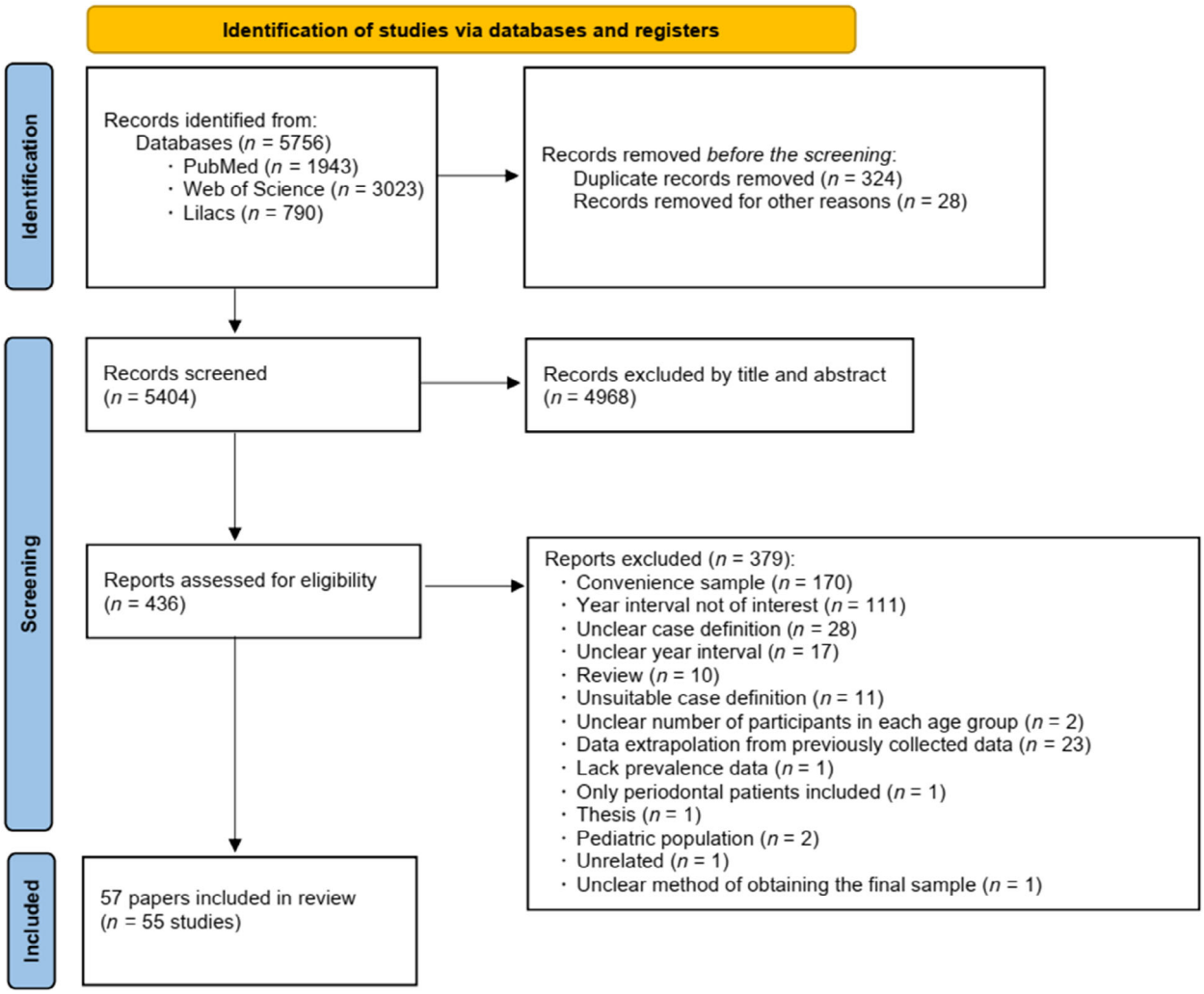

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flow diagram for new systematic reviews that included searches of databases and registers only. Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools. *Source*: M. J. Page et al. (2021). For more information, visit: http://www.prisma-statement.org/.

geographical variation and difference in populations, we could not assume the existence of a true effect size; so we employed a random-effects model (Schwarzer et al., 2015), as previously described (Schwarzer, 2007). All random-effects meta-analysis and forest plots were performed in R version 3.4.1 using the *meta* package (Schwarzer, 2007). The results are presented as percentage prevalence ($p \times 100\%$) and 95% confidence intervals (CI). Heterogeneity was explored through the I^2 index and Cochrane's Q statistic ($p < .1$) and χ^2 test for the overall homogeneity (Higgins et al., 2019). Substantial heterogeneity was defined as $I^2 > 50\%$. All tests were two-tailed, with α set at .05.

We conducted a series of a priori sensitivity analyses (i.e., subgroup analyses) to examine the effect of the case definition of confidence (confident vs. non-confident) and risk of bias (low vs. moderate-to-high) to the overall estimates. Meta-regression was used to explore adjusting effects, particularly confounding variables, on the prevalence estimates, particularly female/male ratio, latitude, longitude, and study sample size.

3 | RESULTS

3.1 | Study selection

The electronic searches retrieved a total of 5756 records (1943 from PubMed, 3023 from Web of Science, and 790 from LILACS; Figure 1). After removal of duplicates, 4968 articles were excluded based on title/abstract assessment, and 28 articles were unable to be accessed. Out of the articles remaining, 379 were excluded in the full-text appraisal, due to not meeting the inclusion criteria (with the respective reason detailed in Supplementary File 2). Finally, a total of 57 articles (Moya et al., 2012; Figueiredo et al., 2013; Araya Vallespir

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et al., 2014; Jaafar et al., 2014; Juarez et al., 2014; Thanakun et al., 2014; Bhat et al., 2015; Eke et al., 2015; Giacaman et al., 2016; Khan et al., 2016; Holde et al., 2017; Ramírez et al., 2017; Shyagali et al., 2017; Silva-Junior et al., 2017; Zaitsu et al., 2017; Balaji et al., 2018; Bhat et al., 2018; Eke et al., 2018; He et al., 2018; Iwasaki et al., 2018; Ortiz et al., 2018; Pinto-Filho et al., 2018; Shariff et al., 2018; Skośkiewicz-Malinowska et al., 2018; Wahlin et al., 2018; Botelho et al., 2019; Dhaifullah et al., 2019; Helmi et al., 2019; Lasta et al., 2019; J. B. Lee et al., 2019; K. Lee & Kim, 2019; Shimizu et al., 2019; Zhao et al., 2019; Bongo et al., 2020; Díaz-Reissner et al., 2020; Ha et al., 2020; Nakamura et al., 2020; Romero-Castro et al., 2020; Schmidt et al., 2020; Sekiguchi et al., 2020; Singh et al., 2020; Sun et al., 2020; Bilgin Çetin et al., 2021; Clauss et al., 2021; Costa et al., 2021; Germen et al., 2021; Ghassib et al., 2021; Goel et al., 2021; Gomes-Filho et al., 2021; Han & Kim, 2021; Iwasaki et al., 2021; Jiao et al., 2021; Kocher et al., 2021; Oliveira et al., 2021; Sakurai et al., 2021; Song et al., 2021; Stødle et al., 2021; Su et al., 2021) were included in the qualitative and quantitative analyses of the present systematic review. Two studies had their data reported in more than one article, so these papers were grouped under a single name (Bhat et al., 2015; Eke et al., 2015; Bhat et al., 2018; Eke et al., 2018). Therefore, 55 articles were finally included. Inter-examiner reliability at full-text screening was considered excellent (κ [kappa] score = 0.86, 95% CI: 0.83–0.89).

One study did not report data for the overall prevalence of periodontitis, but it reported data for the subgroup analysis information of moderate to severe periodontitis (Ha et al., 2020). To complete information on the year range of interest, we used the official report where this information was detailed (Australian Research Centre for Population Oral Health, 2019).

3.2 | Study characteristics

Studies from 25 different countries across Asia, America, Europe, Australia, and Africa were included (Table 1). Most studies (n = 30, 54.5%) reported periodontal outcomes using a non-confident case definition, either the community periodontal index (CPI) score 3/4 in at least one quadrant, at least one site with PPD >4 mm, or CAL ≥1 mm. Within the confident periodontal definitions, the CDC/AAP 2012 was the most employed, being reported in 15 studies (27.2%); the remaining reported periodontitis based on confident case definitions.

3.3 | Risk of bias

Forty-four studies were considered of moderate risk of bias, while only 11 were of low risk of bias (Supplementary File 3). Overall, studies failed to report prevalence data that represented closely the national population regarding relevant variables (81.8%, n = 45) and to use an acceptable case definition of periodontitis (45.5%, n = 25). Non-response bias was minimal (78.2%, n = 43), while 61.7% (n = 50) used some form of random selection and 67.3% (n = 37) studies had the prevalence period as the parameter of interest. The remaining items had predominantly low risk of bias (over 90% of the studies). Inter-examiner reliability at risk of bias assessment was considered excellent (κ score = 0.82, 95% CI: 0.79–0.84).

3.4 | Pooled estimates

Between 2011 and 2020, a total of 88,917 adults were included in the overall pool of analyses, with 44,614 adults reported to have periodontitis. We started by comparing non-confident with confident case definitions of periodontitis. Overall, the results confirmed a significant difference (p < .00001), with confident case definitions (61.6%, 95% CI: 55.1–67.9, p < .000001, I^2 = 99.1%) reporting nearly twice the prevalence than non-confident classifications (38.5%, 95% CI: 30.4–46.9, I^2 = 99.7%). For this reason, and following the instruction of GRADE, we focused on the estimates using confident periodontal case definitions (Schünemann et al., 2008).

Furthermore, we explored the impact of partial-mouth protocols and non-reported protocols in the overall estimates. Sensitivity analyses showed that studies using a full-mouth protocol reported nearly twice the prevalence (45.7%, 95% CI: 38.0–53.6, p < .000001, I^2 = 99.4%, number of studies = 32) as partial-mouth protocols (55.1%, 95% CI: 44.3–65.6, p < .000001, I^2 = 99.7%, number of studies = 19) or non-reported protocols (40.9%, 95% CI: 8.9–78.2, p < .000001, I^2 = 99.8%, number of studies = 3). The comparison for subgroup differences was not significant (p = .3528).

3.4.1 | Total prevalence

The overall prevalence of periodontitis was estimated at 61.6% (95% CI: 55.1–67.9, p < .000001, I^2 = 99.1%), comprising 17 different countries. This estimate was confirmed to be affected by the methodological quality (p = .0497), comparing studies of low risk of bias (54.1%, 95% CI: 47.4–60.6, p < .000001, I^2 = 98.9%) and studies with moderate risk of bias (64.7%, 95% CI: 56.3–72.6, p < .000001, I^2 = 99.0%). There was substantial heterogeneity.

The latitude (estimate = 0.000, SE = 0.002, p = .805), longitude (estimate = 0.000, SE = 0.001, p = .774), and sample size (estimate = 0.000, SE = 0.000, p = .9410) were confirmed to have no influence on the final estimates through meta-regression. In addition, no publication bias was detected (Egger test = 0.61, SE = 3.63, p = .8671).

Considering the case definition, there were significant differences between all four reported classifications (p = .0101; Table 2). Estimates using CDC/AAP 2012 case definition presented the highest estimate (68.1%), while those using the CDC/AAP 2007 presented the lowest (48.8%).

We further analysed whether the age interval of participants in the included studies would influence the results. Overall, the test for subgroup differences could not confirm a difference between the age

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TABLE 1 Study characteristics

Authors (year) (country)	Inclusion criteria	Exclusion criteria	Invited participants/ initial sample (*n*)	Response rate/ eligibility % (*n*)	Edentulous participants (*n*)	Periodontal criteria (confidence)	Periodontal examination protocol	Periodontitis/ healthy (*n*)	Age interval (years)	Male/ female	Funding source
Moya et al. (2012) (Chile)	≥60 years old, beneficiary of the public health system, and assisted at the health center at East Santiago of Chile	NR	NR	NR	7.2%	CPI (non-confident)	Partial-mouth (CPI)	168/212	≥60	NR	NR
Figueiredo et al. (2013) (Brazil)	Kiriri Indians aged 19 years and older who were living in an isolated Indian area in the state of Bahia, in Northeast Brazil	Cardiovascular diseases and other conditions that require antibiotics before periodontal probing	1025	22.0 (225)	0.0%	CDC/AAP 2007 (confident)	Full-mouth (six sites)	85/130	≥19	96/119	Research grant
Thanakun et al. (2014) (Thailand)	NR	Patients with systemic diseases, as well as those who had received medications	125	100.0 (125)	0.0%	Armitage 1999 (confident)	Ful-mouth (six sites)	90/35	35–76	53/72	Research grant
Jaafar et al. (2014) (Malaysia)	≥19 years old	NR	586	100.0 (586)	0.0%	CPI (non-confident)	Partial-mouth (CPI)	228/309	≥19	218/319	Research grant
Araya Vallespir et al. (2014) (Chile)	35–44 years old, belonging to the family health center Lorenzo Arenas from the municipality of Concepción, Chile	NR	58	100.0 (58)	0.0%	CDC/AAP 2012 (confident)	Ful-mouth (six sites)	32/26	35–44	NR	NR
Juarez et al. (2014) (Chile)	18–70 years old, ≥2 teeth in the mouth	Pregnant, underwent periodontal treatment during the last 6 months, undergoing current periodontal treatment, on antibiotic treatment for a week or more in the last 6 months, or on treatment with immunosuppressive	136	100.0 (136)	0.0%	PPD ≥4 mm (non-confident)	Ful-mouth (6 sites)	67/69	18–70	51/85	NR

(Continues)

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TABLE 1 (Continued)

Authors (year) (country)	Inclusion criteria	Exclusion criteria	Invited participants/ initial sample (*n*)	Response rate/ eligibility % (*n*)	Edentulous participants (*n*)	Periodontal criteria (confidence)	Periodontal examination protocol	Periodontitis/ healthy (*n*)	Age interval (years)	Male/ female	Funding source
		agents, all conditions that alter the periodontal status; antibiotic consumption for 7 days in the past 6 months, the current consumption of nifedipine, >70 years old, and presented abdominal hernia									
Khan et al. (2016) (Pakistan)	≥18 years old	Participants who had received periodontal treatment in the last 4 months, participants on antibiotics within the past 4 months, pregnant women and lactating mothers, mentally handicapped, or on prophylactic antibiotics, or systemic/topical steroidal anti-inflammatory drugs for the last 4 months	443	100.0 (443)	0.0%	CPI (non-confident)	Partial-mouth (sextants)	310/133	≥18	287/156	Self-funded
Giacaman et al. (2016) (Chile)	The entire population of the Maule Region, divided according to the ages of epidemiological surveillance indicated by the WHO, that is, 6, 12, 15, 35 –44, and 65–74 years	Systemic conditions that contraindicate periodontal evaluation, people who suffered heart disease, bleeding disorders or were under anticoagulant drug therapy, and all participants who were within the study ages but	891	100.0 (891)	NR	CPI (non-confident)	Partial-mouth (CPI)	162/531	35–44; 65–74	124/ 569	Research grant

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TABLE 1 (Continued)

Authors (year) (country)	Inclusion criteria	Exclusion criteria	Invited participants/ initial sample (*n*)	Response rate/ eligibility % (*n*)	Edentulous participants (*n*)	Periodontal criteria (confidence)	Periodontal examination protocol	Periodontitis/ healthy (*n*)	Age interval (years)	Male/ female	Funding source
		suffered from some cognitive deficit or mental disability									
Ramírez et al. (2017) (Colombia)	≥35 years old, full clinical history and periodontal chart, presence of at least 10 teeth in the mouth excluding third molars	NR	NR	NR	0.0%	Armitage 1999 (confident)	Full-mouth (six sites)	314/153	≥35	112/355	NR
Zaitsu et al. (2017) (Japan)	Adults aged 19–70 years old, employed at 11 companies (Company A–K) in the Kanto region of Japan	NR	1078	100.0 (1078)	0.0%	CPI (non-confident)	Partial-mouth (sextants)	109/969	19–70	798/270	Research grant
Silva-Junior et al. (2017) (Brazil)	Adults aged between 20 and 64 years	NR	248	100.0 (248)	0.0%	CPI (non-confident)	Partial-mouth (sextants)	107/141	20–64	NR	Research grant
Shyagali et al. (2017) (India)	Subjects who indulged in the use of tobacco products more than four times a week and for not less than a year	Subjects who consumed any of the tobacco products less than four times a week, who had a systemic disease, and who were on medication for such diseases	NR	NR	0.0%	CPI (non-confident)	Partial-mouth (CPI)	143/337	18–50	NR	NR
Holde et al. (2017) (Norway)	Adults aged 20–79 years, living in Troms County, Norway	Edentulous or only one tooth	2909	65.7 (1911)	0.0%	CDC/AAP 2012	Full-mouth (six sites)	946/965	20–79	1016/895	Research grant
He et al. (2018) (China)	Subjects within the 35–44, 55–64, and 65–74 years age groups, had the ability to understand and answer the questionnaire, and	Subjects from 45 to 54 years age group, undergoing orthodontic treatment, teeth were covered by lots of calculus	540	88.9 (480)	0.0%	CDC/AAP 2012 (confident)	Full-mouth	296/184	35–44; 55–64; 65–74	243/237	Research grant

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	had lived in the selected communities or villages for more than 6 months in the past year										
Iwasaki et al. (2018) (Japan)	NR	Participants who had chronic hepatitis C infection and chronic hepatitis B infection	1280	95.8 (1226)	0.0%	PPD ≥4 mm (non-confident)	Full-mouth (six sites)	941/285	40–59	NR	Self-funded
Ortiz et al. (2018) (Puerto Rico)	NR	History of clinically diagnosed diabetes, less than four natural teeth, a history of conditions that increase the risk of systemic complications during a periodontal exam, and inability to complete study procedures, fasting, two-hour glucose, or HbA1c levels met the American Diabetes Association thresholds for diabetes at the baseline exam	773	95.1 (735)	0.0%	CDC/AAP 2007	Full-mouth (six sites)	438/297	41–70	204/531	Research grant
Bhat et al. (2015, 2018) (India)	Participants aged 35–54 years, dentate	Any participant reporting medical conditions (uncontrolled diabetes, heart disease, bleeding disorders) that contra-indicated periodontal probing	1401	62.0 (869)	0.0%	CDC/AAP 2012	Full-mouth (six sites)	405/464	35–54	472/397	NR

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TABLE 1 (Continued)

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Balaji et al. (2018) (India)	≥18 years old	Participants who were pregnant, mentally ill, edentulous, non-ambulatory, or critically ill	1000	100.0 (1000)	0.0%	CAL ≥1 mm (non-confident)	NR	423/577	≥18	NR	Research Grant
Eke et al., (2015, 2018) (USA)	Adults 30 years or older who had one or more natural teeth and no health conditions requiring antibiotic prophylaxis before periodontal probing	Medical conditions, Incomplete oral examinations, and institutionalized participants	19,931	34.8 (6940)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (6 sites)	3320/3620	≥30	NR	NR
Pinto-Filho et al. (2018) (Brazil)	Kiriri Indians aged ≥19 years living in an isolated area in Bahia state, northeast Brazil	Patients with missing information	226	99.6 (225)	0.0%	Severe periodontitis ≥2 proximal sites CAL ≥6 mm, not on the same tooth, and ≥1 proximal site with a PPD ≥5 mm. (non-confident)	Full-mouth (six sites)	65/160	≥19	101/124	Research grant
Shariff et al. (2018) (USA)	≥65 years old	NR	964	89.2 (860)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (6 sites)	691/169	≥65	NR	Research grant
Skośkiewicz-Malinowska et al. (2018) (Poland)	≥65 years old, local resident, able to communicate, and a written consent to participate in the survey	Coexisting systemic diseases in which dental pocket probing leading to transient bacteremia might have posed a risk for the patient's overall health condition: cardiovascular diseases (patients with heart valves, after heart transplant, with	500	100.0 (500)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (6 sites)	448/52	≥65	NR	Research grant

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		congenital heart diseases, or with infective endocarditis), blood diseases (thrombocytopenia, haemophilia, von Willebrand disease), viral diseases (B and C type hepatitis, AIDS/HIV), as well as patients with Multi-Drug Resistant Organisms (MDRO), as well as lack of a written consent, or mental disorders									
Wahlin et al. (2018) (Sweden)	20–80 years old	Edentulous and if they had any type of implants or prosthesis	621	100.0 (621)	0.0%	PPD ≥4 mm (non-confident)	Full -mouth (four sites—mesial, mid-buccal, mid-lingual, mesial)	248/373	20–80	NR	NR
Zhao et al. (2019) (China)	≥30 years old	NR	4930	80.2 (3952)	0.0%	CPI (non-confident)	Partial-mouth (CPI)	403/3, 549	30–68	NR	NR
J. B. Lee et al. (2019) (Republic of Korea)	≥30 years old	NR	31,006	31.6 (9798)	0.0%	CPI (non-confident)	Partial-mouth (sextants)	2771/7027	≥30	3717/6081	Company grant
Silva Junior et al. (2017) (Brazil)	Piracicaba residents aged 20–64 years old, mentally capable to answer the study questionnaire and agreeing to participate in the research	A physical or psychological state that prevented the achievement of clinical procedures or understanding of the questionnaire	NR	NR	0.0%	PPD ≥4 mm (non-confident)	Partial-mouth	43/100	20–64	NR	Research grant
	≥60 years old	NR	278	84.5 (235)	42.1%			3/47	≥60	NR	NR

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Lasta et al. (2019) (Brazil)						CPI (non-confident)	Partial-mouth (sextants)				
Botelho et al. (2019) (Portugal)	≥18 years old (adults and elderly), living in the municipalities of Almada and Seixal	NR	1064	100.0 (1064)	0.0%	EFP/AAP 2018	Full-mouth (six sites)	637/427	18–95	447/617	Self-funded
Helmi et al. (2019) (Saudi Arabia)	≥18 years old	Patients who were not within the specified age range, with no BW radiographs, with radiographs in which the cement-enamel junction (CEJ) and alveolar bone crest were not visible, who did not have at least two approximating teeth or where the inter-proximal space was too narrow to observe the bone crest	6265	18.1 (1131)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (2 sites—mesial and distal)	893/ 238	≥18	508/ 623	Research grant
Shimizu et al. (2019) (Japan)	60–99 years old	Participants without data on carotid intima-media thickness (CIMT) and those without any remaining teeth	1925	47.1 (907)	0.0%	"ADVANCED" PPD ≥6.0 mm (non-confident)	Full-mouth (2 sites—mesial-buccal and mid-buccal	197/710	60–99	353/NR	Research grant
Dhaifullah et al. (2019) (Saudi Arabia)	18–40 years old At least 20 natural teeth	Pregnancy, periodontal treatment within the past 4 months, a history of systemic diseases or medications known to affect periodontal health status (i.e., diabetes, topical or	700	54.3 (380)	0.0%	CPI (non-confident)	Partial-mouth (sextant)	25/283	18–40	154/154	Self-funded

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		systemic corticosteroids use, and/or antibiotics intake)									
Sun et al. (2020) (China)	55–74 years old, who had lived longer than 6 months in the sampling areas	Those who withheld consent or had serious diseases	9054	97.0 (8804)	0.0%	PPD ≥4 mm (non-confident)	Full-mouth	6066/2738	55–74	4514/4540	Research grant
Bongo et al. (2020) (Norway)	Adults in Finnmark County in Northern Norway	Missing questionnaire, missing clinical data, or both, unknown target age, missing written consent, or not accounted for and thus given missing unknown status	2520	82.5 (2078)	0.0%	EFP/AAP 2018 (confident)	Full-mouth (six sites)	1032/1046	18–75	894/1184	Research grant
Romero-Castro et al. (2020) (México)	18–75 years old, who reside in the state of Guerrero, Mexico	Pregnant or lactating women, as well as patients with systemic diseases or aggressive periodontitis	NR	NR	0.0%	Armitage 1999 (confident)	NR	98/63	18–75	NR	NR
Ha et al. (2020) (Australia)	NR	Required antibiotic prophylaxis before dental check-up, congenital heart murmur, heart valve problems, congenital heart disease, bacterial endocarditis, rheumatic fever, kidney disease, haemophilia, pacemaker or automatic defibrillator, hipbone	4402	86 (3792)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (three sites—mesio-buccal, mid-buccal, disto-buccal)	-	≥34	1854/2011	Research grant

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		or joint replacement, transplanted organs									
Schmidt et al. (2020) (Switzerland)	≥55 years old	Edentulous participants; endocarditis	1673	86.9 (1454)	0.0%	PPD ≥4 mm (non-confident)	Partial-mouth (FDI Index teeth)	614/840	≥55	NR	Research grant
Nakamura et al. (2020) (Japan)	≥20 years old	Immunocompromised patients (i.e., patients who received chemotherapy, those with severe immunodeficiency, and those with autoimmune disease, who received immunosuppressant therapies)	201	94.5 (190)	0.0%	PPD ≥4 mm (non-confident)	Full-mouth	115/75	≥20	NR	Research grant
Singh et al. (2020) (Nepal)	35–44; 65–74 years old	Psychiatric illness	310	100.0 (310)	0.0%	CPI (non-confident)	NR	21/96	35–44; 65–74	NR	Self-funded
Sekiguchi et al. (2020) (Japan)	≥18 years old	The participants without all oral examinations, those whose measured probing pocket depth (PPD) and clinical attachment loss (CAL) were not measured, those without General Oral Health Assessment Index (GOHAI) scores, and those who underwent health check-ups more than two times in the 3-year period	3742	31.6 (1183)	0.0%	PPD ≥4 mm (non-confident)	Full-mouth (two sites- Mesio-Buccal and mid-buccal)	594/589	≥18	NR	Research grant
Díaz-Reissner et al. (2020) (Paraguay)	18–59 years old, Paraguayans and foreign nationals with more than 14 years of	NR	NR	NR	1.2%	CPI (non-confident)	Partial-mouth (Ramfjört teeth)	19/310	18–59	NR	Self-funded

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	residence in the country										
Sakurai et al. (2021) (Japan)	Individuals insured by the national health insurance system (including self-employed workers, farmers, and the elderly) and aged 30 years and older	NR	14,932	28.0 (4184)	0.0%	CPI (non-confident)	Partial-mouth CPITN	1907/2199	≥30	NR	Research grant
Jiao et al. (2021) (China)	35–45; 55–65; 65–75 years old	NR	13,463	100.0 (13459)	1.96%	EFP/AAP 2018 (confident)	Full-mouth (most severe site)	8391/4804	35–45; 55–75	NR	Research grant
Goel et al. (2021) (Nepal)	20–65 years old, tobacco users who were currently consuming tobacco in the form of smoking or smokeless tobacco, non-tobacco users who had never used tobacco in any form (smoke or smokeless tobacco)	Former smokers, patients who actively consume alcohol, patients suffering from known systemic illness, pregnant and lactating females	1578	27.9 (440)	0.0%	CDC/AAP 2012 (confident)	NR	315/125	20–65	186/254	Self-funded
Germen et al. (2021) (Turkey)	35–74 years old	Individuals who required antibiotics after routine periodontal procedures	488	488	0.0%	CDC/AAP 2012 (confident)	Full-mouth (six sites)	302/186	35–74	NR	Self-funded
Han & Kim (2021) (Republic of Korea)	40–80 years old	Aged <40 years, edentate, and those missing values in the health assessment or questionnaires	9450	88.1 (8327)	0.0%	CPI (non-confident)	Partial-mouth (FDI Index teeth)	3339/4988	40–80	3572/4755	Self-funded
Costa et al. (2021) (Brazil)	≥18 years old At least eight natural teeth	People with mental health disorders, under orthodontic treatment, and pregnant women	450	100.0 (450)	0.0%	CPI (non-confident)	Partial-mouth (sextants)	304/146	≥18	NR	Research grant

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TABLE 1 (Continued)

Authors (year) (country)	Inclusion criteria	Exclusion criteria	Invited participants/ initial sample (*n*)	Response rate/ eligibility % (*n*)	Edentulous participants (*n*)	Periodontal criteria (confidence)	Periodontal examination protocol	Periodontitis/ healthy (*n*)	Age interval (years)	Male/ female	Funding source
Song et al. (2021) (Republic of Korea)	Six or more natural teeth	NR	330	91.5 (302)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (2 sites—mesial and distal))	270/143	47–86	NR	Research grant
Gomes-Filho et al. (2021) (Brazil)	>18 years old, registered in basic health units	Diagnosed with neoplasia, HIV, pregnancy, required antibiotic prophylaxis prior to periodontal examination, used anti-inflammatories in the previous 6 months before the examination, received prior periodontal treatment or used antibiotics 6 months before the examination	1011	100.0 (1011)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (6 sites)	851/160	≥18	332/NR	Research grant
Oliveira et al. (2021) (Brazil)	NR	Requirement of antibiotic prophylactic, psychiatric or mental problems, less than two teeth, less than 18 years old, presenting clinical attachment loss in two adjacent teeth	1092	53.6 (585)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (six sites)	519/66	≥18	NR	Research grant
Clauss et al. (2021) (Burkina Faso)	35–44 years old, member of a randomly chosen household within the HDSS Household Survey in in Nouna	NR	427	100.0 (427)	0.0%	CPI (non-confident)	Full-mouth (six sites)	341/86	35–44	NR	Research grant
Su et al. (2021) (Japan)	Smokers and patients with a medical history of hypertension,	Subjects with oral cancer or potentially malignant oral disorders (i.e.,	149	83.2 (124)	0.0%	PPD ≥4 mm (non-confident)	Full-mouth (6 sites)	72/52	35–90	NR	Research grant

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	diabetes, hyperlipidemia, stroke, heart disease, or bone and joint disease	leukoplakia or lichen planus), cancer patients receiving surgical treatment, chemotherapy or radiotherapy, those with auto-immune diseases receiving steroid therapy and those with severe immunodeficiency									
Iwasaki et al. (2021) (Japan)	At least 18 years of age and able to read and understand Japanese	Having fewer than two teeth and previous diagnosis of a severe or terminal disease, such as advanced heart failure, end-stage kidney disease, or advanced-stage cancer	215	92.6 (199)	0.0%	CDC/AAP 2012 (confident)	Full-mouth (six sites)	118/81	19–77	NR	Research grant
Stødle et al. (2021) (Norway)	≥19 years old and residents of the county	No radiographs, edentulous	7347	67.1 (4933)	0.66%	EFP/AAP 2018 (confident)	Full-mouth (six sites)	3.573/1.290	≥19	NR	Research grant
Bilgin Çetin et al. (2021) (Turkey)	NR	Patients younger than 18 years, edentulous patients	573	94.4 (541)	0.0%	EFP/AAP 2018 (confident)	Full-mouth (six sites)	221/320	≥18	252/289	Research grant
Kocher et al. (2021) (Germany)	Adults 35–44; 65–74	NR	2007	92.2 (1851)	0.0%	CPI (non-confident)	Partial-mouth (FDI Index teeth)	893/948	35–44; 65–74	NR	Research grant

Abbreviations: AAP, American Academy of Periodontology; CAL, clinical attachment level; CDC, Centers for Disease Control; CPI, Community Periodontal Index; EFP, European Federation of Periodontology; NR, not reported; PPD, periodontal probing depth.

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TABLE 2 Periodontitis prevalence according to the type of confident case definition

	n	ES	95% CI	*T*	T^2	I^2 (%)	*p*-value	Egger test [SE] (*p*-value)
Overall	24	61.6	55.1–67.9	0.16	0.03	99.1	<.000001	0.61 [3.63] (.867)
Risk of bias								
Low	7	54.1	47.4–60.6	0.09	0.01	98.9	<.000001	-
Moderate	17	64.7	56.3–72.6	0.18	0.03	99.0	<.000001	−3.76 [5.58] (.511)
Case definition								
EFP/AAP 2018	6	52.3	38.2–66.2	0.18	0.03	99.4	<.000001	-
CDC/AAP 2012	12	68.1	59.7–76.0	0.15	0.02	99.2	<.000001	12.35 [5.20] (.039)
CDC/AAP 2007	3	48.8	38.2–66.2	0.10	0.01	95.0	<.000001	-
AAP 1999	3	66.7	61.3–71.8	0.04	0.00	50.5	<.000001	-
Age interval								
Wider age interval (≥18/≥19)	11	57.1	45.9–67.9	0.19	0.04	99.4	<.000001	−9.31 [7.73] (.259)
≥30 years old	7	61.4	55.4–67.2	0.08	0.01	99.3	<.000001	-
<65 years old	2	59.4	34.5–81.9	0.18	0.03	98.7	<.000001	-
≥65 years old	3	79.3	64.2–91.2	0.15	0.02	97.5	<.000001	-
Continent								
Asia	10	62.4	55.0–69.5	0.15	0.01	97.6	<.000001	−0.91 [3.16] (.780)
Europe	5	65.5	48.7–80.5	0.19	0.04	99.5	<.000001	-
North America	4	62.6	48.3–75.9	0.15	0.02	99.2	<.000001	-
South America	5	54.9	33.4–75.5	0.06	0.25	99.4	<.000001	-

Note: Effect size (ES) with 95% confidence interval (CI), tau (*T*), tau squared (T^2) and *I*-squared (I^2), *p*-value and Egger test are presented.

intervals defined in the studies ($p = .0101$). Yet, studies reporting prevalence data of elderly participants (≥65 years or older) presented the highest estimates with an average a 79.3% overall percentage (95% CI: 64.2–91.2, $p < .000001$, $I^2 = 97.5\%$).

3.4.2 | Prevalence per continent

Considering the geographic location, the pooled estimate from the European continent was the highest (65.5%), while the South American continent had the lowest (54.9%; Table 2). Yet, all continents reported significant pooled estimates exceeding 50%.

3.4.3 | Severity

Concerning severity (Table 3), the pooled measures pointed to an estimated moderate to severe periodontitis prevalence of 53.2% (95% CI: 44.3–61.9, $p < .000001$, $I^2 = 99.2\%$). Although having substantial heterogeneity, this estimate was relatively stable and not influenced by the female/male ratio (−0.220, $p = .2952$), latitude (0.001, $p = .3641$), longitude (0.000, $p = .8570$), or sample size (−0.000, $p = .8172$). The estimated prevalence of severe periodontitis was 23.6% (95% CI: 17.6–30.1, $p < .000001$, $I^2 = 99.4\%$). Similarly, we observed high heterogeneity, and this estimate was significantly influenced by the male/female ratio (−0.401, $p = .0334$) but not by the remaining variables (sample size, latitude, and longitude).

3.5 | Additional analysis

When inspecting the existence of publication bias, funnel asymmetry was found in studies reporting periodontitis using the CDC/AAP 2012 (estimate = 12.35, SE = 5.204, $p = .039$; Table 2). For the remaining estimates, no publication bias was observed.

4 | DISCUSSION

4.1 | Summary of main results

The results of this systematic review confirm that periodontitis continues to be an alarming world public health problem, with nearly 62% pooled prevalence in dentate adults as seen from studies performed between 2011 and 2020. Pooled prevalence for moderate to severe cases was 53.2% while for severe periodontitis it was 23.6%.

Pooled estimates from confident case definitions presented almost double the prevalence. The CDC/AAP 2012 classification was the most used diagnostic criterion and gave the highest prevalence estimate (68.1%), while the EFP/AAP 2018 case definition gave a pooled estimate of 52.3%.

4.2 | Evidence quality and potential bias in the review process

This study's strengths and limitations are based primarily on the methodological quality of the included studies per se, while the study was

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TABLE 3 Periodontitis prevalence according to the form of periodontitis

Periodontitis	*n*	ES	95% CI	*T*	T^2	I^2 (%)	*p*-value	Egger test [SE] (*p*-value)
Moderate to severe versus mild to no	20	53.2	44.3–61.9	0.20	0.04	99.2	<.000001	2.38 [4.32] (.589)
Severe versus non-severe	20	23.6	17.6–30.1	0.17	0.03	99.4	<.000001	1.29 [5.00] (.799)

Note: Effect size (ES) with 95% confidence interval (CI), tau (*T*), tau squared (T^2) and I-squared (I^2), *p*-value, and Egger test are presented.

prepared and reported according to state-of-the-art guidelines and comprehensively analysed the possible confounding variables that could affect the results. Indeed, prevalence was strictly affected by periodontal case definitions with regard to their confidence. As for the remaining variables, they did not influence the final estimates. Defining the confidence of a case definition always implies an uncertain degree of selection bias, yet this decision was based on a previous study by Muñoz-Aguilera (2020), which found a significant weight on the results. Similarly, studies with confident case definitions reported almost twice the prevalence as those using non-confident classifications according to the present results.

Still on the periodontal case definitions, our meta-analytical estimates differ from those of previous studies using the GBD approach (Marcenes et al., 2013; Kassebaum et al., 2014; Chen et al., 2021; Wu et al., 2022) and aligns with a recent meta-analysis on the global prevalence of aggressive periodontitis (Bouziane et al., 2020). On one hand, GBD estimates are based on complex and strong iterative approaches and thus provide worldwide approximations (IHME, 2018) yet using less reliable diagnostic criteria (such as the CPI of treatment needs). On the other hand, our approach provides more reliable estimations based on full-mouth examinations and diagnostic consensus; nevertheless, the existence of several confident case definitions confuses the comparison among studies. Consequently, arriving at a consensus to strengthen the surveillance of periodontitis will certainly benefit periodontal research and future meta-epidemiological studies. Defining mandatory periodontal clinical measures (such as PPD, CAL, PISA, or PESA) and thresholds and providing results based on at least two diagnostic criteria (CDC/AAP 2012 and EFP/AAP 2018) are suggestions that may contribute to the robustness of periodontal prevalence reporting. Yet, narrowing the results according to the confidence of case definition may have certainly resulted in less geographic coverage and was contingent upon available epidemiological studies. Only 25 countries (17 of which were using confident diagnostic criteria) were accounted in the final analyses, without representation from Africa and Oceania.

One possible explanation for the obtained differences in results between the 2007 definition and its updated version of 2012 may be due to the fact the original version was designed to capture only moderate and severe periodontitis while in the 2012 update the mild case was introduced. The incorporation of a mild stage may have reduced the number of periodontally healthy cases, thereby leading to a potential increase in the number of periodontitis cases, a factor that could partially explain these noticeable differences.

Finally, several studies were lacking in information on male/female prevalence ratio, clear age intervals, distribution according to smoking habits, socio-economic data, and distribution of periodontitis according to its severity. Thus, our examination on additional sources of heterogeneity and interpretation of the results was restricted and could be expanded in the future if studies provide such information. Moreover, the inclusion of edentulous participants may have an impact on the prevalence reported, but due to missing data, we were not able to measure its magnitude.

4.3 | Agreements and disagreements with other reviews or studies

There is overall agreement that the prevalence and incidence of periodontitis have been increasing, possibly due to population growth and ageing (Marcenes et al., 2013; Kassebaum et al., 2017; Peres et al., 2019; Watt et al., 2019; GBD 2017 Oral Disorders Collaborators et al., 2020; Wu et al., 2022). These results align with this consensus and highlight the need for better periodontal care programmes mainly focusing the poor and socially disadvantaged populations that are disproportionally affected. As such, these estimates can flag worrisome levels that will contribute to the World Health Organization Resolution on Oral Health within the road map for neglected tropical diseases for 2021–2030 (WHO, 2021).

In Wu et al. (2022), GBD data allowed the assessment of all regions and countries, which was not possible with our estimates. In the latter, periodontitis was mostly prevalent in 55–59-year-olds, with substantial prevalence from 55 years onwards. Similarly, our age subgroup meta-analysis showed individuals of 65 years or older to have the highest prevalence when compared with younger age groups. Regarding severe periodontitis, our results report a substantial prevalence of severe periodontitis (24%). Compared to the 11.2% of severe periodontitis reported globally by Kassebaum et al. (2014), our estimate is definitely higher. However, the methodologies used in the two estimates differ, as in Kassebaum et al. the results relied on probing depth, which leads to an underestimation of periodontitis in adults. Despite this estimation discrepancy, our estimates point to a worrisome forecast of severe periodontitis among dentate adults.

The findings from this study can inform global health stakeholders about the prevalence of periodontitis from epidemiological studies to preempt and better manage public periodontal health strategies. However, because of the limited number of countries represented in the final sample, the generalizability of these estimates is limited. Therefore, we emphasize the need for continued epidemiological surveillance, from both national and regional settings, using appropriate

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diagnostic strategies, to better convey accurate estimates and to allow meta-analytical global outputs.

5 | CONCLUSION

Within the limits of this systematic review, it can be concluded that, over the last decade (from 2011 to 2020), the estimated pooled prevalence of periodontitis is nearly 60%, with its severe stage affecting approximately 24% of the studied population. These results show an alarmingly high prevalence compared to estimates from 1990 to 2010.

Based on this data, the worldwide periodontitis estimates of this study are crucial to establish priorities for research, development, public health policy, and funding to governments and domestic and international non-governmental organizations.

AUTHOR CONTRIBUTIONS

Diogo Trindade contributed to data acquisition and interpretation and drafted and critically revised the manuscript; João Botelho contributed to conception, design, data acquisition, and analysis and drafted and critically revised the manuscript; Vanessa Machado contributed to conception and design and critically revised the manuscript; Rui Carvalho contributed to data interpretation and critically revised the manuscript; José João Mendes and Leandro Chambrone contributed to data analysis and interpretation and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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