Definitions used for a healthy periodontium—A systematic review

An Li1 | Renske Z. Thomas1,2 | Luc van der Sluis1 | Geerten-Has Tjakkes1 | Dagmar Else Slot3

1Center for Dentistry and Oral Hygiene, University Medical Center Groningen (UMCG), University of Groningen, Groningen, The Netherlands
2Department of Dentistry, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands
3Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

Correspondence
Renske Z. Thomas, Department of Periodontology, Center for Dentistry and Oral Hygiene, University Medical Center Groningen (UMCG), University of Groningen 9713 AV, Groningen, The Netherlands. Email: renskethomas@gmail.com

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Abstract
Objective: To investigate the explicitness and variability of the definition of periodontal health in the current scientific literature.

Material and methods: The authors conducted a systematic literature review using PubMed and CENTRAL (2013-01/2019-05) according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the guidelines of the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) statement.

Results: A total of 51 papers met the predefined inclusion criteria. Of these, 13 papers did not report any explicit definitions of periodontal health. Out of the 38 remaining articles, half of them used a reference to support their definition and half of them did not. The studies published in periodontics-related journals or those that scored a low risk of bias for the methodical quality presented more explicit and valid definitions. Probing pocket depth was the most frequently used individual parameter for defining periodontal health. However, there were substantial variations in the methods of measurement and cut-off values.

Conclusions: Given the diversity of periodontal health definitions, a cross-study comparison is difficult. The results of this review may be useful in making others aware of the significance of standardizing the definition of a healthy periodontium.

KEYWORDS
definition, periodontal health, periodontium, systematic review

1 | INTRODUCTION

The main objective of periodontal care is to reach and maintain a healthy periodontium. The definition of periodontal health plays a crucial role in population surveillance and the determination of critical therapeutic targets for clinicians. Most studies traditionally regarded that a healthy periodontium is the opposite of case definitions of periodontal disease, as does the World Health Organization (WHO) defining health as an absence of illness. Specifically, periodontal health refers to a state free from inflammation and characterized by shallow pockets and the absence of gingival bleeding. However, there are a variety of case definitions, and these definitions refer to an array of clinical signs and symptoms, such as probing pocket depth (PPD), clinical attachment loss (CAL), and bleeding on probing (BOP). Consequently, we assume that there is heterogeneity in the definitions of periodontal health. The definition of
periodontal health should be consistent, facilitating comparison of clinical studies. Periodontal health was recently defined as the absence of clinically detected inflammation by the 2018 World Workshop of the European Federation of Periodontology (EFP) and the American Academy of Periodontology (AAP). This EFP/AAP definition is mainly based on PPD and BOP scores. To date, no overview of periodontal health definitions has been conducted. Therefore, this systematic review (SR) investigates the current scientific literature related to the definition of periodontal health.

2 | MATERIALS AND METHODS

2.1 | Protocol development

The protocol for this SR was developed “a priori,” following an initial discussion among members of the research team according to the Cochrane Handbook for Systematic Reviews of Interventions and the guidelines of PRISMA and MOOSE.

2.2 | Search strategy

A structured literature search of the National Library of Medicine, Washington, DC (PubMed-MEDLINE), and the Cochrane Central Register of Controlled Trials (Cochrane-CENTRAL) was performed up to May 2019. Since the Centers for Disease Control and the American Academy of Periodontology (CDC/AAP) case definition of periodontal disease was updated in 2012, this report covers all studies published and cited since January 2013. We hand-searched all of the reference lists of selected papers. This forward citation check was carried out in four rounds to identify additional published work that could meet the eligibility criteria of the study, so-called “snowball procedure.” For details regarding the search terms used, see Appendix S1.

2.3 | Eligibility criteria

Publications were included only when they (a) were original studies, (b) were conducted in a human population, (c) were published in English, (d) contained a defined group of periodontal health or a non-defined control group as an opposite to the defined periodontal disease, and (e) their definitions described measurements and identified thresholds.

2.4 | Screening and selection

Two reviewers (AL and RZT) screened the titles and abstracts of the studies obtained during the search for eligible papers independently. After the screening, the reviewers read the full texts of eligible papers in detail. Any disagreement concerning eligibility was resolved by consensus, and if conflict persisted, the decision was settled through arbitration led by a third reviewer (DES). The papers that met all the selection criteria were processed for data extraction.

2.5 | Assessment of heterogeneity

Heterogeneity across studies was detailed according to the following factors: study design, published journal type, subject characteristics, potential confounding factors, measurement tools and procedures, the number of explicit definitions, clinical parameters and cut-off values.

2.6 | Methodological assessment of risk of bias

The two reviewers independently scored the methodological qualities of each study as well (AL and RZT). The appropriate critical appraisal checklists from the Joanna Briggs Institute were used depending on the study design of the paper. Studies that met 80% of the criteria were considered to have a low risk of bias. And 60% to 79% was a moderate one; 40% to 59% criteria were substantial one; and less than 40%, high one.

2.7 | Data extraction and analysis

The characteristics of the published journal type, study design, country, sample frame, sample size, group, age, gender, smoking status, medical condition, examination area, measurement tool, probing location and definition of periodontal health were extracted. Papers that included detailed measuring parameters and clear cut-off values were regarded as having an “explicit definition”. Moreover, the “explicit definition” papers that used references to support their definitions were viewed as having a “valid definition”. The extracted criteria for periodontal health were recorded with Microsoft Excel 2017. All quantitative analyses were conducted with SPSS Statistics 25.

3 | RESULTS

3.1 | Search results

The search through online databases resulted in 1236 unique studies (Figure 1). The initial screening of the titles and abstract resulted in 49 studies that went on to full-text review. Then, a detailed reading of the full texts was performed. Two independent reviewers excluded 20 studies (Appendix S2), leaving 29 eligible papers. Furthermore, a manual search through the reference list of the 29 papers led reviewers to identify 22 additional relevant studies (Appendices S3 and S4). Finally, a total of 51 studies were included for the evaluation of the definition of periodontal health. Among
the selected papers, 38 provided a definition of periodontal health. Thirteen studies did not report an explicit periodontal health definition and rather referenced periodontal health as the opposite of disease. This study outlines the characteristics of the included papers. These characteristics are summarized in Table 1.

3.2 Methodological quality assessment

The methodological quality of the included studies was used to estimate the potential risk of bias and is presented in detail in Appendices S5.1-5. The estimated potential risk of bias was low for 15 studies, moderate for 25 studies, substantial for eight studies, and high for three studies.

3.3 Study characteristics

The papers were published in journals of different categories, targeting periodontology (29%), dentistry (29%) and general medicine (41%). The studies were designed as cross-sectional studies (37/51), longitudinal studies (4/51), and randomized or non-randomized allocated control studies (10/51). A total number of 372,983 individuals were enrolled in the studies, ranging from 18 to 354,850 individuals for each
| Reference (year) | Type of journal | Study design | Sample frame | Country | Sample size of all | Healthy group: number/ age/ gender | Smoking status | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|-----------------|----------------|--------------|--------------|---------|-------------------|-------------------------------|--------------|----------------|----------------|----------------|---------------------------------------------------------------|
| Mourão et al, 2013<sup>34</sup> Medical journal | Substantial | RCT study | Dental clinic | Brazil | AL: (n = 60) | Periodontal health group: (n = 20) 48.6 ± 7.4, ♀: 12/ ♂: 8 | Not recorded | Full mouth | Probe type unclear | Inter-proximal sites | Explicit definition of periodontal health |
| Jones et al, 2013<sup>35</sup> Dental journal | Substantial | RCT study | General population | United Kingdom | AL: (n = 369) | 6-month group: (n = 125) 37.1 ± 10.4, ♀: 68 (54.4%)/ ♂: 57 (45.6%) 12-month group: (n = 122) 39.6 ± 10.8, ♀: 79 (64.8%)/ ♂: 43 (35.2%) 24-month group: (n = 122) 36.4 ± 10.6, ♀: 88 (72.1%)/ ♂: 34 (27.9%) | Recorded | Full mouth | WHO probe | Six sites | Basic Periodontal Examination (BPE) | Explicit definition of periodontal health |
| Graziani et al, 2018<sup>36</sup> Periodontal journal | Moderate | RCT study | Dental hospital | Italy | AL: (n = 60) | Group 1: (n = 15) 28.7 ± 9.8, ♀: 6 (40%)/ ♂: 9 (60%) Group 2: (n = 14) 26.1 ± 3.7, ♀: 8 (57%)/ ♂: 6 (43%) Group 3: (n = 16) 26.4 ± 5.2, ♀: 9 (56%)/ ♂: 7 (44%) Group 4: (n = 15) 26.4 ± 5.4, ♀: 8 (53%)/ ♂: 7 (47%) | Excluded | Full mouth | UNC-15 probe | Six sites | Consensus report of the 5th European Workshop in periodontology<sup>29</sup> © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd Explicit definition of periodontal health |
| Sukhtankar et al, 2013<sup>37</sup> Medical journal | Moderate | Non-randomized experimental study | Department of periodontics and oral implantology | India | © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd (24-55), ♀: 20/ ♂: 20 © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd | Excluded | Full mouth | UNC-15 probe | Site unclear | Explicit definition of periodontal health |
| Sharma et al, 2014<sup>38</sup> Medical journal | Moderate | Non-randomized experimental study | Dental hospital | India | © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd 25-60 | Excluded | Full mouth | Probe type unclear | Six sites | © 2020 The Authors. International Journal of Dental Hygiene published by John Wiley & Sons Ltd<sup>27</sup>: Opposite of periodontal disease | (Continues) |
| Reference (year)                          | Type of journal | Risk of bias | Study design                     | Sample frame | Country              | Sample size of all | Healthy group: number/ age/ gender | Smoking status | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|------------------------------------------|-----------------|--------------|----------------------------------|--------------|-----------------------|--------------------|----------------------|----------------|-----------------|------------------|----------------|---------------------------------------------------------------|
| Guentsch et al, 2014                     | Periodontal journal | Moderate     | Non-randomized experimental study | Dental hospital | Germany             | ALL: (n = 30) | Periodontal health group: (n = 15) | 26 (23-39), ♀: 11/ ♂: 4 | Excluded | Full mouth | UNC-15 probe | Six sites | Armitage classification<sup>7</sup>; Explicit definition of periodontal health |
| Hassan et al, 2015                       | Medical journal  | Moderate     | Non-randomized experimental study | General population | Egypt          | ALL: (n = 30) | Periodontal health group: (n = 10) | 37.81 ± 8.3, ♀: 6/ ♂: 4 | Excluded | Full mouth | Michigan 0 probe | Six sites | Explicit definition of periodontal health |
| Leite et al, 2014                        | Medical journal  | Low          | Non-randomized experimental study | General hospital | Brazil        | ALL: (n = 55) | Periodontal health group: (n = 55) | 33.18 ± 6.42, ♀: 67%/ ♂: 33% | Excluded | Full mouth | Michigan 0 probe | Four sites | Explicit definition of periodontal health |
| Al-Hamoudi et al, 2018                   | Dental journal   | Low          | Non-randomized experimental study | Dental hospital | Saudi Arabia | ALL: (n = 137) | Obese patients without CP: (n = 34) | 37.5 (31-42), ♀: 2/ ♂: 32 | Excluded | Full mouth | UNC-15 periodontal probe | Six sites | Opposite of periodontal disease |
| Muthu et al, 2015                        | Dental journal   | Moderate     | Non-randomized experimental study | Dental hospital | India         | ALL: (n = 220) | (35-50), ♀: 96%/ ♂: 124 | Control group: (n = 90) | Excluded | Examination area | unclar | Probe type unclear | Site unclear | Explicit definition of periodontal health |
| Raber-Durlacher et al, 2013              | Medical journal  | High         | Cohort study                     | Dental hospital | Netherlands | ALL: (n = 18) | 41.8 ± 13.4 (19-64) | ♀: 11 (61%)/ ♂: 7 (39%) | Not recorded | Full mouth | Probe type unclear | Four sites | Explicit definition of periodontal health |
| Ricardo et al, 2015                      | Medical journal  | Moderate     | Cohort study                     | Population    | United States | ALL: (n = 10,755) | 41.5 ± 0.5, ♀: 50%/ ♂: 50% | CKD (+) without periodontitis group: (n = 1,142): 51.9 ± 1.2, ♀: 62.1%/ ♂: 37.9% | Recorded | Chronic kidney disease (CKD) patients | Full mouth | Probe type unclear | Site unclear | CDC/AAP case definition<sup>6</sup>; Opposite of periodontal disease |

(Continues)
| Reference (year) | Type of journal | Study design | Sample frame | Country | Sample size of all | Healthy group: number / age / gender | Smoking status | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|------------------|------------------|--------------|--------------|---------|-------------------|--------------------------------------|---------------|-----------------|-----------------|----------------|---------------------------------------------|
| Lee et al, 2017  | Medical journal  | Cohort       | General population | Korea | ALL: (n = 354,850) | Periodontal health group: (n = 154,824) 40-49: 46.8%, 50-59: 27.6%, 60-69: 19.6%, 70-79: 6%, 80+: 49.2%, 90+: 50.8% | Recorded | Full mouth | Probe type unclear | Inter-proximal sites | Armitage classification 17: Opposite of periodontal disease |
| Lourenço et al, 2014 | Periodontal journal | Case-control study | Division of Graduate Periodontics | Brazil | ALL: (n = 97) | Periodontal health group: (n = 27) 24.2 ± 6.9, ♀: 77.8%, ♂: 22.2% | Recorded | Full mouth | UNC-15 probe | Site unclear | Armitage classification 17: Explicit definition of periodontal health |
| Zimmermann et al, 2013 | Periodontal journal | Cross-sectional | Dental hospital | Brazil | ALL: (n = 78) | NW non-periodontitis (NP) group: (n = 20) 42.9 ± 7.2, ♀: 14%, ♂: 6% Obese non-periodontitis group: (n = 18) 43.2 ± 7.4, ♀: 14%, ♂: 4% | Excluded | Full mouth | UNC-15 probe | Six sites | Armitage classification 17: Explicit definition of periodontal health |
| Apatzidou et al, 2013 | Dental journal | Cross-sectional | Department of periodontology | Greece | ALL: (n = 78) | Healthy individuals: (n = 27) 31 ± 5, ♀: 15%, ♂: 12% | Excluded | Full mouth | UNC-15 probe | Six sites | Explicit definition of periodontal health |
| Ebersole et al, 2013 | Medical journal | Cross-sectional | Population | United States | ALL: (n = 80) | Healthy adults: (n = 30) 31.4 ± 6.8, ♀: 46.7%, ♂: 53.3% | Recorded | Full mouth | UNC-15 probe | Inter-proximal sites | Armitage classification 17: Explicit definition of periodontal health |
| Rathnayake et al, 2013 | Periodontal journal | Cross-sectional | Dental hospital | Sweden | ALL: (n = 451) | PD-group: (303) 42.6 ± 15.5, gender unclear | Recorded | Full mouth | UNC-15 probe | Four sites | Explicit definition of periodontal health |
| Wang et al, 2013 | Medical journal | Cross-sectional | Dental hospital | China | ALL: (n = 16) | 30-65, gender unclear | Excluded | Examination area unclear | Probe type unclear | Site unclear | Explicit definition of periodontal health |
| Gursoy et al, 2013 | Periodontal journal | Cross-sectional | Population | Finland | ALL: (n = 230) | Control subject group: (n = 81) 47.9 ± 5.7, ♀: 64.2%, ♂: 35.8% | Recorded | Full mouth | Probe type unclear | Four sites | Explicit definition of periodontal health |

(Continues)
| Reference (year) | Study design | Sample frame | Risk of bias | Sample size of all Healthy group: number/ age/ gender | Smoking status | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|-----------------|--------------|--------------|--------------|-------------------------------------------------|---------------|----------------|-----------------|-----------------|-------------------------------------------------|
| Kebschull et al, 2013 | Cross-sectional | Clinic of post-doctoral periodontics United States | Substantial | ALL: (n = 310) "Healthy" group: (n = 69) 45.7 ± 11.6 (24-76), ♀: 50.8%/ ♂: 49.2% | Excluded | Full mouth | Probe type unclear | Six sites | Armitage classification; Explicit definition of periodontal health |
| Salazar et al, 2013 | Cross-sectional | Population Germany | Moderate | ALL: (n = 400) Healthy periodontium group: (n = 20) 48.6 ± 11.4, ♀: 50%/ ♂: 50% | Recorded | Examination area unclear | SHIP-2: PCP11 probe; SHIP-TREND: PCPUNC probe 15 Site unclear | Explicit definition of periodontal health |
| Gokhale et al, 2013 | Cross-sectional | Department of Periodontics India | Low | ALL: (n = 120) 30-60 Periodontal health group: (n = 30) | Excluded | Full mouth | UNC-15 probe | Four sites | Armitage classification; Explicit definition of periodontal health |
| Wara-aswapati et al, 2013 | Cross-sectional | General hospital Thailand | Moderate | ALL: (n = 35) Control individuals without periodontitis: (n = 16) 34.0 ± 15.8, ♀: 14%/ ♂: 2 | Not recorded | Area unclear | UNC-15 probe Site unclear | Armitage classification; Opposite of periodontal disease |
| Javed et al, 2014 | Cross-sectional | Dental hospital Pakistan | Low | ALL: (n = 88) Controls: (n = 28) 51.7 ± 12.9, ♀: 0%/ ♂: 28 | Excluded | Full mouth | Hu-Friedy probe | Six sites | Armitage classification; Opposite of periodontal disease |
| Kim et al, 2013 | Cross-sectional | Dental hospital Korea | Low | ALL: (n = 125) 57.85 ± 1.03, ♀: 48%/ ♂: 77 | Recorded | Area unclear | WHO probe Site unclear | WHO community periodontal index of treatment needs | Explicit definition of periodontal health |
| Pushparani et al, 2014 | Cross-sectional | Department of periodontology India | Low | ALL: (n = 600) Control healthy individual: (n = 150) 35.46 ± 106.74, ♀: 70%/ ♂: 80 Type 2DM without periodontitis: (n = 150) 46.26 ± 10.02, ♀: 72%/ ♂: 78 | Excluded | Area unclear | Probe type unclear Site unclear | Armitage classification; Opposite of periodontal disease |
| Shetty et al, 2016 | Cross-sectional | Dental hospital India | Moderate | ALL: (n = 120) Healthy group: (n = 30) | Excluded | Area unclear | Probe type unclear Site unclear | Explicit definition of periodontal health |
| Reference (year) | Study design | Sample size of all Healthy group: number/ age/ gender | Smoking status | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|-----------------|--------------|------------------------------------------------------|----------------|------------------|------------------|-----------------|-------------------------------------------------|
| Panezai et al, 2018 62 | Cross-sectional Dental hospital | ALL: (n = 86) Healthy group: (n = 14) 44.4 ± 6.6, ♂: 5/ ♀: 9 | Recorded | Full mouth | Hu-Friedy probe | Four sites | Explicit definition of periodontal health |
| Medical journal Low | | | | | | | |
| Medical journal Huang et al, 201863 | Cross-sectional Dental hospital | ALL: (n = 68) ♂: 31 (43 ± 12.1)/ ♀: 37 (47 ± 11.7) Healthy group: (n = 20) | Not recorded | Area unclear | Probe type unclear | Site unclear | Armitage classification 17: Explicit definition of periodontal health |
| Moderate | China | | | | | | |
| Medical journal Papathanasiou et al, 201464 | Cross-sectional Population | ALL: (n = 42) periodontally healthy group: (n = 14) 26.3 ± 2.6, ♂: 78.6%/ ♀: 21.4% | Excluded | Full mouth | UNC-15 probe | Six sites | Explicit definition of periodontal health |
| Periodontal journal Moderate | | | | | | | |
| Mesa et al, 201465 | Cross-sectional Dental hospital | ALL: (n = 77) Periodontal health group: (n = 36) 46.25 (19-79), ♂: 46/ ♀: 31 | Recorded | Full mouth | UNC-15 probe | Six sites | Explicit definition of periodontal health |
| Periodontal journal Low | | | | | | | |
| Schjetlein et al, 201466 | Cross-sectional General hospital | ALL: (n = 62) 57.0 (51-60), ♂: 28/ ♀: 34 Without periodontitis group: (n = 49) 57.0 (51-61), ♂: 24/ ♀: 25 | Recorded | Full mouth | WHO probe | Site unclear | Periodontal Screening Index Explicit definition of periodontal health |
| Medical journal Moderate | | | | | | | |
| Singh et al, 201467 | Cross-sectional Department of periodontics and oral implantology | ALL: (n = 106) Periodontally healthy individuals: (n = 22) 40.6 ± 8.6, ♂: 17 (77.3%)/ ♀: 5 (22.7%) | Excluded | Full mouth | Probe type unclear | Site unclear | Armitage classification 17: Explicit definition of periodontal health |
| Low | | | | | | | |
| Beklen and Tsaous Memet, 201468 | Cross-sectional General hospital | ALL: (n = 20) Periodontal health group: (n = 10) 33-39, gender unclear | Excluded | Full mouth | Probe type unclear | Inter-proximal sites | Explicit definition of periodontal health |
| Medical journal Moderate | Turkey | | | | | | |
| Duran-Pinedo et al, 201469 | Cross-sectional General hospital | ALL: (n = 13) Periodontally healthy individuals: (n = 6) 27.5 (22-50), ♂: 16/ ♀: 6 | Excluded | Examination area unclear | Probe type unclear | Site unclear | Explicit definition of periodontal health |
| Medical journal Substantial | United States | | | | | | |
| Tabari et al, 201370 | Cross-sectional Department of Periodontology | ALL: (n = 50) Individuals with a healthy periodontium: (n = 25) 20-45, ♂: 11 (44%)/ ♀: 14 (56%) | Excluded | Full mouth | UNC-15 probe | Four sites | Armitage classification 17: Explicit definition of periodontal health |
| Reference (year) | Type of journal | Study design | Sample frame | Country | Risk of bias | Sample size of all Healthy group: number/ age/ gender | Smoking status | Medical condition | Examination area | Measurement tool | Probing location | Explicit definition of periodontal health or Opposite of periodontal disease |
|-----------------|-----------------|--------------|--------------|---------|-------------|--------------------------------------------------|---------------|------------------|-----------------|----------------|-----------------|--------------------------------------------------|
| Tabari et al, 2013 | Periodontal journal Low | Cross-sectional | Department of Periodontology | Iran | Low | ALL: (n = 40) Periodontally healthy individuals: (n = 20) 33.85 ± 6.84, ♀: 65% / ♂: 35% | Excluded | | Full mouth | UNC-15 probe | Four sites | Armitage classification
Explicit definition of periodontal health |
| Gameata et al, 2015 | Medical journal Moderate | Cross-sectional study | General hospital | Romania | Moderate | ALL: (n = 238) 57.0 (50.0-64.8), ♀: 40% / ♂: 60% Periodontal health group: (n = 58) 55.5 (42.3-61.0), ♀: 43% / ♂: 57% | Recorded | Stable chronic hemodialysis patients | Full mouth | Probe type unclear | Site unclear | Explicit definition of periodontal health |
| Torrungruang et al, 2015 | Medical journal Substantial | Cross-sectional study | Population | Thailand | Substantial | ALL: (n = 1,362) No/mild periodontitis: (n = 479) 46.6 ± 4.4, ♀: 211 / ♂: 268 | Not recorded | | Full mouth | Probe type unclear | Six sites | CDC/AAP case definition
Opposite of periodontal disease |
| Ghallab et al, 2015 | Periodontal journal Moderate | Cross-sectional | Dental hospital | Egypt | Moderate | ALL: (n = 50) Periodontal health group: (n = 10) 47.8 ± 2.9, ♀: 5 / ♂: 5 | Excluded | | Full mouth | Michigan 0 probe | Six sites | Armitage classification
Explicit definition of periodontal health |
| Lavu et al, 2015 | Medical journal Moderate | Cross-sectional | Dental hospital | India | Moderate | ALL: (n = 400) Periodontal health group: (n = 200) 29.64 ± 5.5 (20-55), ♀: 52.4% / ♂: 47.5% | Excluded | | Full mouth | UNC-15 probe | Six sites | Armitage classification
Explicit definition of periodontal health |
| Kurşunlu et al, 2015 | Dental journal Moderate | Cross-sectional study | Department of periodontology | Turkey | Moderate | ALL: (n = 80) Periodontally healthy subjects (n = 20) | Excluded | | Full mouth | Probe type unclear | Site unclear | Armitage classification
Explicit definition of periodontal health |
| Chaiyarit et al, 2015 | Dental journal High | Cross-sectional | General hospital | Thailand | High | ALL: (n = 90) Healthy subjects: (n = 30) 54.4 ± 11.03 (35-75), ♀: 17 / ♂: 13 | Not recorded | | Examination area unclear | Probe type unclear | Site unclear | Armitage classification
Explicit definition of periodontal health |
| Özcın et al, 2015 | Dental journal Moderate | Cross-sectional | Department of periodontology | Turkey | Moderate | ALL: (n = 72) Healthy subjects: (n = 23) 34.50 ± 7.09 (35-75), ♀: 11 / ♂: 12 | Excluded | | Examination area unclear | Michigan 0 probe | Site unclear | Explicit definition of periodontal health |
| Kirst et al, 2015 | Medical journal Substantial | Cross-sectional | General hospital | United States | Substantial | ALL: (n = 50) Healthy controls: (n = 25) | Not recorded | | Examination area unclear | Probe type unclear | Site unclear | Explicit definition of periodontal health |
| Velosa-Porras et al, 2016 | Dental journal Low | Cross-sectional | Dental hospital | Colombia | Low | ALL: (n = 150) Mean = 50.2 Periodontal health group: (n = 75) ♀: 44 / ♂: 31 | Recorded | | Full mouth | Electronic probe | Site unclear | Armitage classification
Opposite of periodontal disease |
Most publications were authored by research groups in India (14%) and the United States (12%). Most studies (82%) recruited patients from a hospital setting with comorbidities such as diabetes, chronic kidney disease or chronic haemodialysis. Concerning confounding factors, such as smoking habits and medical condition, 28 of the studies excluded participants with smoking habits. Those with complicated medical conditions were excluded from 45 studies (Table 1).

### 3.4 Measurement methods

In 39 out of the 51 papers, a full-mouth assessment was conducted (Table 1). Various types of periodontal probes were used. Twenty-four studies did not report the details of the probe, 16 studies used the UNC-15 probe, and four studies used the Michigan 0 probe. The number and location of probing sites varied. Four sites (mesiobuccal, mesiolingual, distobuccal and distolingual) per tooth were used in 8 studies, and six sites (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual and distolingual) per tooth were used in 17 studies. Moreover, five studies specifically measured the indicators at the location of the inter-proximal sites.

### 3.5 Presence of an explicit or valid definition according to journal type, study design and risk of bias

A precise definition of periodontal health is offered in 38 (75%) of the included studies. The remaining 13 papers provided the references and defined the opposite of disease as periodontal health (Table 2). An explicit definition with a supporting reference was reported in 19 papers. In contrast, the other 19 studies only used a definition rather than indicating any reference (Table 2; for details, see Appendix S6). The two most frequently used references were the Armitage classification (1999), used in 22 papers, and the CDC/AAP case definition, used in five papers. None of the papers reporting details of the classification followed the original proposed definition strictly, but a wide variance was applied (Appendices S7.1-2).

The number of explicit and valid periodontal health definitions was sub-analysed according to journal categories, study designs and resource of patients as well as assessed methodological risk of bias. In the periodontal journals, the definitions used were more explicit (87%) than those used in the dental or medical journals (Appendix S8.1). Moreover, the papers collected from a department of periodontology tended to provide explicit definitions (91%) compared with other studies. The studies scoring a low risk of bias for the methodological quality had more valid definitions (Appendix S8.2).

### 3.6 Clinical parameters and cut-off values

Table 3 summarizes the different periodontal health definitions used (38 studies). Notably, Loureço provided two definitions of
TABLE 2 Classification of included papers according to explicit and valid definitions

| ALL = 51 | Full-text reading | N (%) | Definition analysing | N (%) |
|----------|-------------------|-------|-----------------------|-------|
| 1        | Definition of health* | 38 (74.5) | 1a Definition of health with referenceb | 19 (37.25) |
|          |                    |       | 1b Definition of health without reference | 19 (37.25) |
| 2        | Disease to define health | 13 (24.5) | 2a Definition of disease with reference | 12 (23.5) |
|          |                    |       | 2b Definition of disease without reference | 1 (2) |

*The “only definition” and “reference and definition” groups were regarded as explicit definitions of periodontal health.

**The “reference and definition” group was regarded as a valid definition of periodontal health.

periodontal health in the one study. Therefore, the table contains 39 definitions. The table also presents the differences regarding cut-off points, PPD, CAL, BOP, and other relevant information for each study. Probing pocket depth was almost used for all definitions (n = 35), whereas BOP was used in less than half of the cases (n = 16). Probing pocket depth appeared in nine studies used as a single criterion. A combination of PPD with CAL appeared in 10 studies. A combination of PPD with BOP appeared in five studies, and a triple set of PPD, CAL, and BOP was used in 10 papers.

Figure 2A-C presents the numbers of papers using a threshold. The most frequently used PPD cut-off was ≤3 mm, which appeared in 20 studies. However, 11 studies reported a threshold of 3.5 mm or higher. A considerable amount of variety was observed concerning the CAL threshold, ranging from 0 to 4 mm. Nine studies reported the absence of CAL, and 15 studies did not report CAL (Figure 2B). Figure 2C demonstrates that among the reported BOP thresholds, the most commonly used was 10% sites, but the majority of the included papers (n = 23) did not report BOP.

4 | DISCUSSION

This SR aims to conduct an exploratory analysis of the definitions of periodontal health and the methods used to measure a healthy periodontium. To the best of our knowledge, this is the first SR exclusively dedicated to exploring a variety of periodontal health definitions. Although the significance of periodontal health is well known, a universal, formal definition did not exist until the World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions, which was organized by the EFP and the AAP. The main findings of this review were that (a) there is a lack of an explicit definition of periodontal health and consequently, a lack of application of references, (b) there is significant heterogeneity in measuring methods, and (c) there are considerable inconsistencies in the different periodontal parameters and cut-off values used.

Operational definitions and consistent criteria for a healthy periodontium were not provided in the majority of papers. The studies that did not provide a definition or a reference were excluded (Appendix S2). Some did provide a definition but lacked a reference, and some only gave a reference but lacked a definition. Only 37% (19 of 51) of the papers included in this study reported an explicit definition with detailed clinical parameters and cited a reference. The two most commonly cited references were the 1999 International Workshop for the Classification of Periodontal Disease (21 out of 31) and the CDC/AAP case definition for population-based studies of periodontitis (5 out of 31) (Appendix S6). Even when a proper reference was used, there existed a variety of interpretations. Misuse of the original criteria of the references created even more heterogeneity and introduces inevitable bias. As with the definition of periodontitis, it was difficult to achieve the goal of reproducing and analysing the results from different studies.

A periodontal pocket is the most common sign of periodontitis and easy to detect and assess in the clinical practice using various periodontal probes. The regularization of using periodontal probes will raise the accuracy of the process of diagnosing the condition and evaluating the treatment outcome. The present SR has identified a great amount of variety in the methods and materials used, such as the periodontal probing methods, particularly the type of probe and probing site. The procedure of measuring PPD and CAL was described as being assessed by either four or six sites per tooth. The number of sites used and especially the proportion of interden- tal sites assessed may influence the outcome. In any case, uniformity in material and methods can reduce the measurement bias. The EFP/AAP workshop recommended the use of an International Organization for Standardization (ISO) periodontal probe.

A cut-off or a reference point is needed to distinguish health from recurring signs and symptoms of periodontal disease. A wide range of parameters and cut-offs were identified in the present systematic review. Probing pocket depth was the most frequently used periodontal parameter. Given the fact that it is rather easy to detect and measure, PPD has been recognized for many years as the essential parameter for the diagnosis of periodontal health and disease. Half of the studies (51%) reported a threshold of PPD ≤3 mm. This cut-off value is also used to identify periodontal case types of health. In contrast, there were still 11 (29%) definitions that used the threshold of 3.5 mm PPD or deeper. The cut-off PPD ≤3 mm might be excessively strict if a population is assessed such that only a few end up in the category of healthy. This may be the reason that researchers
### TABLE 3  Summary of periodontal health definitions

| Papers (N)/definitions (n) | PPD (mm) | CAL (mm) | BOP (%) | Other | Reference |
|---------------------------|----------|----------|---------|-------|-----------|
| N = 38/ n = 39            | n = 35   | n = 24   | n = 16  |       |           |
| 1                         | \( \leq 3 \) |          |         |       | Beklen et al, 2014\(^{67}\) |
| 2                         | \( \leq 3 \) |          |         |       | Özcan et al, 2015\(^{76}\) |
| 3                         | \( \leq 3 \) |          |         |       | Duran-Pinedo et al, 2014\(^{59}\) |
| 4                         | \( \leq 3.5 \) |          |         |       | Jones et al, 2013\(^{35}\) |
| 5                         | \( \leq 3.5 \) |          |         |       | Schjetlein et al, 2014\(^{14}\) |
| 6                         | \( < 4 \) |          |         |       | Garneata et al, 2015\(^{16}\) |
| 7                         | \( < 4 \) |          |         |       | Gursoy et al, 2013\(^{52}\) |
| 8                         | \( \leq 4 \) | No clinical sign + no X-ray bone loss |         |       | Ramirez et al, 2014\(^{44}\) |
| 9                         | \( \leq 5 \) |          |         |       | Prodan et al, 2016\(^{79}\) |
| 10                        | \( \leq 3 \) |          |         |       | Kirst et al, 2015\(^{77}\) |
| 11                        | \( \leq 3 \) |          |         |       | Kim et al, 2013\(^{58}\) |
| 12                        | \( < 3 \) |          |         |       | Graziani et al, 2018\(^{36}\) |
| 13                        | \( \leq 3 \) | No X-ray bone loss |         |       | Rathnayake et al, 2013\(^{50}\) |
| 14                        | \( = 0 \) | No clinical sign + no X-ray bone loss |         |       | Huang et al, 2018\(^{63}\) |
| 15                        | \( < 3 \) |          |         |       | Wang et al, 2013\(^{51}\) |
| 16                        | \( \leq 3 \) |          |         |       | Guentsch et al, 2014\(^{40}\) |
| 17                        | \( \leq 3 \) |          |         |       | Tabari et al, 2014\(^{70}\) |
| 18                        | \( \leq 3 \) |          |         |       | Pushparani et al, 2014\(^{50}\) |
| 19                        | \( \leq 3 \) |          |         |       | Ghallab et al, 2015\(^{72}\) |
| 20                        | \( \leq 3 \) |          |         |       | Hassan et al, 2015\(^{41}\) |
| 21                        | \( \leq 3 \) |          |         |       | Mesa et al, 2014\(^{45}\) |
| 22                        | \( \leq 3 \) |          |         |       | Zimmermann et al, 2013\(^{47}\) |
| 23                        | \( \leq 3 \) |          |         |       | Kebschull et al, 2013\(^{53}\) |
| 24                        | \( \leq 4 \) |          |         |         | Tabari et al, 2013\(^{70}\) |
| 25                        | \( \leq 4 \) |          |         |         | Apatzidou et al, 2013\(^{43}\) |
| 26                        | \( \leq 4 \) |          |         |         | Salazar et al, 2013\(^{54}\) |
| 27                        | \( \leq 4 \) |          |         |         | Muthu et al, 2015\(^{44}\) |
| 28                        | \( \leq 4 \) |          |         |         | Raber-Durlacher et al, 2013\(^{45}\) |
| 29                        | \( \leq 3 \) |          |         |         | Kurşunlu et al, 2015\(^{74}\) |
| 30                        | \( \leq 3 \) |          |         |         | Mourão et al, 2013\(^{34}\) |
| 31                        | \( \leq 3 \) |          |         |         | Lavu et al, 2015\(^{73}\) |
| 32                        | \( \leq 3 \) |          |         |         | Singh et al, 2014\(^{48}\) |
| 33                        | \( \leq 3 \) |          |         |         | Sukhtankar et al, 2013\(^{37}\) |
| 34                        | \( \leq 3 \) |          |         |         | Sağlam et al, 2017\(^{82}\) |
| 35\(^{a}\)                | \( \leq 3 \) |          |         |         | Lourenço et al, 2014\(^{18}\) |
| 36                        | \( \leq 4 \) |          |         |         | Lourenço et al, 2014\(^{18}\) |
| 37                        | \( \leq 4 \) |          |         |         | Leite et al, 2014\(^{42}\) |
| 38                        | \( \leq 4 \) |          |         |         | Papathanasiou et al, 2014\(^{44}\) |

Abbreviations: BOP, bleeding on probing; CAL, clinical attachment level; PPD, probing pocket depth.

\(^{a}\)Lourenço et al provided two sets of periodontally healthy definition in one paper. ‘Gray shades’ means a single criterion or combination involving PPD/CAL/BOP to define periodontal health.
in large epidemiology studies stretch the PPD cut-off point. For instance, Hugoson used the following cut-off of periodontal health and disease: ≤10% sites with PPD ≥4 mm. Nevertheless, even the largest cut-off value of PPD did not exceed 5 mm in the current review. A systematic review reported that probing depth up to 6 mm or even more should be taken into account as a high-risk factor to predict further disease progression in periodontal patients.

Other frequently used parameters are CAL and BOP. Clinical attachment loss, the second most frequently used parameter, varies across studies. This was used in three (8%) studies as the single parameter and in 21 (55%) as an adjunct to PPD. The most commonly used threshold using CAL is the absence of attachment loss. As ageing comes with natural bone loss, some CAL is physiological. Therefore, the absence of CAL is likely due to the outdated concept. Periodontal health is identified as the absence of any deficit of supporting tissues. The strict and sometimes idealistic definition of absence of CAL can result in an overestimation of disease. The third most commonly used parameter, BOP, is never used alone, but serves as an adjunct. Notably, criteria consisting of BOP and PPD appeared in five (13%) articles, whereas BOP was only used in 16 out of 39 definitions (41%). The most frequently used BOP cut-off is less than 10%. Stable periodontium can manifest as the absence of extensive BOP. The cut-off values of BOP used to identify health and disease vary. A large-scale epidemiological study used a cut-off of <20% BOP, without referencing evidence. Patients with BOP sites ≥16% have a higher chance of losing attachment. After active non-surgical treatment during the maintenance/supportive phase, the risk of tooth loss is considerably greater for patients with 30% bleeding. Overall, a limited amount of positive symptoms for BOP is accepted in the healthy periodontium. Interestingly, the most frequently used cut-off value (BOP <10%) is consistent with the EFP/AAP classification. Nevertheless, there is no clear evidence to support the used cut-off values. Compared to previous values, bleeding sites of 10% might underestimate the number of people with a healthy periodontium.

The current review is not without limitations. After a full-text reading and analysis of the reference lists, 22 extra papers were included (for details, see Figure 1). Although this snowball procedure was conducted carefully, it remains possible that some studies describing periodontal health were not included in our search. Searching for definitions of periodontal health is complicated as it is often used as a category describing the opposite of disease. Thus, periodontal health often does not appear as a search term in the title and abstracts of studies. This also explains why the snowball procedure reveals more papers than those obtained from the initial search and selected based on the given criteria. A recommendation for further studies is that there is a need for evaluations such as what probe to use and what measurements to collect, in order to make a proper diagnosis for daily clinical practice and epidemiological studies.

The definition of periodontal health recommended by the EFP/AAP Workshop was defined as less than 10% of sites having BOP and PPD ≤3 mm in intact periodontium or ≤4 mm in reduced periodontium. Previous studies took CAL into account as a critical factor in describing accumulated lesions and the susceptibility of the disease. However, loss of periodontal attachment has not been incorporated, partly because the newly proposed definition focuses on the current status of different periodontium. Periodontal inflammatory activity or inactivity can be identified according to the extent of BOP and PPD instead of CAL. Similar to the assessment

FIGURE 2 Distribution of severity and extent for PPD (A), CAL (B) and BOP (C) used to define periodontal health among 36 studies showed by number and percentage. Notably, one of studies provided two definitions of periodontal health. Therefore, the total number of definitions is 37.
of periodontal inflammatory burden, non-bleeding pockets are regarded as periodontal tissue without inflammation. The quantity of inflammation is related to the inflamed periodontal surface area, which is calculated by the PPD values of bleeding teeth.

Periodontal health can also present in an anatomically reduced periodontium. In other words, periodontal health does not merely mean that there is an absence of supporting tissue deficit. It also refers to an individual’s level of comfort, the stability of a functioning periodontium, and one’s psychological and social well-being. This concept of holistic periodontal health has not been taken into account in this paper. Notably, the feasibility of directly regarding the definition of periodontal health in a reduced periodontium (PPD ≤4 mm and BOP ≤10%) as the treatment goal among patients remains uncertain. However, a certain PPD value after treatment needs to be interpreted in the light of variance in susceptibility and personalized medicine. Lang and Tonetti built a functional diagram to assess periodontal risk in supportive periodontal therapy, which can help clinicians distinguish whether a treatment goal is reached or not. Moreover, the number of residual pockets with a probing depth of ≥5 mm to a certain extent reflects the degree of success of periodontal treatment, which is different from the PPD threshold in the new definition. In the randomized clinical trial, the subjects presenting ≤4 sites with PD ≥5 mm at one year represented a successful treatment outcome. Therefore, the endpoint of therapy should seek the most optimal balance between over- and underestimation of health status among treated periodontal patients. It is important to acknowledge the distinction between the diagnoses of periodontal health of initial patients versus treated patients. For the latter, a more flexible, comprehensive and detailed assessment would be recommended.

5 | CONCLUSION

This SR revealed a variety of definitions of periodontal health in existing scientific literature. This heterogeneity was measured according to study characteristics, measurement methods, explicit definitions, references and cut-off values used. The definition of periodontal health proposed by the EFP/AAP Workshop offers an opportunity for the field to standardize and achieve uniformity in terms of methodologies in order to draw comparisons between different studies. This study also revealed that the number of people thought to have periodontal disease is likely overestimated due to the strict cut-off value.

6 | CLINICAL RELEVANCE

6.1 | Scientific rationale for the study

There is no standard reference for periodontal health, and the diagnostic properties of the various definitions have not been studied.

6.2 | Principal finding

Marked heterogeneity in the definitions of different measuring methods and clinical parameters in periodontal health may be affecting interpretations of research.

6.3 | Practical implications

The new definition of periodontal health proposed by the EFP/AAP workshop in 2018 offers an opportunity to standardize and unify the cut-off values of clinical parameters, which would allow for a better comparison of clinical studies and support research and decision-making.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

An Li, first author, contributed to the acquisition, analysis and interpretation of data, and drafted the manuscript. Renske Z. Thomas, overall daily supervisor, contributed to the design of study, the acquisition, analysis and interpretation of data, and drafted the manuscript. Luc van der Sluis contributed to the design of study and critically revised the manuscript. Geerten-Has Tjakkes contributed to the design and critically revised the manuscript. Dagmar Else Slot contributed to the conception and design of the study, supported the analysis and interpretation of the data, and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of this work, ensuring its integrity and accuracy.

ORCID

An Li https://orcid.org/0000-0001-5750-526X
Renske Z. Thomas https://orcid.org/0000-0002-5546-6348
Dagmar Else Slot https://orcid.org/0000-0001-7234-0037

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.

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