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A systematic review of definitions of periodontitis and methods that have been used to identify this disease

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Abstract

Objective: To perform a systematic review and critical analysis of the definitions of periodontitis and the methods which have been used to identify and measure this disease.

Material and Methods: Relevant publications were identified after searching MEDLINE, EMBASE, SCISEARCH and LILACS electronic databases. Screening of titles and abstracts and data extraction was conducted independently by two reviewers. To be included in the review, studies were required to define periodontitis and to indicate how it was measured. Studies that related purely to gingivitis, and/or intervention studies, and/or studies where prevalence or severity of periodontitis was not a principal outcome were excluded.

Results: From a total of 3472 titles and abstracts, 104 potentially relevant full text papers were identified. Of these, 15 met the criteria for inclusion in the final stage of the review. The survey revealed heterogeneity between the studies in the measurement tools used, particularly the types of probes and the sites and areas of the mouth that were assessed. There was also heterogeneity in the use of clinical attachment loss (CAL) and pocket probing depth (PPD) as criteria for periodontitis. In the 15 studies, the threshold for a diagnosis of periodontitis when CAL was the criterion ranged from 2 to $\geqslant$6 mm and when PPD was used, from 3 to $\geqslant$6 mm.

Conclusions: This review has confirmed previous work which has suggested that epidemiological studies of periodontal diseases are complicated by the diversity of methodologies and definitions used. The studies that were reviewed utilized a minimum diagnostic threshold defining periodontitis, at a given site in terms of CAL of 2 mm and PPD of 3 mm.

Key words: epidemiology; definition; periodontal disease; periodontitis; systematic review

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From a pathological point of view, periodontitis can be defined as the presence of gingival inflammation at sites where there has been a pathological detachment of collagen fibres from the cementum and the junctional epithelium has migrated apically. Inflammatory events associated with connective tissue attachment loss also lead to the resorption of coronal portions of tooth supporting alveolar bone (Armitage 1995).

The point at which the presence of a condition can be identified is termed the diagnostic threshold. Ideally, an appropriate diagnostic threshold should be accurate, consistent, easily diagnosed and occur as early as practicable in the life-history of the disease.

The criteria used to define periodontitis must be unequivocal and suitable for any examiner to use such that the same diagnosis is achieved by other examiners under identical conditions. Previous studies have used an array of clinical signs and symptoms such as gingivitis, bleeding on probing (BOP), pocket probing depth (PPD), clinical attachment loss (CAL), as well as radio-

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graphically assessed alveolar bone loss. The most commonly used clinical measures in epidemiological studies for periodontitis are CAL and pocket probing depth (PPD). The method for measuring CAL and PPD with a manual probe was described by Ramfjord (1959). Although CAL, is a measure of accumulated past disease at a site rather than current activity it remains a diagnostic standard for measuring periodontitis (Goodson 1992), as it utilizes a fixed reference point rather than gingival margins whose levels are subject to alterations with change in inflammatory state.

The absence of consensus on how best to incorporate CAL and PPD into a definition of periodontitis continues to hamper clinical and epidemiological research (Burt 2005). These inconsistencies in the use of disease indicators make large variations in the definition of periodontitis inevitable (Borrell & Papapanou 2005).

Previous literature reviews relating to periodontal epidemiology have all highlighted similar diagnostic and methodological problems. In May 1999, a MEDLINE search (restricted to the preceding 5 years) was performed using the terms ''periodontal disease'' and ''epidemiology'' as keywords (Papapanou 1999). The conclusions from the review reflected the wide range of different methodologies that had been used and further stressed the obvious lack of uniformity in a case definition of periodontitis.

One of the main conclusions of the Borrell & Papapanou (2005) review, with regard to the definition of periodontitis, was the need to include a range of several signs and symptoms of the disease that may be graded to reflect different severity levels. Some of the signs and symptoms that can be used were suggested in an American Academy of Periodontology position paper (Burt 2005). This paper also reiterated that historical indices which scored gingivitis and periodontitis on the same scale should be considered invalid and should be discarded. It further suggested that a current case definition for periodontitis will not only need to establish how to include probing measures and BOP but what depth of CAL, at any one site will constitute evidence of disease process and how many of these affected sites need to be present in order to clinically establish the presence of disease.

A recent definition of periodontitis suggested that it should be: the presence of an inflamed pathological pocket $\geqslant 4$ mm deep in conjunction with attachment loss (Van der Velden 2005); however, this definition does not take into account the number of affected sites. The Group C consensus report of the 5th European workshop in periodontology (Tonetti & Claffey 2005) identified the definition of periodontitis as being one of the most important issues that impacted upon data interpretation. The report emphasized that attachment loss should be the primary outcome variable used in studies of risk factors for periodontitis. However, it stressed that periodontitis cannot be reflected by measurements of only a single variable such as attachment loss or bone loss but required the additional measurements of BOP and/or pocket depth.

It is evident from the periodontal literature that there is a lack of uniformity in the definition of periodontitis used in epidemiological studies. There are also inconsistencies in the methodologies used to obtain information from the studies (Papapanou 1996). The implications of this are that findings from studies using differing case definitions and differing survey methodologies are not readily interpretable or comparable (Gera 2000, Eaton 2002).

Against this background, the aim of the current study was to perform a systematic review of the literature related to the definitions of periodontitis and the methods that have been used to identify and measure this disease. It represents a step towards the future validation of a definition for periodontitis and the method(s) used to measure it.

Material and Methods

Protocol development

The review protocol detailed all the methods, including aim, search, eligibility criteria for study inclusion, methods for screening and data abstraction, and data analysis.

The types of studies (and search terms) eligible for inclusion in the review were those that related to:

- population,
- screening,
- prevalence,
- epidemiologic surveys.

The studies also had to include:

- a definition of disease,
- description of level of periodontal attachment,
- a measure of periodontitis,
- a definition of periodontitis.

Studies that were excluded from the review were those limited to gingivitis or studies where prevalence or severity of periodontitis was not a principal outcome. Intervention studies were also excluded as the primary aim of the study was epidemiological.

Search strategy

The search was performed using electronic databases for studies published up to August 2006. These were MEDLINE, Excerpta Medica database (EMBASE), Science Citation Index (SCISEARCH) and Latin American & Caribbean Health Sciences Literature (LILACS).

An electronic search strategy was developed for MEDLINE via OVID and revised appropriately for each database. The search also utilized a combination of controlled vocabulary and free text terms in the following combinations:

- Periodontal Diseases (MeSH term and Keyword),
- Alveolar Bone Loss (MeSH term and Keyword),
- Periodontal Attachment Loss (MeSH term and Keyword),
- Periodontitis (MeSH term and Keyword),
- Periodontal Pocket (MeSH term and Keyword),
- Epithelial Attachment (MeSH term and Keyword),
- Clinical Attachment Loss (Keyword),
- Lifetime Cumulative Attachment Loss (Keyword).

The total number of citations generated was then combined using the Boolean variable and with the sum total generated by the following combinations:

- Prevalence (MeSH term),
- Epidemiologic Studies (MeSH term),
- Cohort Studies (MeSH term),
- Epidemiology (MeSH term),
- Epidemiologic Research Design (MeSH term),
- Risk (MeSH term).

The citations generated were limited to human studies and although there were no specific language restrictions, only articles for which the reviewers were able to obtain translations were included in the review.

All titles and abstracts of publications were scanned independently by two reviewers (A. S. and K. E.). Full text papers were obtained for publications that appeared to meet the inclusion criteria, or for which there was insufficient information in the title and abstract to make a clear decision. They were assessed independently, in duplicate, by the two reviewers to establish whether the publications met the required inclusion criteria or not. All disagreements were resolved by discussion and where necessary, a third reviewer was consulted.

The references of all publications, selected for inclusion, were checked for other additional relevant studies. The authors tried to identify any unpublished studies by searching abstracts and conference proceedings. In addition, reference lists of review papers and text book chapters were examined to try to identify additional potentially relevant studies.

Methodological quality assessment

The methodological quality of the reviewed studies was assessed by examining criteria in relation to the studies and grouping them into generic factors and factors specific to periodontitis, respectively.

The main criteria that comprised the two groups were as follows:

Generic factors

- Random selection/representative sample.
- Examiner calibration or training.

Factors specific to periodontitis

- Definition of periodontitis used.
- Measure and/or index used.
- Measurement tools/probe type.

These specific criteria were selected to assess the potential for bias in the reviewed studies particularly selection bias in the case of generic factors and measurement bias for factors that were specific to periodontitis.

The data were synthesized qualitatively following the production of evidence tables.

Results

Outcome of the search

The search terms yielded 3472 publications identified through electronic searches, reference lists and other sources that were available for the review (Fig. 1). By using the exclusion criteria, the two independent reviewers excluded 3368 articles as not relevant to the review from the review leaving a total of 104 potentially relevant articles that were chosen for retrieval and evaluation of the full text using a data extraction sheet. The authors were unable to obtain translators for 15 non-English language publications, at the initial yield, to identify if they met the criteria for inclusion in the review. The κ score for agreement between the reviewers was 0.86 indicating an excellent level of agreement. Out of the 104 full text articles retrieved, 89 articles were excluded because they did not meet the inclusion criteria leaving a total of 15 relevant articles that attempted to offer a definition of periodontitis and measure(s) used to identify it.

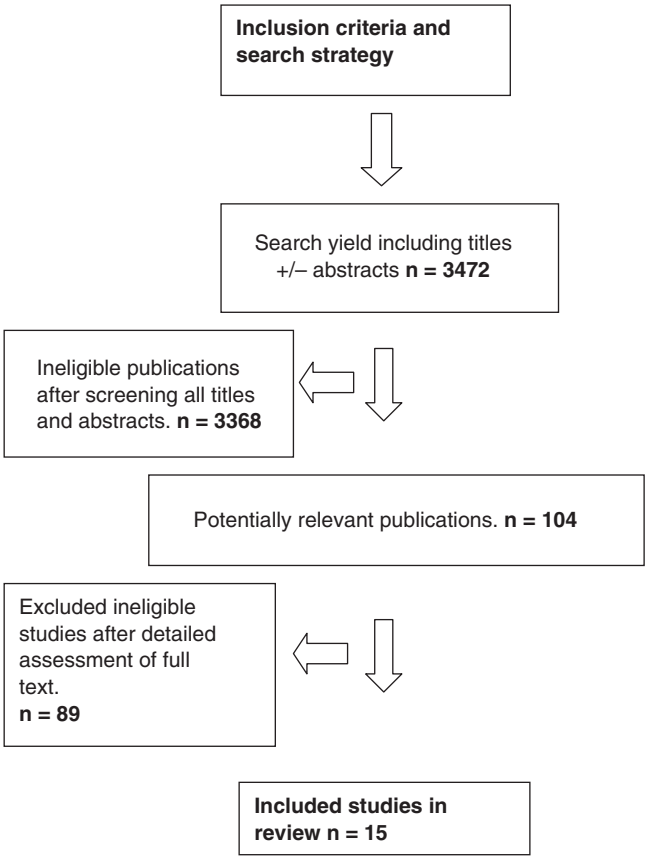

Fig. 1. Flow summary of the systematic review.

Geographic distribution

From Table 1 it can be seen that the majority (12) of the 15 studies were undertaken during the past 20 years, with five studies from the United States, two Swedish studies and two Chinese studies. The other six studies were from New Zealand, Indonesia, Greece, Argentina, the United Kingdom and Taiwan.

Sample size and study characteristics

The sample sizes of included studies ranged from 185 participants (Craig et al. 2001) to 15,302 participants (Borrell et al. 2005) (Table 1). This latter study combined participants from the National Health and Nutrition Examination Survey III (NHANES III) and the NHANES 1999–2000 studies. The study of Borrell et al. (2005) was limited to the records of adults 18 years or older who self-ascribed their ethnicity as non-Hispanic black, non-Hispanic white, or Mexican-American, and who had a complete periodontal examination. Four of the studies were longitudinal. Most of the studies were cross-sectional of a general population that encompassed a wide age range. More specific population groups were examined by Agerholm & Ashley (1996), Chiappe et al. (1997), Holmgren et al. (1994) and Querna et al. (1994),

Table 1. Sample characteristics of included studies listed chronologically

Reference	Year of publication	Country	Sample frame	Sample size	Study design	Age range (years)	Smoking status	Medical conditions
Borrell et al. (2005)	2005	United States	General population	15,302	CS	18+	I	Diabetes in pregnant women excluded
Laurell et al. (2003)	2003	Sweden	General population	357	L	20–60	I	U
Craig et al. (2001)	2001	United States	General population	185	CS	19–70	I	E
Paidi et al. (1999)	1999	New Zealand	General population	240	CS	30–70	I	E
Norderyd & Hugoson (1998)	1998	Sweden	University/hospital	547	CS	20–70	I	NE
Timmerman et al. (1998)	1998	Indonesia	Untreated general population	255	L	15–25	NR	NE
Chiappe et al. (1997)	1997	Argentina	University Dental Students	475	L	17–25	NR	NE
Anagnou-Vareltzides et al. (1996)	1996	Greece	General population	339	CS	25–64	NR	NE
Agerholm & Ashley (1996)	1996	United Kingdom	Electronic factory workers	202	L	20–40	NR	NE
Holmgren et al. (1994)	1994	China (Hong Kong)	Middle aged and elderly	855	CS	35–44 65–74	NR	NE
Querna et al. (1994)	1994	United States	Military	1334	CS	18–45+	NR	NE
Machtei et al. (1992)	1992	United States	University/hospital referral and general population	508	CS	25–73	NR	NE
Peng et al. (1990)	1990	Taiwan	General population	673	CS	15–64+	NR	NE
Brown et al. (1989)	1989	United States	General population	1792	CS	19–65+	NR	NE
Wang et al. (1987)	1987	China	General population	2284	CS	18–50	NR	NE

CS, cross-sectional study; I, identified; L, longitudinal study; NE, not excluded; NR, not recorded; U, unclear; E, excluded.

who looked at factory workers, dental students, middle aged/elderly people and military populations respectively. With regard to identifying adverse habits, such as smoking and systemic conditions, six of the studies identified smoking status while participants with medical conditions were excluded from three studies. One study specifically excluded participants with gestational (pregnancy) diabetes.

A summary of the examination methods used in the studies is shown in Table 2. Seven of the studies were described as full-mouth assessments. Three of the studies reportedly excluded measurements from the third molar sites. Two studies were classified as half-mouth studies, while four assessed only index teeth.

The study by Norderyd & Hugoson (1998) was a radiographic study which assessed inter-proximal bone loss. In this study six bite-wing radiographs and a dental pantomogram were assessed for each patient in the 20–30-year age group and full-mouth intra-oral radiographs were assessed for each patient in the 40–80-year-old age group. Laurell et al. (2003) utilized full-mouth intra-oral radiographs to assess inter-proximal bone height during the examination and based its definition of periodontitis on this criterion (Table 2).

The most common measurement tool, used in other studies, was a periodontal probe. However, the type of probe varied from study to study. Specific types of probe were identified in 12 of the 15 studies highlighted in Table 2. The force of probing was identified in three of the studies. Holmgren et al. (1994) noted using light probing force consistent with the CPI probe. Mechanical force controlled probes were used in two of the studies. Machtei et al. (1992) utilized a computerized probe with a 20 *g* force while Timmerman et al. (1998) used a force-controlled probe (Brodontic® Ash/Dentsply 240 N/cm^3, BP, Prima, Byfleet, UK) to measure probing depth, supplemented with a Williams marking Hu–Friedy® (IL, Chicago, USA) probe to determine attachment loss.

The number of sites probed and locations also varied between the studies. Six studies recorded six-point probing while three studies utilized four points per tooth. In one study the specific probing location points were not recorded (Laurell et al. 2003). A further study, Borrell et al. (2005) utilized mid and mesio-buccal probing sites. Another study, Timmerman et al. (1998) used approximal surfaces from the vestibular aspect of all teeth except molars, as well as on the vestibular and lingual surfaces of the Ramfjord teeth (16, 21, 24, 36, 41 and 44). Chiappe et al. (1997) and Wang et al. (1987) also probed the Ramfjord teeth. In four studies the location of probing was not clearly described.

Pocket probing depth (PPD) was recorded in all studies except in the one by Norderyd & Hugoson (1998) where the measurements were radiographic. The clinical attachment loss was recorded in six studies used the terms periodontal attachment level and CAL respectively.

Quality appraisal of the studies

The 15 studies revealed a considerable degree of heterogeneity between the sample selection processes, and the recording of these procedures (Table 3). Five of the studies went through a random selection process, when selecting their study samples. In eight studies, the level of randomization in the sample selection was not clear. The samples in three studies were drawn from specific sampling frames such as dental students, factory workers and the military. In terms of examiner calibration and training, only two studies, reported examiner calibration in the methodology used for data collection. It was not reported in the other three studies what level of

Table 2. Examination methods used in the studies

Reference	Examination area	Measurement tool	Probing location (MB, B, DB, ML, L and DL)	PPD	CAL
Borrell et al. (2005)	Half mouth	Probe (type unclear)	Mid and MB probing of randomly assigned quadrants	R	R
Laurell et al. (2003)	Full mouth	Probe (type unclear) Full-mouth radiographs measuring inter-proximal bone height	Four-point probing (location NR)	R	NR
Craig et al. (2001)	Full-mouth (third molars excluded)	North Carolina periodontal probe	Six-point probing MB, B DB, DL, L and ML	R	R
Paidi et al. (1999)	Half mouth	Williams marked probe	Six-point probing MB, B DB, DL, L and ML of randomly assigned contra-lateral diagonal quadrants	R	R
Norderyd & Hugoson (1998)	Full mouth (radiographic)	Six Bitewings and one DPT (20–30 years olds) Full-mouth intra-oral radiographs (40–80-year olds)	Location NR	NR	NR
Timmerman et al. (1998)	Part mouth	Probing depth – force-controlled probe (Borodontic® Ash/Dentsply 240 N/cm^3 Attachment loss – Hu-Friedy® probe (Williams calibration)	MB, DB surfaces of all teeth except molars, as well as on vestibular and lingual surfaces of the Ramfjord teeth (16, 21, 24, 36, 41 and 44) Specific location NR	R	R
Chiappe et al. (1997)	Selected index teeth	Conventional probe (CP12 probe)	Four-point probing MB, DB, DL and ML	R	R
Anagnou-Vareltzides et al. (1996)	Full mouth	Calibrated probe with tip diameter of 0.45 mm	Six-point probing MB, B DB, DL, L and ML	R	R
Agerholm & Ashley (1996)	Full-mouth (third molars excluded)	PQW periodontal probe with Williams's markings (Hu-Friedy®)	Four-point probing MB, DB, DL and ML	R	R
Holmgren et al. (1994)	Full mouth	Community periodontal index – C periodontal probe using light probing force consistent with CPI probe	Six-point probing MB, B DB, DL, L and ML	R	R
Querna et al. (1994)	Selected index teeth	Glickman 26-G periodontal probe with round ended 0.5-mm diameter tip	Six-point probing MB, B DB, DL, L and ML	R	NR
Machtei et al. (1992)	Full-mouth (third molars excluded)	Computerized probe with standardized 20 *g* force	Six-point probing MB, B DB, DL, L and ML	R	R
Peng et al. (1990)	Full mouth	World Health Organization probe	Location NR	R	NR
Brown et al. (1989)	Selected index teeth	Hu-Friedy® CP6 round probe with 0.48 mm diameter	Location NR	R	NR
Wang et al. (1987)	Selected index teeth	Glickman periodontal probe	Probing on Ramfjord teeth (16, 11, 24, 36, 41 and 44) Specific location NR	R	NR

PPD, pocket probing depth; MB, mesiobuccal; L, mid lingual; CAL, clinical attachment loss; B, mid buccal; DL, distolingual; R, recorded; DB, distobuccal; NR, not recorded; ML, mesiolingual.

calibration (if any) was undertaken. Timmerman et al. (1998) undertook an examiner calibrated study in an untreated community in Indonesia.

Definition of periodontitis and/or indices used

Most of the studies listed in Table 3 also gave a definition of periodontitis with thresholds using PPD and CAL. Laurell et al. (2003) used radiographs and defined periodontitis as bone loss set at 10% of root length which corresponded to at least 2–3 mm of CAL.

Paidi et al. (1999) did not state a clear threshold to define periodontitis while Norderyd & Hugoson (1998), predominantly used radiographs, and criteria from Hugoson & Jordan (1982). However, although the authors defined periodontitis using criteria from Hugoson & Jordan (1982), the term ''majority of teeth'' in their definition was not clearly presented in the paper. Chiappe et al. (1997) defined periodontitis as the subject having at least one site with loss of attachment $\geqslant$2 mm.

Wang et al. (1987) used the Ramfjord Periodontal Disease Index 1959 to define periodontitis and the criterion selected was 4 which relates to measurements on the Ramfjord teeth (16, 21, 24, 34, 31 and 46). The score of 4 is given if gingival crevice is $\leqslant$3 mm apical to CEJ, score of 5 if 3–6 mm and 6 if $>$6 mm.

Numerical range of CAL and PPD thresholds used in the studies

The review illustrated further heterogeneity when the individual thresholds were examined for CAL and PPD as can be seen from Table 4. When using PPD, as a threshold for periodontitis, the minimum PPD defining periodontitis at an individual or multiple site was a threshold of $\geqslant$3 mm as seen in (Borrell et al. 2005 – two sites, Craig et al. 2001 – four sites and Peng et al. 1990 – worst individual score at any given sextant). Peng et al. (1990) used 3.5 mm that was the CPITN threshold. Brown et al. (1989) using the modified Russell index defined a threshold for periodontitis at a single site $\geqslant$4 mm. This threshold value was shared by Querna et al. (1994) who also defined early periodontitis based on the worst individual score at a sextant occurring at that value. At $\geqslant$5 mm Querna et al. (1994) further defined moderate to advanced periodontitis. This threshold was also used by Machtei et al. (1992) and Peng et al. (1990) as a definition of periodontitis for their

Table 3. Sample selection, periodontitis definition and tool used in the studies

Reference	Sample selection	Examiner calibration	Definition of periodontitis and/or index
Borrell et al. (2005)	Random and representative of general population	U	Threshold – a person who had at least three sites with clinical attachment loss ⩾4 mm and at least two sites with PPD⩾3 mm. However, these conditions did not have to be present in the same site or tooth
Laurell et al. (2003)	Random and representative of general population	U	Threshold – bone loss was set at 10% of the tooth length, which corresponded to a bone loss of at least 2–3 mm
Craig et al. (2001)	Does not appear to be random and representative of general population	R	Threshold – a periodontal diseased subject was defined as having at least 20 teeth and at least four sites with pocket depths >3 mm and at least four sites with attachment loss >3 mm (based on radiographic inter-proximal loss)
Paidi et al. (1999)	Does not appear to be random and representative of general population	R	Threshold – use of three terms. (a) Prevalence of LOA: as the percentage of LOA of *x* mm (where *x* = 2, 4, 6 and 9 mm). (b) Extent of LOA: as the mean percentage of sites with LOA of *x* mm or more per person. (c) Severity: LOA of *x* mm or more per person. Threshold defining periodontitis – NR
Norderyd & Hugoson (1998)	Does not appear to be random and representative of general population	R	Threshold – criteria from Hugoson & Jordan (1982). Group 3 – alveolar bone loss around the majority of the teeth not exceeding 1/3 of the length of roots, Group 4 – alveolar bone loss around the majority of the teeth ranging between 1/3 and 2/3 of the length of the roots. Group 5 – alveolar bone loss around the majority of the teeth exceeding 2/3 of the length of the roots; presence of angular bony defects and/or furcation defects
Timmerman et al. (1998)	Representative study of community	R	Threshold – criteria from Brown et al. (1990). No or minor periodontitis – 0–2 mm maximum attachment loss, moderate periodontitis – 3–4 mm maximum attachment loss, advanced periodontitis ⩾5 mm maximum attachment loss
Chiappe et al. (1997)	Does not appear to be random and representative of general population	R	Threshold – loss of attachment was determined when the clinical attachment loss was ⩾2 mm
Anagnou-Vareltzides et al. (1996)	Random and representative of general population	U	Threshold – level of ⩾6 mm for pocket probing depth and periodontal attachment level was utilized as expressing deep pocketing and advanced attachment losses as an arbitrary definition of severe periodontal disease
Agerholm & Ashley (1996)	Does not appear to be random and representative of general population	U	Threshold – clinical attachment loss at 2, 3 or 4 mm. Subsets made up of 10 index teeth recommended by the WHO for partial recording (two molars in each quadrant and maxillary right and mandibular left central incisors) and a subset comprising maxillary buccal and mandibular lingual sites (''Pritchard sites'')
Holmgren et al. (1994)	Does not appear to be random and representative of general population	R	Threshold – definition based on ⩾6 and 9 mm loss of attachment
Querna et al. (1994)	Does not appear to be random a nd representative of general population	NR	Threshold – subjects with inflammation and PPD of over 3 mm but <5 mm were categorized as early periodontitis Over 5 mm moderate to advanced periodontitis periodontal screening exam (PSE) index
Machtei et al. (1992)	Does not appear to be random and representative of general population. ''Convenience'' sample also used	R	Threshold – the clinical entity of established periodontitis is suggested based on the presence of clinical attachment level ⩾6 mm in two or more teeth and one or more sites with Pocket probing depth ⩾5 mm
Peng et al. (1990)	Random and representative of general population	R	Threshold – periodontitis included teeth with pocketing and attachment loss – CPITN 3 – pocket depth between 3.5 and 5.5 mm, CPITN 4 – pocket depth >5.5 mm Definition made according to the modified method of Gaengler (1984)
Brown et al. (1989)	Random and representative of general population	R	Threshold – periodontitis (pockets ⩾4 mm) Advanced periodontitis (pockets ⩾6 mm) Definition based on modified Russell's periodontal index
Wang et al. (1987)	Not random and representative of general population	NR	Threshold – periodontal disease index above 3 was considered to suffer from periodontitis Definition based on Ramfjord periodontal disease index 1959

R, recorded; NR, not recorded; U, unclear; PPD, pocket probing depth; CAL, clinical attachment loss; LOA, loss of attachment; CPITN, community periodontal index of treatment need.

Table 4. Numerical ranges of CAL and PPD thresholds used in the studies

⩽2 mm	⩾2 mm	⩾3 mm	⩾4 mm	⩾5 mm	⩾6 mm
CAL study					
Timmerman et al. (1998) (no or minor periodontitis) at one or more sites	Agerholm & Ashley (1996) at one or two approximal sites Chiappe et al. (1997) at one site	Craig et al. (2001) at four sites Timmerman et al. (1998) (moderate periodontitis) at one or more sites Agerholm & Ashley (1996) at one or two approximal sites	Borrell et al. (2005) at three sites Agerholm & Ashley (1996) at one or two approximal sites	Timmerman et al. (1998) (advanced periodontitis) at one or more sites	Anagnou-Vareltzides et al. (1996) (severe periodontitis) at mean sites Holmgren et al. (1994) at mean sites Machtei et al. (1992) at two or more teeth
PPD study					
		Borrell et al. (2005) at two sites Craig et al. (2001) at four sites Peng et al. (1990) (3.5 mm CPITN) worst individual score at sextant	Querna et al. (1994) (early) worst individual score at sextant. Brown et al. (1989) (modified Russell index) at one site	Querna et al. (1994) (moderate – advanced) at the highest score per sextant Machtei et al. (1992) at one or more teeth Peng et al. (1990) (5.5 mm CPITN) worst individual score at sextant	Anagnou-Vareltzides et al. (1996) (severe periodontitis) at mean sites Brown et al. (1989) advanced periodontitis (modified Russell index) at one site

CAL, clinical attachment loss; CPITN, community periodontal index of treatment need; PPD, pocket probing depth.

study. However, Peng et al. (1990) used 5.5 mm corresponding to the CPITN value to register this threshold value. Severe and advanced periodontitis was defined by Anagnou-Vareltzides et al. (1996) at mean site and Brown et al. (1989) at an individual site respectively at ⩾6 mm. Brown et al. (1989) used the modified Russell index to define this threshold value corresponding to ⩾6 mm.

The use of CAL at an individual site provided an even greater spectrum in the results. Timmerman et al. (1998) used ⩽2 mm as the threshold of no to minor periodontitis which was the same threshold as 2 mm used by Chiappe et al. (1997). Three different threshold values of ⩾, ⩾4 and ⩾6 mm were used by Agerholm & Ashley (1996) in order to determine which individuals in their sample had the worst periodontitis based on CAL at different diagnostic thresholds. Timmerman et al. (1998) defined moderate periodontitis at CAL of ⩾3 mm. This threshold value was shared by Craig et al. (2001) based on four sites. Borrell et al. (2005) utilized a threshold of ⩾4 mm at three sites. Advanced periodontitis was defined by Timmerman et al. (1998) using a threshold value of ⩾5 mm while Anagnou-Vareltzides et al. (1996) defined severe periodontitis with a mean threshold value of ⩾6 mm which was the same as Holmgren et al. (1994). Machtei et al. (1992) also used a threshold value of ⩾6 mm that was based on two sites.

Discussion

This systematic review investigated the literature related to definitions of periodontitis and methods that have been used to identify and measure this disease. The reason for selecting this methodology was to find and appraise the totality of the evidence, in this case, which definitions of periodontitis had been used. The reason for excluding many records was that the search was deliberately made to be highly sensitive i.e. a high probability of finding potentially eligible studies, but with the risk of finding many ineligible papers. All records were screened in order to find the eligible ones. This is standard procedure where indexing of potential studies is not efficient and therefore the search is made to be inclusive to avoid missing relevant papers. Therefore, the benefits of using a systematic approach are important and they are, searching and retrieval of totality of evidence, objective critical appraisal of the evidence and structured synthesis leading to minimization of bias.

Therefore this systematic review documented that the reviewed studies utilized a minimum diagnostic threshold defining periodontitis, at a given site in terms of CAL of 2 mm and PPD of 3 mm. The review has additionally confirmed previous findings of a considerable lack of methodological consistency in periodontal epidemiology.

Only 15 of the 104 publications, identified through the search, gave a quantitative definition of periodontitis and it was noted that smoking or medical conditions were not clearly identified in most of the reviewed articles. Furthermore, the methods of sample selection and examiner calibration were also not clearly highlighted in all the studies. More specific findings revealed heterogeneity between the studies in the measurement tools, particularly the types of probes used. Differences also existed in the areas surveyed (full/part mouth), indices used and location of probing between the various studies. It was further noted that the use of CAL and/or PPD as single, multiple or mean scores at any given site varied between the studies resulting in heterogeneity in the threshold(s) by which periodontitis was defined.

A number of specific weaknesses were apparent. The first weakness was that smoking and/or medical conditions were not clearly identified in most of the papers that were reviewed. This is important because smoking and certain medical conditions are associated with increased bone loss resulting in greater PPDs and clinical attachment loss which

affects disease severity. Given that smoking (Haber et al. 1993) and systemic diseases such as diabetes are well known risk factors for periodontitis (Genco 1996), and that the search term RISK encompassed the studies with these factors, the small number of papers that were found was perhaps surprising. It may be that because the majority of the studies reported were performed in the early 1990s and during that period the primary outcomes of these epidemiological surveys were not generally smoking and systemic health; this aspect may not have been incorporated into the protocols for the studies.

The second major weakness was that methods of sample selection were not clearly defined in many of the studies that were included in the review. In a simple prevalence study, an epidemiologist merely needs to determine if a disease or condition is present or not. If the sample in question is small the epidemiologist may examine all the people. With a larger sample frame, the epidemiologist will need to examine a representative sample. Examiner calibration was also not clearly defined and should ensure repeatability and consistency of all the measurements. In addition, clearly defined and reported methods of calibration allow not only for reproducible results but also for the results of the studies to be analysed and compared with other studies.

Perhaps unsurprisingly, the third weakness revealed by the review was heterogeneity in the measurement tools used, particularly the types of probes used in the 15 studies. It has been suggested that ideally probe tips need to have a diameter of 0.6 mm and a probing force of 0.2 *g*. is required to reach the base of the pocket (Garnick et al. 2000). The shape of the probe tip (round, parallel sided and tapered) can contribute to significant differences. There is a tendency for the parallel-sided tine to yield deeper readings in some cases (Atassi et al. 1992). Different probe designs therefore give slightly different readings which can have a significant influence on the results. Disease definitions are based on a single clinical sign (e.g. deep pockets or attachment loss measurements) or on a combination of different signs and symptoms which can be influenced by the performance properties of the probe.

Most of the cross-sectional and longitudinal epidemiological studies in this review used different diagnostic tools and criteria. Consequently, such findings are difficult to compare (Gera 2000). The measurement of periodontal attachment loss is a valuable measure of the severity of periodontal tissue loss, and may be indicative of a previous destructive disease process, as such it is a historic measure of the extent and severity of past disease activity (Eaton et al. 2001, Susin et al. 2005).

The conversion of the junctional epithelium to pocket epithelium has been regarded as a hallmark in the progression of gingivitis to periodontitis (Bosshardt & Lang 2005). This breakdown in attachment is usually measured by probing. However, the ability to detect change due to breakdown may vary. The probe tine diameter and calibration should also therefore be considered in addition to other variables of periodontal probing (Van der Zee et al. 1991). The position of the probe tip may be affected by the probing force. Probing force can be achieved either by a manual or electronic pressure sensitive probe. Some of the studies that were reviewed such as those of Holmgren et al. (1994), Machtei et al. (1992) and Timmerman et al. (1998) made an attempt to control this by the use of a consistent force probe. Other difficulties associated with probing include angulation of the probe, shape of the tooth, subgingival deposits and cooperation of the patient Haffajee et al. (1983). Despite these shortcomings in the attachment level measurement, at present this technique appears to provide an indication and estimate of periodontal breakdown.

Methods aimed at improving the reliability of recordings, such as use of calibrated instruments (Philstrom 1992), stents (Clark et al. 1987) and electronic probes. (Gibbs et al. 1988) have been reported in the literature (Alves et al. 2005). The use of periodontal probes is further supported by an expert opinion position paper prepared by the research, science and therapy committee of the American Academy of Periodontology (Academy Report 2003), which supported the view that probing depth and clinical attachment loss measurements obtained with periodontal probes are practical and valid methods for assessing periodontal status. A universal periodontal probe would not only make studies and surveys more comparable but would also allow for better and more accurate statistical analysis of any data generated in the future by reducing measurement bias. This goal of uniformity may however be difficult to achieve given the different probes commercially available and individual operator preference.

Differences existed in the area of the mouth surveyed (full/part), indices used and location of probing between the various studies. Eaton (2002) stated that it was perhaps unsurprising, as concepts of the nature of chronic inflammatory periodontal diseases have changed over the years and many methods and indices have been developed and used to assess the disease, both clinically and epidemiologically.

Along with the various indices the other factor that needs to be taken into account is the range and scope of the survey (i.e. full mouth or part mouth). Part-mouth assessments (Wang et al. 1987, Brown et al. 1989, Querna et al. 1994, Timmerman et al. 1998, Paidi et al. 1999, Laurell et al. 2003, Borrell et al. 2005) have the distinct advantages of being quick and can be duplicated in large populations. Nevertheless, they do have the potential to underestimate the prevalence of periodontal breakdown in populations with less susceptibility (Beck & Löe 1993) or overestimate the prevalence when the particular teeth selected are first molars and lower incisors (Carlos et al. 1986).

Full-mouth assessments (Peng et al. 1990, Agerholm & Ashley 1996, Anagnou-Vareltzides et al. 1996, Laurell et al. 2003) provide the optimal examination of periodontal conditions. However, important priorities when examining periodontal status of subjects in population studies include short examination time and avoidance of subject discomfort, in order to maximise numbers people examined in the time available and to encourage subject compliance (Agerholm & Ashley 1996). Although it is desirable to monitor as many sites as possible to increase the probability of detecting disease prevalence, one of the main drawbacks of full-mouth assessments is that it can be time consuming. Therefore if part-mouth assessments are performed a correction factor should be calculated by performing full-mouth assessments on a certain percentage of subjects and comparing the results with those obtained from part-mouth assessments.

In the studies reviewed, the use of CAL and/or PPD at individual, multiple or mean site(s) in the assessment of periodontal breakdown varied. Al-

though a commonly observed sign of periodontal disease is an increased pocket depth, this may occur due to conditions other than periodontitis, such as delayed passive eruption and inflammatory or fibrous gingival enlargement. Deep pockets, therefore, may not be diagnostic for either gingivitis or periodontitis. Indeed, periodontitis may develop and progress without significant increase in pocket depth if gingival recession occurs (Jenkins et al. 2001). Agerholm & Ashley (1996) report that in their population if screening had been based on PPD $\geqslant$ 6 mm, as an approximation for CAL $\geqslant$ 4 mm, then the test would have overestimated those affected in the youngest two age groups (aged 20–30 years) and underestimated those affected in the group aged 36–40 years. This cast doubts on conclusions drawn from surveys where reliance has been placed on PPD measurement or categorization.

Collectively, the findings of this review indicate a strong need for future uniformity in the design of epidemiological periodontal studies. Such studies need to be designed to allow the resulting data to be compared with those obtained from other studies. The first step in this process, as mentioned in previous reviews, should be the use of a uniformly agreed measure and a measuring tool that clearly defines the disease threshold and the surveyed area (full mouth/part mouth). This may be difficult to achieve due to the wide variation of probes available and individual operator preference. If part-mouth assessments are made then a correction factor should be calculated to account for possible differences between part-mouth and full-mouth assessments. Further more there should be a requirement for training/calibration of the examiners and the nature of that training to be clearly reported in the study. Finally, in order to truly reflect disease activity, and reiterating previous reviews on the subject, the combined use of CAL and PPD should be considered as the two key variables to be assessed in future epidemiological studies.

Conclusions

A number of conclusions can be drawn from this systematic review.

The first is that this review has confirmed the view that epidemiological studies of periodontal diseases are complicated by the diversity of definitions and measurements used to describe and quantify these diseases. The second is the lack of consensus as to a uniform definition and classification of periodontal disease (Kingman & Albandar 2002). The third is a further confirmation of the heterogeneity between all the studies and the indices that were used and the areas of the mouth surveyed, making direct comparisons and specific answers to the focused questions difficult. The fourth point relates to the methodological inconsistency, particularly in terms of clearly identifying the methods used in selecting and generating the sample to ensure it is representative of the population studied and clearly recording the level of examiner training and calibration received.

The fifth conclusion which significantly adds to the existing evidence base in defining periodontitis is that the studies reviewed utilized a minimum diagnostic threshold, at a given site in terms of CAL of 2 mm and PPD of 3 mm.

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Clinical Relevance

Scientific rationale for the study: It is evident from the periodontal literature that there is a lack of uniformity in the definition of periodontitis used in epidemiological studies. The aim of the current study was to perform a systematic review of the literature related to the definitions of periodontitis and the methods that have been used to identify and measure this disease.

Principal findings: The studies that were reviewed utilized a minimum diagnostic threshold defining periodontitis, at a given site in terms of CAL of 2 mm and PPD of 3 mm.

Practical implications: This review represents a step towards the future validation of a definition for periodontitis and the method(s) used to measure it.