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EPIDEMIOLOGIC PATTERNS OF CHRONIC AND AGGRESSIVE PERIODONTITIS

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INTRODUCTION

The currently used definitions of chronic and aggressive periodontitis were introduced at the 1999 World Workshop for the Classification of Periodontal Diseases and Conditions (2). This revised classification system was meant to address a number of widely recognized shortcomings of the 1989 World Workshop diagnostic scheme, according to which the majority of the pathologic periodontal conditions were classified under three main categories: ‘Early Onset Periodontitis’, ‘Adult Periodontitis’, and ‘Refractory Periodontitis’. The 1999 classification did indeed address some key deficiencies of the earlier system including (i) the lack of a diagnostic category describing exclusively gingival lesions, (ii) the dependence on knowledge about the time of disease onset for distinguishing between ‘Early Onset-’ and ‘Adult’ periodontitis, and (iii) the highly heterogeneous ‘Refractory Periodontitis’ group, a term whose appropriate use required prior knowledge of the volume and quality of therapy rendered, as well as of patient compliance. Nevertheless, although one of the 1999 Classification’s explicitly expressed goals was “to discard classification terminologies that were age-dependent or required knowledge of rates of progression” (5), the new system admittedly offered only limited substantial improvement on either front. For example, one of the primary features of the newly introduced ‘Aggressive Periodontitis’ is “rapid attachment loss and bone destruction” (33). With respect to age, “circumpubertal onset” continues to constitute a key feature of Localized Aggressive Periodontitis, while Generalized Aggressive Periodontitis is suggested to “usually affect persons under 30 years of age, but patients may be older” (33). Considering that another primary diagnostic feature of Aggressive Periodontitis is “familial aggregation” of the disease, a feature that is often impossible to ascertain upon examination of a patient, one quickly recognizes that appropriate assignment of this particular diagnosis by the clinician –let alone by the epidemiologist- remains highly problematic.

Nevertheless, use of the search terms ‘chronic periodontitis’ and ‘aggressive periodontitis’ in the PubMed database alone at the time of authorship of this text (July 2009) identified approximately 3,300 and 1,650 publications, respectively. Interestingly, articles using the term ‘chronic periodontitis’ covered a time span dating back to 1948, while the earliest indexed publication retrieved using ‘aggressive periodontitis’ as a keyword was published the same year, indicating that these terms have been obviously used in a variety of different contexts. Hence, given the substantial body of literature using these terms and in order to contrast with earlier reviews of the epidemiology of periodontitis that heavily relied on publications employing terminology no longer in use (9, 41), we decided to limit the present

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text to epidemiologic studies published over the past decade, anticipating that they would have utilized the 1999 World Workshop nomenclature. For an overview of the literature prior to 1999, the reader is referred to the above earlier quoted texts. In our review, we first address some methodological considerations related to the assessment of chronic and aggressive periodontitis in epidemiologic studies. We particularly address the issue of disease onset and the impact of age in the determination of diagnosis. Subsequently, we present current data on the global prevalence of destructive periodontitis and its variability with respect to demographic characteristics. Our review does not include the study of diagnosis-specific genetic and environmental risk factors for chronic or aggressive periodontitis, as these are dealt with in detail in Chapter 10.

METHODOLOGICAL ISSUES – CASE DEFINITION

Earlier reviews (9, 39, 41) have pointed out the lack of uniformity in the definition of periodontitis in epidemiologic studies and the resulting substantial variability in the global prevalence estimates of the disease that is due to methodological inconsistencies alone. In fact, a recent methodological study has objectively quantified the influence of case definition on prevalence by demonstrating that periodontitis prevalence rates varied from 14% to 65% when using six different case definitions among the same participants (14). Likewise, in a publication discussing the impact of using four different classification systems to describe periodontal conditions in adolescents (37), discrepancies in prevalence estimates by a factor of 10 and a factor of 30 were noted for localized and generalized periodontitis, respectively. While it is well accepted that the site-specific diagnosis of periodontitis requires the combined presence of clinical inflammatory signs (manifested as bleeding on probing), loss of connective tissue support (i.e., attachment loss), and likely -but not necessarily- an increase in probing depth, unequivocal thresholds defining destructive disease or pathologic deepening of the gingival crevice have not been universally accepted. More importantly, the *extent* of the disease, i.e., the number or percentage of affected dental units required to ascribe a diagnosis of ‘periodontitis’ to a particular patient, has varied greatly. A recent systematic review of the definitions of periodontitis used in epidemiologic studies (43) reported that the *site-specific thresholds* for increased probing depth have ranged between 3mm to 6mm, and those for clinical attachment loss between 1 mm and 6 mm. The required *extent* of affected teeth or tooth surfaces exceeding the site-specific thresholds to qualify a proband as a case has ranged from a minimum of 1 teeth (4) to > 30% of the sites in the dentition (48).

Another important methodological consideration pointed out earlier is the use of full-mouth versus partial mouth examination protocols in the assessment of periodontal conditions (18, 30–32). It is clear that the validity of the estimates generated by a partial recording methodology will depend on the actual prevalence and extent of periodontitis in the population in question, and consequently, on the age of the subjects examined. The less prevalent and/or extensive the disease in a particular population, the higher the risk for invalid estimates when using a partial-mouth methodology. Thus, there is consensus that the best means of accurately assessing prevalence, extent and severity of periodontitis in an epidemiologic study is by using a full-mouth clinical examination (i.e., by using probing assessments at multiple sites per tooth at all teeth present). There is also a need for standardization of additional sources of variance across studies including probe tip dimensions, manual or pressure sensitive devices and, most importantly, carefully calibrated clinical examiners.

We want to draw the attention of the reader to the fact that the methodological variability discussed above relates solely to the definition of the ‘periodontitis case’, irrespective of clinical diagnosis. As alluded to in the introduction, the distinction between chronic and

aggressive periodontitis presents with additional complexity. Although the primary clinical variables recorded for the assessment of either disease are identical, a differential diagnosis between them must be made by contrasting the primary features of each disease as described in the 1999 World Workshop consensus reports. However, none of the three primary features of aggressive periodontitis (systemically healthy patient; rapid attachment loss and bone destruction; familial aggregation) (33) are capable of consistently facilitating a correct differential diagnosis in the setting of an epidemiologic study: the first because it is entirely nonspecific, the second because it requires at least a pair of examination occasions, and the third because it is frequently difficult to ascertain without extensive interviewing and adequate verification. What appears to be the single feasible approach facilitating the differential diagnosis between the two diseases, in the setting of an epidemiologic study and according to the 1999 classification framework, is a diagnostic tool that would factor in the age of the patient in the diagnostic decision making. In this context, it is important to realize that although the 1999 classification system abolished age as the *primary classification criterion* in the differential diagnosis of the different forms (and thus eliminated the categories of Early-Onset and Adult periodontitis), this should not be interpreted to suggest that age is to be disregarded from the diagnostic process. This is a point of paramount importance, because an evaluation of the amount of supporting periodontal tissue lost due to the disease in relation to the duration of the exposure to the causative factors -reflected through the individuals subject's age- is frequently the sole means of ascertaining whether the disease is 'aggressive' based on a single examination.

However, utilization of a combined 'attachment loss in relation to age' diagnostic tool for the differential diagnosis between chronic and aggressive periodontitis in the setting of an epidemiologic study requires introduction of additional criteria with respect to severity and extent. This is essential for several reasons:

First, the consensus reports of the 1999 World Workshop clarified that young individuals can also be affected by Chronic Periodontitis, as a result of exposure to etiologic agents. Therefore, the maximum amount of periodontal tissue loss in young individuals that can be considered as commensurate to the level of exposure, both with respect to its intensity and duration, and thus may be regarded as compatible with the diagnosis of chronic periodontitis, needs to be defined.

Second, it is well recognized that attachment loss may frequently manifest itself in buccal tooth surfaces of young subjects as a result of trauma due to faulty oral hygiene practices. Therefore, a distinction between trauma-induced recession and periodontitis is required.

Third, attachment loss may develop at individual teeth due to additional causes other than periodontitis or trauma, including items such as tooth malposition, advanced endodontic lesions, and tooth fractures. It is thus reasonable to propose that a reliable distinction between periodontitis-induced attachment loss and incidental attachment loss due to different etiologies will require involvement of a minimum of two, non-adjacent tooth surfaces located on different teeth.

In a recent publication (38), a working group from the Center for Disease Control and the American Academy of Periodontology introduced a new case-definition for use in population-based surveillance of periodontitis. This clinical definition of periodontitis in epidemiologic studies was based on a combination of probing depth and clinical attachment levels assessments as follows:

Severe periodontitis was characterized as presence of 2 interproximal sites with 6 mm clinical attachment loss, not on the same tooth *and* presence of 1 interproximal sites with a 5 mm probing depth. *Moderate periodontitis* was defined as presence of 2 interproximal

sites with 4 mm clinical attachment loss occurring at two or more different teeth *or* 2 interproximal sites with 5 mm probing depth not on the same tooth.

As discussed earlier, the attachment loss criteria used in the CDC/AAP definitions do facilitate a distinction between periodontitis and incidental attachment loss, since they are applied exclusively to interproximal surfaces and require presence of at least two affected teeth in the dentition. On the other hand, these definitions (i) do not incorporate any measure of current inflammatory status, and (ii) classify an individual harboring as few as two 5 mm interproximal pockets into the “moderate periodontitis” category, therefore, they obviously increase the probability for false positive diagnoses. Interestingly, the authors of the report postulated that “for the purposes of surveillance, there seems to be no reason for separating chronic and aggressive periodontitis” (38), acknowledging that the proposed system is incapable of distinguishing between the two forms of the disease.

As will become evident by the systematic query of the recent literature described below, despite the extensive use of the terms ‘chronic’ and ‘aggressive’ periodontitis, no epidemiological studies explicitly attempting to segregate between the two diagnoses have been carried out so far. Instead, the available studies have aimed at describing the prevalence, extent and severity of a single clinical pathologic condition, namely ‘periodontitis’. Thus, in order to interpret the literature with respect to our assigned task, but also as a basis for future studies that will attempt a distinction between chronic and aggressive periodontitis, we propose an adaptation of the above CDC/AAP definitions to incorporate an assessment of the loss of periodontal tissue *in relation to age* as follows:

In ages 25 years, presence of 2 interproximal, non-adjacent sites with 4 mm attachment loss occurring at a minimum of two different teeth, and accompanied by bleeding on probing will signify aggressive periodontitis. In ages between 26 and 35 years, a diagnosis of aggressive periodontitis will require presence of 2 interproximal, non-adjacent sites with 6 mm attachment loss occurring at a minimum of two different teeth and accompanied by bleeding on probing. In other words, our proposed criteria (i) define the maximum attachment loss that may be considered compatible with *chronic periodontitis* as a function of the age of the examinee, (ii) incorporate a measure of current inflammatory status, expressed through bleeding on probing, rather than a threshold for a deepened periodontal pocket. We consider the latter point as an advantage over the CDC/AAP proposal since destructive disease with no concomitant deep pockets, reported to occur in some Asian and African populations (6–8), will still be captured when using our proposed system. However, the above age-adjusted approach will admittedly fail to facilitate the differential diagnosis between severe chronic and aggressive periodontitis in a subject over the age of 35 years. Access to disease progression data derived from sequential examinations and/or confirmation of familial aggregation according the 1999 consensus report seem to be the only way to distinguish between severe chronic periodontitis and aggressive periodontitis in older patients, but the feasibility of such an approach in the setting of an epidemiologic study remains highly questionable.

We also feel that the secondary descriptors of severity of chronic periodontitis, i.e., the terms “slight”, “moderate” and “severe” that have been recommended in the consensus report (36) may also benefit from an age-adjustment. For example, an attachment loss of 5 mm affecting multiple interproximal sites in a 30-year old individual arguably represents a disease of different severity from that occurring in an 80-year old patient, as it signifies an entirely different prognosis with respect to tooth survival. In the latter case, but not in the former case, this level of attachment loss is most likely compatible with the retention of the entire dentition throughout the patient’s life. Therefore, we suggest that an age-based adjustment of severity may result in a more meaningful periodontal diagnosis, both when

used in epidemiologic studies and, particularly, in the clinical setting. Earlier described systems that have used the amount of periodontal tissue support loss in relation to both the root length of the particular tooth and the age of the individual to define thresholds that seem to be incompatible with long-term tooth survival (49) may be useful in this context.

ESTIMATES OF PREVALENCE, SEVERITY AND EXTENT

Cross-sectional data

As noted above, our original intent was to provide a summary of published prevalence data for chronic and aggressive periodontitis based on the definitions of the 1999 International Workshop for a Classification of Periodontal Diseases and Conditions (33, 36). However, our initial screening of the published literature suggested a dearth of prevalence data based on the above definitions and diminished the potential for a meaningful review. Conversely, this initial screening identified a number of studies that reported prevalence data based on either the recently published joint CDC/AAP definition (38) or on the extent and severity of clinical attachment loss beyond specific severity thresholds (i.e., from 3 through 6 mm). We therefore decided to additionally include periodontitis prevalence data based on these definitions. Although this approach is still not ideal for reviewing global periodontitis prevalence data, it is a reasonable compromise that will facilitate a broader comparison of data based on comparable definitions of periodontitis.

Our initial screening of the literature focused on (i) human studies; (ii) published in the English language between January 1st, 2000 (i.e., immediately after the publication of the Consensus documents (1) and the date of the search (July 19, 2009); that (iii) included in the title or abstract *either* of the words “periodontal” or “periodontitis” in addition to *either* of the words “epidemiology” or “prevalence” in addition to the word “population”. Thus, the complete PubMed search criteria were defined as follows:

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((periodontal[Title/Abstract]) OR (periodontitis[Title/Abstract])) AND
((epidemiology [Title/Abstract]) OR (prevalence [Title/Abstract])) AND
(“2000”[Publication Date]: “2009/07/19”[Publication Date]) AND
(English[Language]) AND (population[Title/Abstract]) AND (Humans[Filter])).
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The above search strategy identified a total of 289 publications. All abstracts were reviewed and publications were excluded from further consideration due to the following reasons: (i) the manuscript did not present periodontitis prevalence data based on any of the definitions used in this review (i.e., the 1999 International Classification Workshop criteria (33, 36) or the CDC/AAP criteria (38) or extent of attachment loss beyond specific thresholds); (ii) data arose from a highly selected population that severely limited the generalizability and representativeness of the data for the underlying population (e.g., studies exclusively of participants with type 2 diabetes); (iii) the study specifically excluded participants without periodontitis and, thus, precluded the calculation of prevalence estimates; (iv) results were entirely duplicative of another publication from the same population. Using these additional restrictions, a total of 21 publications were considered eligible for final review.

We have organized the data from the above studies in three Tables: Table 1 presents prevalence estimates based on the CDC/AAP definitions (38). Table 2 uses the severity thresholds of the 1999 International Classification Workshop (5). Finally, Table 3 presents estimates of periodontal disease according to extent and severity of clinical attachment loss. While Table 3 does not allow for meaningful inferences on the prevalence of chronic vs. aggressive periodontitis, it does allow for some level of standardized comparison of periodontal destruction across various populations and age and gender subgroups.

Severe periodontitis prevalence estimates based on the CDC/AAP definition (Table 1) ranged anywhere from 1% among 20–29 year-old participants in the Study of Health in Pomerania (SHIP) report (27) to 39% among participants aged ≥ 65 years in the Erie County Study (23). The substantial variation in these estimates was largely due to the variation in age ranges included. In comparisons across relatively homogeneous age ranges, less variability is evident. For example, when considering the prevalence of severe periodontitis among participants aged approximately 40–50 years, estimates were 21% in Germany (27) and 16% (47), 28% and 32% (23) in various populations from the United States. However, varying risk factor distributions and access to dental care across populations have certainly also contributed beyond age to the overall variability in prevalence estimates. Notably, nationally representative estimates of severe periodontitis according to the CDC/AAP definitions in the general adult population were only available from the United States (15) and Australia (45) and show the respective prevalences to be 2% and 4%.

Using the 1999 International Workshop severity thresholds (Table 2), prevalence estimates for generalized severe periodontitis ranged from 6% (12) to 50% (46), and were highest (92%) for individuals ≥ 70 years in a Brazilian cohort (46). The two studies reporting prevalence estimates across all three severity categories (11, 12) (Table 2) both indicate that nearly all participants have some form of periodontitis, although a substantial proportion was mild in the French population (11). In contrast, the Canadian data (12) indicate that participants tended to experience periodontitis of higher severity. Interestingly, Table 2 also indicates that, in France (11), mild periodontitis tended to be equally split between localized and generalized forms whereas moderate and severe periodontitis occurred more frequently in a generalized than a localized form. The opposite trend was observed in the Canadian data. The reasons for these patterns are unclear but are most likely the consequence of either differential tooth extraction practices or differential periodontal treatment availability in the two source populations. In comparison to the French and Canadian studies, the two reports from Brazil (16, 46) indicate a very high level of severe generalized periodontitis, although these data are not representative of the entire Brazilian population.

Only a single study fulfilling the inclusion criteria of our search presented data on aggressive periodontitis (35). Specifically, this study examined periodontal conditions among male and female Israeli army personnel in ages between 18 and 30 years, and reported a prevalence of localized aggressive periodontitis of 4% while the prevalence of generalized aggressive periodontitis was found to be 2%. This surprising paucity of prevalence data for aggressive periodontitis is primarily due to the fact that most initially identified studies using the term “aggressive periodontitis” in their title or abstract were conducted exclusively among participants who were determined to have the disease prior to enrollment. Therefore, true prevalence estimates could not be determined based on these reports. Likewise, case-control study designs were commonly utilized in the context of aggressive periodontitis, which also precluded the computation of valid prevalence estimates. As a result, the global prevalence of aggressive periodontitis remains elusive, which is reflective of the unresolved debate about its accurate definition. In order to mitigate this lack of prevalence data on aggressive periodontitis, we attempted to bridge our aforementioned suggested adaptation to the CDC/AAP definitions with the currently available data as follows: (i) the criteria for our proposed definition of aggressive periodontitis among participants ≥ 25 years of age are met or exceeded by the CDC/AAP definition of moderate or severe periodontitis; (ii) our proposed definition of aggressive periodontitis among participants 26 – 35 years of age most closely corresponds to the CDC/AAP definition of severe periodontitis. Using these approximations, it appears that the prevalence of aggressive periodontitis among individuals younger than 35 years ranges from approximately 1% to a maximum of 15% depending on age and study. For example, data from the Study of Health in Pomerania (SHIP) (27) show a prevalence of moderate/severe periodontitis among participants 29 years and under to be

13% and the prevalence of severe periodontitis among participants 30–39 to be 7%. Since the CDC/AAP definitions are likely to be overestimates of what our proposed definition would yield, in addition to the fact that the reported age ranges in Table 1 include participants over the age 25 and 35 respectively, further overestimation is probable. However, these overestimates were likely offset to some degree by the use of half-mouth exams in SHIP, which generally underestimate disease prevalence. Consequently, these estimates of 13% and 7% are almost certainly biased towards overestimation. Although the degree of overestimation cannot be precisely established from these data, it appears useful to define an approximate ‘ceiling’ characterizing the highest likely estimate of aggressive periodontitis in a given population. In comparison, applying this approach to prevalence data reported by Genco and colleagues (23) from the Erie County Study, suggests a prevalence ‘ceiling’ of approximately 15% for aggressive periodontitis (averaging severe periodontitis estimates for 25–29 and 30–39 age ranges and considering that 1/3 ~of participants were over age 35 and should not contribute to the estimate), while data from Taylor and Borgnakke from Michigan, USA suggest a prevalence ‘ceiling’ of 11% for aggressive periodontitis among participants under 26 years of age (47). In contrast, the NHANES III (21) data suggest an aggressive periodontitis ‘ceiling’ prevalence of around 3% but these estimates are difficult to reconcile with our proposed definition of aggressive periodontitis because they (i) combine moderate and severe periodontitis categories (according to the CDC/AAP definition); and (ii) combine participants aged 20–35 years, which completely merges the two age ranges we have suggested (25 and 26–35 years). Taken together, these two facts are likely to overestimate aggressive periodontitis prevalence, while the half-mouth examinations in NHANES certainly result in an underestimate of the disease. The degree of over vs. underestimation is impossible to determine presently. Similarly, the Australian national data (20) also merged the CDC/AAP definitions of moderate and severe periodontitis and grouped participants aged 15–35 making it difficult to reconcile with our proposed definition. Thus, the ‘ceiling’ estimate for the prevalence of aggressive periodontitis in the Australian population is 8%. It should be noted that, overall, these estimates of aggressive periodontitis mostly ignore disease among adolescents, as only three studies included participants under age 20 (15, 20, 47). Consequently, the ‘ceiling’ estimates are almost certainly overestimates of aggressive periodontitis in any source population including the full age range of adolescents.

Table 3 provides estimates of the extent of clinical attachment loss across various severity thresholds and demonstrates that the prevalence of attachment loss extent varies substantially across age, gender and region. Similar to the trends seen in Tables 1 and 2, attachment loss extent estimates in Table 3 were consistently higher in men vs. women and among older vs. younger participants. Of the 14 studies presented in Table 3, seven provided attachment loss extent estimates for either the 3 or 4 mm severity thresholds, six provided estimates for the 5 mm threshold and four provided estimates for attachment loss beyond the 6 mm threshold. Although extent and severity definitions are not specific enough for clinical definitions of periodontitis, their ease of use and general resistance to underestimation in protocols using anything less than a full-mouth examination makes them an attractive option for reporting in epidemiologic studies. However, continuous extent and severity definitions (i.e., the mean percentage of sites per mouth that exhibits attachment loss at or above specific severity thresholds) are not dichotomous and thereby fail to identify what proportion of a population exhibits disease at a given threshold.

Despite the substantial inter-study variation in the reported periodontitis prevalence estimates, the data corroborate the well-established notion in the periodontal literature that (i) men experience more periodontitis than women, although the disparity varied considerably across studies; and (ii) the prevalence of periodontitis increases with age. In regard to the consistently observed age gradient, the data indicate that prevalence based on

the CDC/AAP definition tends to reach its peak around the 5th or 6th decade at which point the trends stabilizes or at least attenuates. For example, data from SHIP (27) demonstrate that severe periodontitis (CDC/AAP definition) increases by ~30 fold between the 3rd and 6th decade from 1% to 31% and then remains stable into the 80s (Table 1). Results from other populations were similar although the gradient was not as extreme. In contrast to the results in Table 1, a plateau of prevalence estimates trends in the oldest age groups was not evident when using extent and severity definitions. Instead, the estimates in Table 3 generally increased throughout the age span. This is likely influenced by the reduced specificity of extent and severity definitions, the prevalence of which increases for reasons other than true periodontitis.

Periodontitis Prevalence Time Trends

Few studies have been performed that allow for valid estimation of secular trends in periodontitis prevalence. Again, one important reason for a lack of time trend data is the fact that periodontal examination protocols often vary over time. The historical experience in the United States related to the National Health and Nutrition Examination Surveys is emblematic of this difficulty. Page and Eke (38) have recently summarized the complicated history of NHANES in relation to dental examination protocols and the subsequent difficulty in producing valid secular trend data. Nevertheless, these authors concluded that “it is clear that the prevalence and severity of periodontitis have decreased significantly over the last 50 – 60 years”, although the precise magnitude of this decrease is difficult to ascertain due to the constant evolution of periodontal examination protocols and case definitions. Accordingly, focused analyses restricted to recent NHANES cross-sections using more comparable periodontal examinations protocols support the concept of decreasing prevalence of periodontitis over time. Borrell et al. reported that periodontitis prevalence decreased by about 3% in absolute terms from 7.3% to 4.2% and these trends were consistent across race/ethnic groups (10). Note that although the definition of periodontitis in their analysis was different than the definitions under consideration presently, the within study consistency of their case definition over time still provides a meaningful estimate of variation in prevalence patterns. Moreover, NHANES data published by Dye and colleagues (21) and presented in Table 1 show similar patterns of decline in periodontitis.

Similarly, a number of studies from Scandinavia have demonstrated consistent improvements in periodontal health, although as noted earlier (24, 41), these improvements tend to be restricted to gingivitis and mild/moderate forms of periodontitis while the prevalence of more severe forms of periodontitis appears to remain relatively stable. Recently published data from four serial cross-sections over 30 years demonstrate this point (28). These investigators reported general improvement in oral health and that “the proportion of periodontally healthy individuals increased from 8% in 1973 to 44% in 2003 and the proportion of individuals with gingivitis and moderate periodontitis decreased.” Interestingly, despite decreases in moderate periodontitis, the proportion of individuals with advanced forms of periodontitis remained unchanged. These observations are unique and particularly valuable because of the high degree of periodontal examination standardization over an extended time span. Similar trends, although based in less-precise methodologies, have been published from Norway (44), Finland (3) and the Netherlands (29). Nevertheless, one should be cautious to extrapolate from the above data and conclude that the global prevalence of periodontitis is declining, as the data reviewed above originate exclusively from Europe and North America. It should also be realized that tooth retention in older age cohorts may likely translate into presence of teeth with some degree of attachment loss. In other words, a decline in edentulism must be expected to contribute to an increase in prevalence of periodontitis in the elderly.

Limitations

Some important limitations of, and caveats about, this review should be noted. First, although we attempted to include only studies that provided reasonable estimates of disease prevalence from the source population studied, most studies are not comprised of nationally representative samples, which precludes true international comparisons. In general, prevalence estimates arising from national samples tended to be lower than estimates arising from non-national samples.

Second, despite the fact that the inclusion criteria applied in this versus older reviews resulted in relatively homogeneous examination methodologies, the residual variation in the periodontal examination methods used among the reviewed studies must be recognized. Important differences relate to full- vs. half-mouth examination protocols, the varying number of periodontal sites assessed per tooth and/or per mouth, and the types of periodontal probing devices used. These differences should be considered before making definitive inferences based on any specific between-population comparisons that may be of interest to the reader.

Third, this review does not address periodontitis incidence. It is often tempting to speculate about population incidence (number of new cases per time period) patterns based on the observed prevalence patterns. However, because prevalence is a function of both incidence and disease duration (26), prevalence does not directly reflect incidence patterns and can be misleading in some situations. For example, assume the age-standardized prevalence of periodontitis to be equal in populations A & B, but with the treatment standards in population A favoring more aggressive tooth extraction practices among periodontitis patients. In this case, the observed prevalence in population A is lower than what would have been observed if tooth extractions were equally likely in population A vs. B (i.e., more teeth with periodontitis in population A were extracted and therefore unavailable for recording in epidemiological studies). Therefore, as pointed out by Hennekens and Buring (26), “a change in prevalence from one time period to another may be the result of changes in incidence rates, changes in the duration of disease, or both”. Importantly, the same is true for between-study variations in disease prevalence.

Concluding remarks

In the present review, we have sacrificed quantity for comparability and observed that the prevalence of periodontitis has considerable international variation. Nevertheless, it remains difficult to make conclusive statements about the global periodontitis prevalence due to an overall dearth of studies reporting comparable estimates. We have summarized only 21 studies, only a few of which are from Asia and none of which are from Africa – two continents that contain much of the global population. Therefore, while there is evidence of increasing standardization in the reporting of periodontitis prevalence estimates, more standardization is needed before comprehensive global comparisons can be made. A decade after the introduction of the current system of Classification of Periodontal Diseases and Conditions, it is apparent that an accurate estimate of prevalence of the currently recognized major diagnostic forms of periodontitis is not feasible. As discussed above, the defined primary features of the two diseases do not facilitate a distinction between them in epidemiologic studies. Thus, while more research is clearly needed before an evidence/biology-based convergence on periodontitis definitions can emerge, adoption of additional criteria is essential to facilitate differential diagnosis in epidemiologic studies and accurate assessment of secular trends. Over the past few years, a number of definitions for descriptive epidemiologic studies of ‘periodontitis’ as a single disease entity have emerged, such as the joint CDC/AAP definition as well as clinical attachment loss extent measures at specific severity thresholds (incipient, moderate, advanced). It is essential for future epidemiologic

studies of periodontitis to provide data on attachment loss and inflammatory status with sufficient detail and in a standardized manner so that more complex ‘case’ definitions can be easily constructed and applied to nationally representative datasets.

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Table 1
Prevalence estimates based on qualifying studies using the CDC/AAP Working Group definition (15)

Authors/Country	N ^a	Ages	Exam Method	All			Males			Females		
				None/Mild	Moderate	Severe	Edentulism	None/Mild	Moderate	Severe	Edentulism	Severe
Holtfreter et al. 2009; Germany; (SHIP)(27)	3,557	20–81	HM, 4 sites	49%	33%	18%	12% ^b	46%	33%	21%	NR	33%
	587	20–29		88%	12%	1%	NR	87%	12%	1%	NR	1%
	745	30–39		66%	27%	7%	NR	62%	28%	9%	NR	5%
	714	40–49		37%	42%	21%	NR	30%	45%	25%	NR	17%
	695	50–59		26%	43%	31%	NR	21%	39%	41%	NR	22%
	544	60–69		20%	47%	33%	NR	14%	45%	41%	NR	26%
	267	70–81		26%	44%	29%	NR	21%	44%	35%	NR	26%
Costa et al. 2009; Brazil (14)	340	30–45	FM, 4 sites	45%	41%	14%	NR	NR	NR	NR	NR	NR
Slade et al. 2007; Australia ^c (NSAOH) (45)	2,999	15–90	FM, 3 sites	71%	25%	4%	NR	NR	NR	NR	NR	NR
D'Aiuto et al. 2008; USA ^d ; (NHANES III) (15)	13,677	17+	HM, 2 sites	86%	12%	2%	NR	NR	NR	NR	NR	NR
Genco et al. 2007; USA; (MSEPerio Study) (23)	1,578	35–72	FM, 6 sites	19%	52%	30%	NR	13%	51%	37%	NR	19%
	50	35–39		36%	60%	4%	NR	NR	NR	NR	NR	NR
	630	40–54		24%	49%	28%	NR	NR	NR	NR	NR	NR
	425	55–64		17%	54%	30%	NR	NR	NR	NR	NR	NR
	374	65+		13%	55%	33%	NR	NR	NR	NR	NR	NR
Genco et al. 2007; USA; (Erie County Study) (23)	1,438	25–74	FM, 6 sites	27%	42%	31%	NR	25%	40%	35%	NR	25%
	116	25–29		50%	40%	10%	NR	NR	NR	NR	NR	NR
	277	30–39		38%	38%	24%	NR	NR	NR	NR	NR	NR
	383	40–54		24%	33%	32%	NR	NR	NR	NR	NR	NR

Authors/Country	N ^a	Ages	Exam Method	All				Males				Females			
				None/Mild	Moderate	Severe	Edentulism	None/Mild	Moderate	Severe	Edentulism	None/Mild	Moderate	Severe	Edentulism
	134	55-64		23%	45%	32%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	215	65+		15%	46%	39%	NR	NR	NR	NR	NR	NR	NR	NR	NR
Taylor & Borgnakke, 2007; USA (47)	455	18-93	FM, 4 sites	64%	24%	12%	NR	60%	22%	18%	NR	66%	26%	8%	NR
	105	18-25		89%	9%	2%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	128	30-39		78%	20%	2%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	129	40-54		56%	28%	16%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	41	55-64		29%	34%	37%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	52	65+		23%	46%	31%	NR	NR	NR	NR	NR	NR	NR	NR	NR
Phipps et al., 2009; USA; (MDS)(42)	1,210	65-95	FM, 6 sites	NR	NR	26%	10%	NR	NR	26%	10%	NR	NR	NR	NR
	634	65-74		NR	NR	23.3%	NR	NR	NR	23.3%	NR	NR	NR	NR	NR
	576	75+		NR	NR	28%	NR	NR	NR	28%	NR	NR	NR	NR	NR
Do et al., 2008; Australia; (NSAOH)(20)	3,161	15+	FM, 3 sites	77%	23% ^b		NR	72%	28% ^b		NR	82%	18% ^b		NR
	598	15-34		92%	8% ^b		NR	NR	NR		NR	NR	NR		NR
	1331	35-54		78%	22% ^b		NR	NR	NR		NR	NR	NR		NR
	692	55-64		60%	40% ^b		NR	NR	NR		NR	NR	NR		NR
	540	65+		48%	52% ^b		NR	NR	NR		NR	NR	NR		NR
Dye et al., 2007; USA ⁷ ; (NHANES III 1988-1994) (21)	16,128	20+	HM, 2 sites	86%	14% ^b		NR	82%	18% ^b		NR	89%	7% ^b		NR
	5,126	20-34		97%	3% ^b		0.5%	NR	NR		NR	NR	NR		NR
	4,065	35-49		91%	9% ^b		4%	NR	NR		NR	NR	NR		NR
	2,982	50-64		80%	20% ^b		17%	NR	NR		NR	NR	NR		NR
	2,084	65-74		76%	24% ^b		29%	NR	NR		NR	NR	NR		NR
	1,871	75+		71%	29% ^b		43%	NR	NR		NR	NR	NR		NR

Authors/Country	N ^a	Ages	Exam Method	All			Males			Females		
				None/Mild	Moderate	Severe	None/Mild	Moderate	Severe	None/Mild	Moderate	Severe
Dye et al. 2007; USA [†] ; (NHANES 1999–2004) (21)	13,159	20+	HM, 2 sites	92%	8% ^b	NR	90%	10% ^b	NR	95%	5% ^b	NR
	3,593	20–34		NR	NR	NR	NR	NR	NR	NR	NR	NR
	3,250	35–49		95%	5% ^b	3%	NR	NR	NR	NR	NR	NR
	2,777	50–64		89%	11% ^b	10%	NR	NR	NR	NR	NR	NR
	1,816	65–74		86%	14% ^b	24%	NR	NR	NR	NR	NR	NR
	1,723	75+		80%	20% ^b	32%	NR	NR	NR	NR	NR	NR

^aSample size reported for dentate participants

^bPeriodontitis definition was not separated according to moderate or severe but rather as a combination of moderate and severe

[†]Indicates nationally representative samples

NR=Not reported

SHIP=Study of Health in Pomerania

NSAOH=Australian National Survey of Adult Oral Health

MoS=Oral Epidemiologic Fractures in Men Study

NHANES=National Health and Nutrition Examination Survey

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Table 2
Prevalence estimates based on qualifying studies using the 1999 International Classification Workshop severity criteria (2)

Authors/Country	N	Age/Gender	Exam Method	Mild		Moderate		Severe	
				Localized	Generalized	Localized	Generalized	Localized	Generalized
Brothwell & Ghiabi 2009; Canada (Sandy Bay First Nation in Manitoba) (12)	94	18+, M/F	PM, 6 sites	1%	34%	27%	16%	16%	6%
Bourgeois et al. 2007; France; (NPSES) (11)	2,144	35–64, M/F	FM, 4 sites	22%	27%	2%	25%	1%	19%
		35–39, M		26%	31%	3%	22%	0.4%	10%
		35–39, F		31%	31%	4%	19%	1%	6%
		40–49, M		19%	28%	1%	31%	1%	16%
		40–49, F		30%	29%	2%	19%	1%	13%
		50–59, M		17%	23%	1%	26%	1%	31%
		50–59, F		22%	23%	2%	28%	2%	21%
		60–64, M		12%	19%	3%	26%	1%	38%
		60–64, F		17%	30%	1%	30%	1%	21%
Dalla Vecchia et al. 2005; Brazil (16)	706	30–65, M/F	FM, 6 sites	NR	NR	NR	NR	NR	43%
	329	30–65, M		NR	NR	NR	NR	NR	51%
	377	30–65, F		NR	NR	NR	NR	NR	35%
Susin et al. 2004; Brazil (46)	848	30–103, M/F	FM, 6 sites	NR	NR	NR	NR	NR	50%
	249	30–39, M/F		NR	NR	NR	NR	NR	22%
	253	40–49, M/F		NR	NR	NR	NR	NR	58%
	175	50–59, M/F		NR	NR	NR	NR	NR	65%
	84	60–69, M/F		NR	NR	NR	NR	NR	73%
	42	70+, M/F		NR	NR	NR	NR	NR	92%

FM=Full-mouth

PM = Partial-mouth examination of pre-specified index teeth.

NR=Not reported

NPSES=National Periodontal Systemic Examination Survey project

Table 3

Estimates of clinical attachment loss severity and extent based on qualifying studies

				All				Males				Females			
Authors/Country	N ^a	Ages	Exam Method	%AL 3	%AL 4	%AL 5	%AL 6	%AL 3	%AL 4	%AL 5	%AL 6	%AL 3	%AL 4	%AL 5	%AL 6
Holtfreter et al 2009; Germany; (SHIP) (27)	3,557	20–81	HM, 4 sites	63%	41%	27%	18%	97%	43%	29%	20%	60%	38%	24%	15%
	587	20–29		22%	5%	2%	1%	24%	6%	2%	1%	20%	5%	1%	0.4%
	745	30–39		50%	22%	10%	5%	53%	24%	11%	6%	46%	19%	8%	4%
	714	40–49		72%	47%	30%	19%	76%	52%	34%	23%	68%	41%	26%	15%
	695	50–59		82%	59%	42%	28%	86%	66%	48%	35%	79%	53%	36%	22%
	544	60–69		91%	75%	56%	40%	95%	80%	64%	48%	88%	69%	49%	33%
	267	70–81		95%	83%	68%	50%	97%	85%	71%	55%	95%	83%	64%	48%
Phipps et al. 2009; USA; (MrOS) (42)	1,210	65–95	FM, 6 sites	NR	NR	13%	NR	NR	NR	13%	NR	NR	NR	NR	NR
	634	65–74		NR	NR	12%	NR	NR	NR	12%	NR	NR	NR	NR	NR
	576	75+		NR	NR	15%	NR	NR	NR	15%	NR	NR	NR	NR	NR
Costa et al. 2009; Brazil (14)	340	30–45	FM, 4 sites	NR	NR	NR	8%	NR	NR	NR	NR	NR	NR	NR	NR
Do et al. 2008; Australia; (NSAOH) (20)	3,161	15+	FM, 3 sites	NR	3.5%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Lee et al. 2008; USA; (NHANES 1999–2002) (34)	1,234	20+	HM, 1 site	NR	7%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Corrani et al. 2008; Brazil(13)	39	12–19	FM, 6 sites	20%	NR	0.1%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	62	20–29		26%	NR	2%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	40	30–39		41%	NR	9%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	27	40–49		57%	NR	21%	NR	NR	NR	NR	NR	NR	NR	NR	NR
	46	50+		79%	NR	44%	NR	NR	NR	NR	NR	NR	NR	NR	NR
Bourgeois et al. 2007; France; (NPSES) (11)	2,144	35–64	FM, 4 sites	29%	9%	3%	0.9%	32%	10%	4%	1.0%	27%	8%	2%	0.5%

				All						Males						Females					
Authors/Country	N ^a	Ages	Exam Method	%AL 3	%AL 4	%AL 5	%AL 6	%AL 3	%AL 4	%AL 5	%AL 6	%AL 3	%AL 4	%AL 5	%AL 6	%AL 3	%AL 4	%AL 5	%AL 6		
		35–39		22%	5%	1%	0.3%	24%	5%	1%	0.3%	20%	4%	1%	0.2%						
		40–49		28%	8%	3%	0.8%	32%	10%	3%	1.0%	24%	7%	2%	0.5%						
		50–59		32%	12%	5%	1.2%	35%	40%	42%	31%	30%	10%	3%	0.7%						
		60–64		37%	14%	6%	1.5%	41%	18%	8%	2%	35%	11%	4%	0.9%						
Elter et al. 2004; USA(22)	6,744	45–64	FM, 6 sites	13%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
Desvarieux et al. 2003; USA; (INVEST)(17)		55+	FM, 6 sites	NR	41%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
Baelum et al. 2003; Thailand(8)	209	30–39	FM, 6 sites	NR	24%	NR	NR	NR	25%	NR	NR	NR	23%	NR	NR	NR			NR		
	154	50–59		NR	64%	NR	NR	NR	66%	NR	NR	NR	62%	NR	NR	NR			NR		
Do et al. 2003; Vietnam(19)	575	35–44	FM, 2 sites	22%**	12%	5%	3%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
Papapanou et al. 2002; Thailand(40)	103	30–34	FM, 6 sites	NR	NR	5%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR			NR		
	104	35–39		NR	NR	11%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
	71	50–54		NR	NR	27%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
	78	55–59		NR	NR	32%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
Griffiths et al. 2001; Britain(25)	100	16–20	FM, 4 sites	1%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		
Albandar et al. 1999; USA ^a ; (NHANES III)(1)	9,689	30–90	HM, 2 sites	20%	NR	NR	NR	23%	NR	NR	NR	17%	NR	NR	NR	NR			NR		
		30–39		8%	NR	NR	NR	10%	NR	NR	NR	6%	NR	NR	NR	NR			NR		
		40–49		16%	NR	NR	NR	21%	NR	NR	NR	11%	NR	NR	NR	NR			NR		
		50–59		28%	NR	NR	NR	33%	NR	NR	NR	23%	NR	NR	NR	NR			NR		
		60–69		35%	NR	NR	NR	40%	NR	NR	NR	29%	NR	NR	NR	NR			NR		
		70–79		39%	NR	NR	NR	42%	NR	NR	NR	36%	NR	NR	NR	NR			NR		
		80–90		50%	NR	NR	NR	54%	NR	NR	NR	47%	NR	NR	NR	NR			NR		

Note that data in this table represent the mean % of sites per mouth beyond specified severity thresholds (3–6 mm). These data do not represent the prevalence of any disease at the given severity thresholds.

^aThe NHANES III data presented by Albandar et al. (1) was published prior to the 1999 International Classification Workshop (41). We identified this publication via bibliography reviews and include it presently because it presents comparable, nationally representative data that we were unable to locate elsewhere.

INVEST=Oral Infections and Vascular Disease Epidemiology Study

MrOS=Osteoporotic Fractures in Men Study

NR=Not reported

NSAOH=Australian National Survey of Adult Oral Health

NHANES=National Health and Nutrition Examination Survey

NPSES=National Periodontal Systemic Examination Survey project

SHIP=Study of Health in Pomerania