CLINICAL REVIEW

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Global Burden of Severe Periodontitis in 1990-2010: A Systematic Review and Meta-regression

ABSTRACT

We aimed to consolidate all epidemiologic data about severe periodontitis (SP) and, subsequently, to generate internally consistent prevalence and incidence estimates for all countries, 20 age groups, and both sexes for 1990 and 2010. The systematic search of the literature yielded 6,394 unique citations. After screening titles and abstracts, we excluded 5,881 citations as clearly not relevant to this systematic review, leaving 513 for full-text review. A further 441 publications were excluded following the validity assessment. A total of 72 studies, including 291,170 individuals aged 15 yr or older in 37 countries, were included in the metaregression based on modeling resources of the Global Burden of Disease 2010 Study. SP was the sixth-most prevalent condition in the world. Between 1990 and 2010, the global age-standardized prevalence of SP was static at 11.2% (95% uncertainty interval: 10.4%-11.9% in 1990 and 10.5%-12.0% in 2010). The age-standardized incidence of SP in 2010 was 701 cases per 100,000 person-years (95% uncertainty interval: 599-823), a nonsignificant increase from the 1990 incidence of SP. Prevalence increased gradually with age, showing a steep increase between the third and fourth decades of life that was driven by a peak in incidence at around 38 yr of age. There were considerable variations in prevalence and incidence between regions and countries. Policy makers need to be aware of a predictable increasing burden of SP due to the growing world population associated with an increasing life expectancy and a significant decrease in the prevalence of total tooth loss throughout the world from 1990 to 2010.

KEY WORDS: periodontal diseases, oral health, world health, statistics, prevalence, incidence.

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INTRODUCTION

The 1999 World Workshop for the Classification of Periodontal Diseases and Conditions identified 3 periodontitis types based on specific etiologic formulation: chronic periodontitis, aggressive periodontitis, and periodontitis as a manifestation of systemic disease (Armitage, 2004). Previous attempts to synthesize the epidemiology of periodontal diseases have shown that 5% to 20% of any population suffers from severe periodontitis (SP), while mild to moderate periodontitis affects a majority of adults (Dye, 2012; Petersen and Ogawa, 2012). A number of continental reviews have also been conducted over the past decade, which varied in terms of the quantity and quality of included studies (Albandar, 2002; Baelum and Scheutz, 2002; Corbet *et al.*, 2002; Gjermo *et al.*, 2002; Sheiham and Netuveli, 2002). Only Dye (2012) provided some details of the methods used for selection of studies. Yet, data on incidence of SP is scarce (Burt *et al.*, 2005). A good understanding of current trends in SP is important for planning dental services and workforce, as well as for updating the dental curriculum.

Quantifying periodontal diseases in a meaningful and reproducible manner has been an ongoing challenge for oral epidemiologists and clinicians. Several classification systems have been developed to describe clinical manifestations of periodontitis, most of which have their own case definitions and scales for quantifying severity. Unification under a single case definition has been a challenge, hitherto without a satisfying solution (Meisel and Kocher, 2009). Heterogeneity of case definitions affects comparison of the results and leads to either overestimation or underestimation of disease prevalence (Costa *et al.*, 2009). The World Health Organization introduced the Community Periodontal Index of Treatment Needs (CPITN) in 1987, recommending the use of pocket depth (PD) as a criterion for identifying cases of SP (World Health Organization, 1987). Influential oral health surveys, such the 2009 Adult Dental Health Survey in the United Kingdom (Kelly *et al.*, 2001; O'Sullivan *et al.*, 2011) and the National Health and Nutrition Examination Surveys in the United States (Dye *et al.*, 2007; Dye *et al.*, 2008; Dye *et al.*, 2011), have measured attachment loss (AL) in addition to PD.

A systematic review of case definitions and methods used to identify periodontitis found that only 15 of 104 relevant publications actually gave a quantitative case definition of periodontitis; among these 15, there was heterogeneity in terms of indices used and areas of mouth surveyed (Savage *et al.*, 2009). Recently, the number of teeth and sites around each tooth to be

examined, the precision of the measurements, the use of PD *vs.* AL, the summarization of site-specific information and case definitions, and the reliability of periodontal disease measures have been highlighted as concerns in most epidemiologic tools to measure periodontal disease (Beltran-Aguilar *et al.*, 2012). We have identified 3 comparable quantitative indicators of SP: CPITN class 4 (PD ≥ 6 mm), AL > 6 mm, and PD > 5 mm.

The goal of the Global Burden of Disease (GBD) 2010 Study has been to systematically produce comparable estimates of the burden of 291 diseases and injuries and their associated 1,160 sequelae from 1990 to 2010 (Murray *et al.*, 2012a; Murray *et al.*, 2012b). We aimed to consolidate all epidemiologic data about SP and, subsequently, to generate internally consistent prevalence and incidence estimates for all countries, 20 age groups, and both sexes for 1990 and 2010.

MATERIALS & METHODS

Detailed methods for each component of the GBD 2010 Study are described elsewhere (Murray *et al.*, 2012a). We provide a description here with emphasis on SP.

Search Strategy for Identification of Studies

A systematic literature review was conducted at the Department of Clinical and Diagnostic Oral Science, Institute of Dentistry, Queen Mary University of London, between 2007 and 2011, following the Cochrane handbook (Higgins and Green, 2011). The case definition of SP for literature review was in order of preference—a CPITN score of 4, a clinical AL more than 6 mm, or a gingival PD more than 5 mm—depending on which the publication used. We sought to identify all studies presenting SP-related descriptive epidemiology data (*e.g.*, prevalence, incidence, remission, duration, case fatality, and cause-specific mortality) between January 1980 and December 2010 regardless of language, geography, age, sex, or publication status (Marcenes *et al.*, 2013).

Electronic searches were carried out in MEDLINE *via* PubMed, EMBASE *via* OVID, and LILACS *via* BIREME. In MEDLINE, we performed keyword- and MeSH-based searches. Keywords were periodont* "attachment loss" or pocket* or "chronic periodontitis"; MeSH terms included "Periodontal Attachment loss/epidemiology" [MeSH] and "Chronic periodontitis/epidemiology" [MeSH]. Our searches in EMBASE used the same keywords, whereas LILACS keywords were "chronic periodontitis" or "periodontal attachment loss" or "pocket." We supplemented our electronic search with hand searches of reference lists of all relevant publications, textbooks, and web pages of government health departments and international health organizations. We wrote to chief dental officers worldwide requesting for any conference reports, theses, government reports, and unpublished survey data (gray literature).

Selection of Studies

Two trained reviewers (M.D. and B.B.) performed independent searches, assessed publication validity, and extracted the data in duplicate. Differences were resolved by discussion, rereading, and consultation with the senior member of the research team (W.M.) when necessary. Records of all references were combined in EndNote X4 (Thomas Reuters, Philadelphia, USA).

Those studies found to be relevant after title and abstract screening were kept in the database. Articles addressing unrelated topics were excluded at this stage—such as genetics, laboratory diagnostic tests, experimental laboratory animal studies, letters to editors, case reports, case series reports, and other patient-based studies (*e.g.*, hospital-based studies). Studies rejected at this or subsequent stages were recorded in a table of excluded studies, and reasons for exclusion were noted.

The full text of all topic-related studies was assessed for methodological quality according to a scale similar to the one devised by Loney *et al.* (1998). We did not, however, use a scoring system, owing to concerns over the validity of this procedure in general when assessing study quality (Juni *et al.*, 1999). All studies meeting the criteria for inclusion in this review were considered of good quality and were used in the metaregression. The inclusion criteria were observational longitudinal or cross-sectional studies (1) based on random samples; (2) representing national, subnational, or community populations; (3) measuring SP as defined for the GBD 2010 Study through clinical examination; (4) with a response rate > 50% for prevalence surveys and an attrition rate < 50% for longitudinal studies; and (5) reporting prevalence, incidence, or relative risk estimates or sufficient data for their calculation.

Data Extraction and Cleaning

Multiple data fields were extracted from each study according to GBD standards: condition name, case definition, country, region, date of study, parameter (*e.g.*, prevalence, incidence, duration, remission, case fatality, and mortality), parameter value, units (per 100, 100,000, *etc*.), lower confidence interval (CI) value, upper CI value, type of CI, standard error, sample size, sex, and age range of participants. We also recorded multiple additional fields, including data extractor's name, citation identifier, year of publication, coverage of study (national, subnational, community), urban *vs.* rural, subject source (*e.g.*, households, schools), method of sampling (*e.g.*, random, systematic, convenient), response or attrition rates, reliability test used (kappa, others), and reliability test values (intra- and interexaminer).

We made only limited modifications to data points. We distributed the total among the groups according to year- and country-specific age distributions when overall sample sizes were reported but not for each age group. If sample size was missing, we assigned it to be 100 (community studies), 250 (subnational studies), and 1,000 (national studies). If no exact age ranges were presented, descriptors such as "grade 5 elementary students" were extrapolated to assign appropriate age ranges. If no data collection date was presented, we assigned it to be 2 yr before publication. Countries were grouped in 21 regions and 7 super-regions by geographical proximity and mean age of death, which reflects both population age structure and age-specific death rates—a simple summary measure of the demographic and epidemiologic transition (Murray *et al.*, 2012b; Wang *et al.*, 2012).

Data Handling and Modeling

The SP database was modeled according to DisMod-MR, a Bayesian metaregression tool developed for the GBD 2010 Study (Flaxman *et al.*, 2012). The generalized negative binomial metaregression model of DisMod-MR combines an age-integrating compartmental model of disease with covariates that predict variation in true rates; covariates that predict variation across studies due to measurement bias; super-region, region, and country random intercepts; and age-specific fixed effects. The natural history of any disease can be described by a number of variables: incidence, prevalence, remission, duration, case fatality, and cause-specific mortality. DisMod-MR uses data on at least 3 of these variables to generate any other estimate when the data were sparse. For example, if prevalence is unknown but incidence, case fatality, and remission are, then prevalence can be calculated with a compartmental model (Harvard Initiative for Global Health *et al.*, 2008). For countries with sparse data, the prediction of true rates was facilitated by defaulting to the average of a region, super-region, or the world and taking advantage of relations with covariates in the metaregression. The estimation equations and approach to numerical solution, with examples, have been reported elsewhere (Murray *et al.*, 2012a).

A number of disease-specific limits were imposed to reflect the known epidemiology of SP. We assigned incidence and prevalence to be zero until ages 15 and 20 yr, respectively, based on the youngest age of a nonzero point estimate in the data set. Excess mortality and relative risk were both fixed at zero before age 30 yr. Bounds were assigned for remission and excess mortality to improve plausibility in DisMod-MR estimates. In finding consistency among the parameters in the model, multiple mathematical satisfactory solutions are sometimes possible. Initial models resulted in estimates of remission that were nearly 100% per year and excess mortality > 20% per year. As we considered those to be biologically implausible, remission was bound 0 to 0.05 and relative risk 1 to 5. We considered both to be within reasonable ranges for the observed natural history of SP.

There was some systematic bias present in the definition of the study populations, as SP is assessed among only dentate people, which implies that any estimates refer to a subgroup and not the entire population. To account for the systematic bias inherent in excluding edentates from the denominator, we had a few options. First, we could attempt to adjust the denominator study by study to accurately reflect the total number in each catchment area. This level of information was not available for most of the studies included. The next option was to invoke a global covariate of total tooth loss. However, the DisMod-MR computational architecture does not allow for covariate values to be different for different ages and sexes. This option was not ideal because the prevalence of total tooth loss is clearly age and sex dependent. The final option, which we elected to pursue, was to adjust the prevalence numbers estimated by DisMod-MR. For instance, if 40% of 70- to 74-yr-old women were estimated to be edentate in a certain region, the corresponding estimates for SP prevalence were reduced to 60% of the original value.

To capture uncertainty in all estimates, we ran 1,000 Monte Carlo simulations of 20,000 individuals for each age, sex, country, and year. Aggregations were made at the level of the 1,000 draws for all estimates. The uncertainty interval (UI) around each quantity of interest is presented as the 2.5th and 97.5th centiles, which can be interpreted as a 95% UI. As such, they are meant to convey the strength of the evidence for any age, sex, country, or year group.

RESULTS

A flowchart describing the systematic review search results is presented in Figure 1. The search yielded 6,394 unique records. After titles and abstracts were screened, 5,881 publications were excluded as clearly not relevant, leaving 513 for review. A further 441 publications were excluded following the validity assessment. All data were drawn from published studies. Nearly all reports identified from searches of the gray literature were publications already included in our database. The remaining unpublished national studies and subnational reports were excluded after the quality assessment. The main source of gray literature was World Health Organization's regional databases, which included mainly published data. Experts and chief dental officers worldwide confirmed lack of data or informed that their data have been published.

Quality of Reviewed Studies

The major quality flaws identified were related to inadequate population samples (297 studies) and outcome measures (134 studies). The former included studies adopting nonpopulation-based, convenient, or nonrandom samples or were carried out with patients, volunteers, or institutionalized (*i.e.*, prisoners, nursing homes), occupational (*i.e.*, army recruits, unemployed), or specific groups (*i.e.*, ethnic minority, immigrants, members of an association, high-risk groups). The latter were studies adopting nonclinical measures. Ten secondary data analysis studies were also excluded after the full text was read.

Included Studies

A total of 72 studies, including 291,170 individuals aged 15 yr or older in 37 countries (covering 16 of the 21 regions and all 7 super-regions), were included in the quantitative synthesis. The full list of included studies is presented in Appendix Table 1. Table 1 presents the characteristics of the included studies by world region. The majority of studies were prevalence surveys (65 studies) and drawn from national or subnational reports (58 studies). Furthermore, more studies were published in scientific journals (67 studies) and increasingly each decade (19 in 1980-1990, 25 in 1991-2000, and 28 in 2001-2010). Most studies (50 of them) reported periodontal outcomes using the Community Periodontal Index.

In sum, 316 data points were extracted from the 72 studies, covering both sexes and 16 unique world regions, with participants ranging in age from 15 to 99 yr. Three types of outcome measures were identified—namely, prevalence (n = 307), incidence (n = 3), and mortality (n = 6) related to SP. Moreover, 65% of data points were from populations aged 30 yr or more, 35% for those over 50 yr of age.

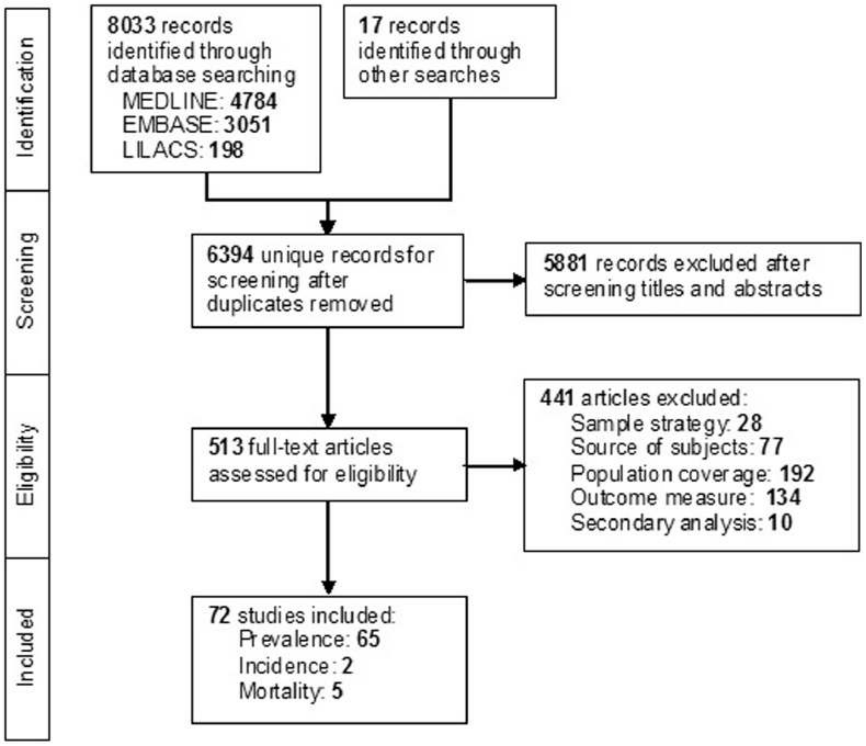

Figure 1. Flowchart of the selection of studies for the review.

Prevalence and Incidence of Severe Chronic Periodontitis

In 2010, SP was the sixth-most prevalent condition, affecting 10.8% (95% UI: 10.1%-11.6%) or 743 million people worldwide. Between 1990 and 2010, the global age-standardized prevalence of SP in the entire population was static at 11.2% (95% UI: 10.4%-11.9% in 1990 and 10.5%-12.0% in 2010). The age-standardized incidence rate of SP in 2010 was 701 cases per 100,000 person-years (95% UI: 599-823), a nonsignificant increase from the 1990 incidence rate of 696 cases per 100,000 person-years (95% UI: 604-808). No significant differences in the global age-standardized prevalence and incidence of SP were found between men and women. Prevalence of SP increased gradually with age, showing a steep increase between the third and fourth decades of life that was driven by a peak in incidence at around 38 yr of age. The prevalence of SP reached its peak at age 40 yr and remained stable at older ages. Although new cases of SP developed with increasing age, incidence was low and fairly constant at older ages. These age patterns have not changed appreciably since 1990 (Figure 2).

Geographic differences in SP prevalence and incidence were readily apparent (Table 2). Age-standardized prevalence and incidence of SP in 1990 and 2010 are reported by country in Appendix Table 2. All-ages prevalence (excluding nonsusceptible population < 15 yr old) is displayed in Figure 3. The corresponding breakdown of 1990 and 2010 prevalence estimates by sex, age groups, and regions is reported in Appendix Table 3. The age-standardized prevalence of SP varied by country, from 3.6% (95% UI: 3.3%-3.9%) in Fiji to 18.7% (95% UI: 17.3%-20.1%) in Chile. While Chile, Brazil, Kenya, Indonesia, Australia, and Greece were the countries where the prevalence of SP was significantly higher than the global mean, several countries had age-standardized prevalence of SP significantly below the global mean (Appendix Table 2).

All-ages incidence rate (in the susceptible population) is shown in Figure 4. The corresponding breakdown of 1990 and 2010 incidence estimates by sex, age groups, and regions is reported in Appendix Table 3. The age-standardized incidence rate of SP varied by country, from 251 new cases per 100,000 person-years in Marshall Islands and Tonga (95% UI: 130-423 and 132-434, respectively) to 1,428 per 100,000 person-years (95% UI: 770-2,545) in Argentina as listed in Appendix Table 2.

DISCUSSION

This pooled analysis, conducted as part of the GBD 2010 Study, provided the most comprehensive epidemiologic data on SP to date, which has generated internally consistent prevalence and incidence estimates for all countries in 1990 and 2010. The global age-standardized prevalence of SP in the entire population was 11.2% (95% UI: 10.4%-11.9% in 1990; and 10.5%-12.0% in 2010) and the age-standardized incidence rate of SP in 2010 was 701 cases per 100,000 person-years (95% UI: 599-823), indicating that a new SP case will develop annually from 142 people followed-up. In line with all GBD analyses at the population level, the present findings correspond to prevalence and incidence of SP for the entire population. If we consider that many persons are not at risk of developing SP (*e.g.*, younger than 15 yr and edentulous persons), the magnitude of the dental public health challenge posed by SP worldwide becomes even more significant. Furthermore, these figures provide a unique perspective in shaping public health policy. They provide governments and national and international nongovernmental agencies the evidence-based data to determine priorities for research, development, policies, and funding (Murray and Lopez, 1996; Murray *et al.*, 2012b).

Our findings compared favorably with most country-level measurements of SP prevalence at the population level, which is not surprising given that our models used all such data as inputs. We also found many similarities with estimates reported in other global and mainly continental periodontal diseases reviews, which supports the external validity of our findings (Albandar, 2002; Albandar and Tinoco, 2002; Baelum and Scheutz, 2002; Corbet *et al.*, 2002; Gjermo *et al.*, 2002; Sheiham and Netuveli, 2002; Dye, 2012; Petersen and Ogawa, 2012). Petersen and Ogawa (2012) have reported, in all their included studies, an

Table 1. Characteristics of the Studies Included in Review by Regions

Study Type	Report Type	Country	Publication Year	Coverage	Outcome[a]
		Asia Pacific, high income			
Prevalence: 4	Scientific paper: 4	Japan: 4	1980-1990: 3	National: 1	CPI = 4: 3
Incidence: 0	Survey report: 0		1991-2000: 1	Subnational: 1	CAL > 6 mm: 1
Mortality: 0			2001-2010: 0	Community: 2	PD > 5 mm: 0
		Asia, East			
Prevalence: 5	Scientific paper: 4	China: 4	1980-1990: 3	National: 3	CPI = 4: 4
Incidence: 0	Survey report: 1	Taiwan: 1	1991-2000: 2	Subnational: 2	CAL > 6 mm: 1
Mortality: 0			2001-2010: 0	Community: 0	PD > 5 mm: 0
		Asia, South			
Prevalence: 2	Scientific paper: 2	India: 2	1980-1990: 1	National: 0	CPI = 4: 2
Incidence: 0	Survey report: 0		1991-2000: 0	Subnational: 1	CAL > 6 mm: 0
Mortality: 0			2001-2010: 1	Community: 1	PD > 5 mm: 0
		Asia, Southeast			
Prevalence: 5	Scientific paper: 5	Indonesia: 2	1980-1990: 3	National: 1	CPI = 4: 3
Incidence: 0	Survey report: 0	Thailand: 2	1991-2000: 1	Subnational: 2	CAL > 6 mm: 2
Mortality: 0		Vietnam:1	2001-2010: 1	Community: 2	PD > 5 mm: 0
		Australasia			
Prevalence: 4	Scientific paper: 2	Australia: 3	1980-1990: 0	National: 3	CPI = 4: 2
Incidence: 0	Survey report: 2	New Zealand: 1	1991-2000: 1	Subnational: 1	CAL > 6 mm: 2
Mortality: 0			2001-2010: 3	Community: 0	PD > 5 mm: 0
		Caribbean			
Prevalence: 1	Scientific paper: 1	Antigua:1	1980-1990: 1	National: 0	CPI = 4: 1
Incidence: 0	Survey report: 0		1991-2000: 0	Subnational: 1	CAL > 6 mm: 0
Mortality: 0			2001-2010: 0	Community: 0	PD > 5 mm: 0
		Europe, Central			
Prevalence: 4	Scientific paper: 4	Croatia: 2	1980-1990: 1	National: 0	CPI = 4: 4
Incidence: 0	Survey report: 0	Bulgaria: 1	1991-2000: 1	Subnational: 4	CAL > 6 mm: 0
Mortality: 0		Slovenia: 1	2001-2010: 2	Community: 0	PD > 5 mm: 0
		Europe, Western			
Prevalence: 17	Scientific paper: 17	Denmark: 1	1980-1990: 4	National: 9	CPI = 4: 14
Incidence: 1	Survey report: 2	Germany: 4	1991-2000: 6	Subnational: 5	CAL > 6 mm: 3
Mortality: 1		Spain: 2	2001-2010: 9	Community: 5	PD > 5 mm: 2
		Finland: 3			
		France: 3			
		UK: 2			
		Ireland: 2[b]			
		Italy: 1			
		Greece:1			
		Latin America, Southern			
Prevalence: 2	Scientific paper: 2	Chile: 2	1980-1990: 0	National: 2	CPI = 4: 1
Mortality: 0	Survey report: 0		1991-2000: 1	Subnational: 0	CAL > 6 mm: 1
Incidence: 0			2001-2010: 1	Community: 0	PD > 5 mm: 0
		Latin America, Tropical			
Prevalence: 4	Scientific paper: 4	Brazil: 4	1980-1990: 0	National: 0	CPI = 4: 2
Incidence: 0	Survey report: 0		1991-2000: 2	Subnational: 2	CAL > 6 mm: 2
Mortality: 0			2001-2010: 2	Community: 2	PD > 5 mm: 0
		North Africa/Middle East			
Prevalence: 6	Scientific paper: 6	Iraq: 1	1980-1990: 1	National: 3	CPI = 4: 6
Incidence: 0	Survey report: 0	Turkey: 2	1991-2000: 2	Subnational: 2	CAL > 6 mm: 0
Mortality: 0		Saudi Arabia: 1[b]	2001-2010: 3	Community: 1	PD > 5 mm: 0
		Jordan: 1			
		Yemen: 1			
		North America, high income			
Prevalence: 5	Scientific paper: 10	Canada: 2	1980-1990: 1	National: 6	CPI = 4: 2
Incidence: 1	Survey report: 0	USA: 8	1991-2000: 5	Subnational: 3	CAL > 6 mm: 3
Mortality: 4			2001-2010: 4	Community: 1	PD > 5 mm: 5

(continued)

Table 1. (continued)

Study Type	Report Type	Country	Publication Year	Coverage	Outcome[a]
		Oceania			
Prevalence: 1	Scientific paper: 1	Fiji: 1	1980-1990: 1	National: 1	CPI = 4: 1
Incidence: 0	Survey report: 0		1991-2000: 0	Subnational: 0	CAL > 6 mm: 0
Mortality: 0			2001-2010: 0	Community: 0	PD > 5 mm: 0
		Sub-Saharan Africa, East			
Prevalence: 1	Scientific paper: 1	Kenya: 1	1980-1990: 0	National: 1	CPI = 4: 1
Incidence: 0	Survey report: 0		1991-2000: 1	Subnational: 0	CAL > 6 mm: 0
Mortality: 0			2001-2010: 0	Community: 0	PD > 5 mm: 0
		Sub-Saharan Africa, Southern			
Prevalence: 1	Scientific paper: 1	Zimbabwe: 1	1980-1990: 0	National: 1	CPI = 4: 1
Incidence: 0	Survey report: 0		1991-2000: 1	Subnational: 0	CAL > 6 mm: 0
Mortality: 0			2001-2010: 0	Community: 0	PD > 5 mm: 0
		Sub-Saharan Africa, West			
Prevalence: 3	Scientific paper: 3	Niger: 1	1980-1990: 0	National: 2	CPI = 4: 3
Incidence: 0	Survey report: 0	Burkina Faso: 1	1991-2000: 2	Subnational: 1	CAL > 6 mm: 0
Mortality: 0		Sierra Leone: 1	2001-2010: 1	Community: 0	PD > 5 mm: 0

[a]CPI, Community Periodontal Index; CAL, clinical attachment loss; PD, pocket depth.
[b]One paper reported estimates for 2 countries (Ireland and Saudi Arabia).

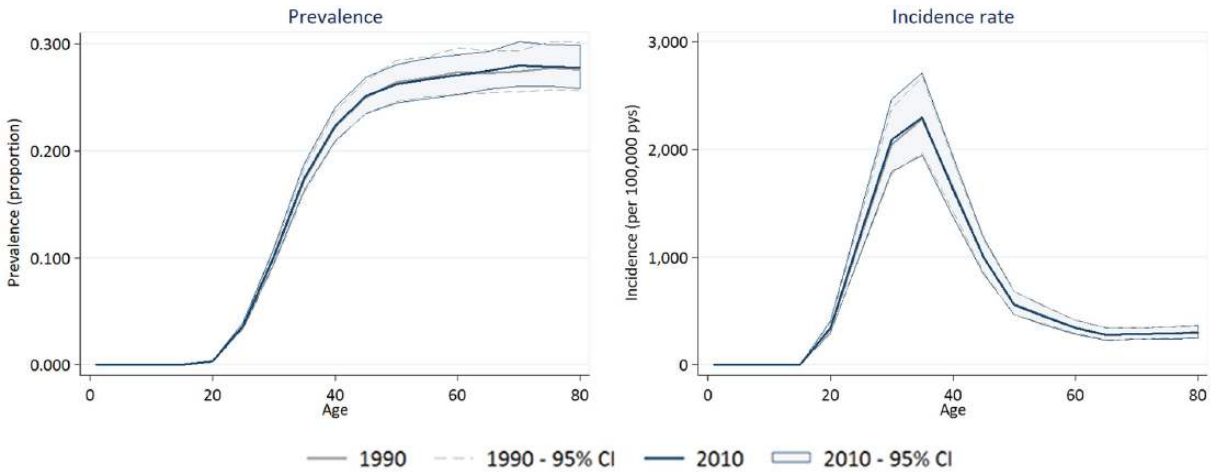

Figure 2. Prevalence (proportion) and incidence (per 100,000 person-years) of severe chronic periodontitis in 1990 (light line) and 2010 (dark line) with 95% uncertainty intervals by age.

average prevalence of 9.2% (95% CI: 8.0%-10.5%), which is within range of our estimates.

Our data provided relevant information to address a gap in the dental literature related to incidence of SP. Only 2 incidence studies met the quality criteria for this review. DisMod-MR uses data on at least 3 available variables (prevalence, remission, case fatality, duration, and cause-specific mortality) to estimate incidence; then, incidence could be calculated with such a disease model. Therefore, incidence was estimated on the basis of direct data from 2 incidence studies and indirect information from 65 studies (Appendix Table 1). Our worldwide incidence estimate of SP closely corresponds to those reported from the Dunedin multidisciplinary study (Thomson *et al.*, 2006; Thomson *et al.*, 2013), where the rate of periodontal destruction was greater between 32 and 38 yr than it was between 26 and 32 yr (Thomson *et al.*, 2013). This apparent acceleration in periodontal AL in the mid- to late 30s was consistent with our estimates of a peak in incidence around age 38 yr and the subsequent steeping increase in SP prevalence.

As was true for all GBD 2010 causes, we sought to identify all relevant and high-quality data sources for SP, but due to time and resource constraints, there may be some sources in some locations that may have been missed. However, the major challenges in reviewing the dental literature were inherent to the measuring or reporting of SP, the lack of data in certain areas of

Table 2. Age-Standardized Prevalence and Incidence Rate of Severe Chronic Periodontitis in 1990 and 2010, by World Regions

	Prevalence[a]				Incidence[b]			
Location	1990		2010		1990		2010	
Global	11.2	(10.4-11.9)	11.2	(10.5-12.0)	696	(604-808)	701	(599-823)
Asia Pacific, high income	7.9	(6.8-9.7)	8.0	(6.6-10.4)	515	(325-777)	521	(330-793)
Asia								
Central	14.2	(10.1-19.2)	13.8	(10.0-19.3)	880	(659-1171)	856	(635-1142)
East	10.4	(8.8-12.1)	10.4	(8.8-12.2)	548	(302-887)	541	(283-902)
South	10.3	(9.2-11.8)	10.2	(9.1-11.8)	681	(426-1075)	682	(420-1071)
Southeast	13.3	(11.4-15.5)	13.1	(11.3-15.1)	765	(577-1010)	751	(560-1013)
Australasia	14.6	(13.1-16.1)	14.9	(13.3-16.5)	909	(519-1496)	917	(545-1484)
Caribbean	8.8	(5.8-13.5)	8.6	(5.7-12.5)	512	(370-687)	508	(373-686)
Europe								
Central	12.0	(8.8-16.4)	12.1	(8.8-16.7)	747	(585-950)	752	(590-978)
Eastern	13.7	(8.0-23.9)	14.0	(8.0-24.0)	856	(555-1298)	850	(516-1306)
Western	9.8	(8.9-10.7)	9.4	(8.6-10.3)	653	(521-831)	628	(512-792)
Latin America								
Andean	15.1	(8.7-24.9)	15.2	(9.2-22.7)	937	(611-1386)	950	(618-1408)
Central	15.4	(9.9-23.4)	15.1	(9.6-22.4)	956	(676-1358)	934	(638-1368)
Southern	20.6	(12.4-31.5)	20.4	(12.3-31.4)	1431	(916-2211)	1427	(922-2254)
Tropical	18.0	(17.0-19.1)	18.5	(17.5-19.6)	1338	(730-2294)	1400	(750-2422)
North Africa/Middle East	10.5	(8.4-13.2)	10.4	(8.4-13.0)	593	(472-740)	586	(472-730)
North America, high income	7.2	(6.4-8.0)	7.2	(6.4-8.1)	491	(448-541)	487	(444-537)
Oceania	4.1	(2.5-7.1)	4.2	(2.4-7.2)	244	(152-385)	253	(160-393)
Sub-Saharan Africa								
Central	13.5	(7.6-22.6)	13.3	(7.7-21.5)	841	(550-1271)	814	(513-1237)
East	20.3	(15.8-26.1)	20.1	(16.1-25.0)	1390	(1100-1726)	1384	(1099-1714)
Southern	8.9	(5.1-15.1)	9.2	(5.0-15.4)	536	(327-841)	551	(342-860)
West	9.2	(6.3-14.1)	9.3	(6.6-14.0)	556	(419-765)	554	(413-753)

Values in parentheses indicate 95% uncertainty intervals.
[a]Per 100 population.
[b]Per 100,000 person-years.

the globe, and the quality of published and unpublished data. CPITN is a very popular index that has a number of limitations to assess periodontal status. Since code 4 (PD ≥ 6 mm) overrules other codes, we were confident to use it to estimate prevalence of PD of 6 mm or more. We would not advocate CPITN to assess other periodontal health indicators, such as bleeding. Also, CPITN assessment tends to use partial mouth assessments (half-mouth, index teeth, or fixed sites), which may underestimate the prevalence and severity of periodontitis. Many studies reported the study population as the number of sextants rather than the number of people affected by SP. Most did not report the number of edentulous subjects but simply excluded them altogether, which determined our post hoc adjustments. Also, we could not adjust the denominator study by study to accurately reflect the total number in each catchment area, because this level of information was not available for most of the studies included. Five regions had no data whatsoever; data were scarce in younger groups; and there was little to directly inform incidence and mortality estimates.

A new proposed gold-standard definition of SP from the American Academy of Periodontology and the Centers of Disease Control and Prevention was published in 2007 (Page and Eke, 2007). The rationale is that because PD peaks around age 40, periodontal disease in older people is systematically underestimated when only PD is measured. The converse—that AL measurement alone underestimates prevalence in younger ages—is also likely true. The combination criteria specified a more strict definition, including ≥ 2 interproximal sites with AL ≥ 6 mm and ≥ 1 interproximal site with PD ≥ 5 mm. While we agree that this represents an improvement in measuring SP, it was a recent development and is inconsistent with a majority of the data, especially from before 2005. Several definitions of periodontitis have been proposed in the past. Unfortunately, there is not a consistent assessment of periodontal health in the dental literature. After much consideration, we have adopted to have any site with CPITN = 4, clinical AL > 6 mm, or PD > 5 mm as an indicator of periodontitis. We endeavored to reflect the measures adopted by the larger community of public health dentistry. We encourage researchers in public health dentistry to publish both PD and AL by tooth per person and report the number of teeth per person and the size of the dentate population. This information would allow generating estimates based on different definitions of SP and adjustments in modeling the burden of SP. Further developments in definitions of severity of periodontitis may benefit from addressing its age and tooth dependency.

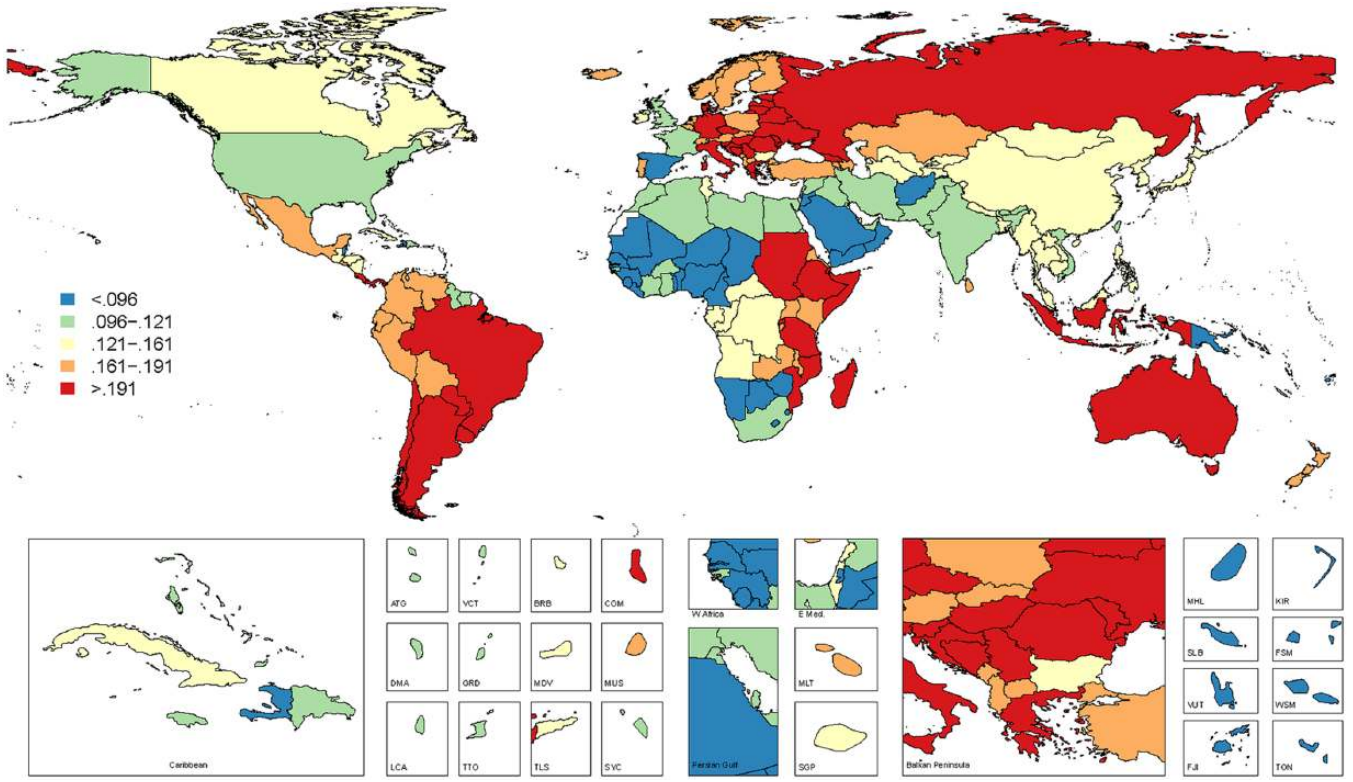

Figure 3. Age-standardized prevalence (proportion) of severe chronic periodontitis in 2010 worldwide.

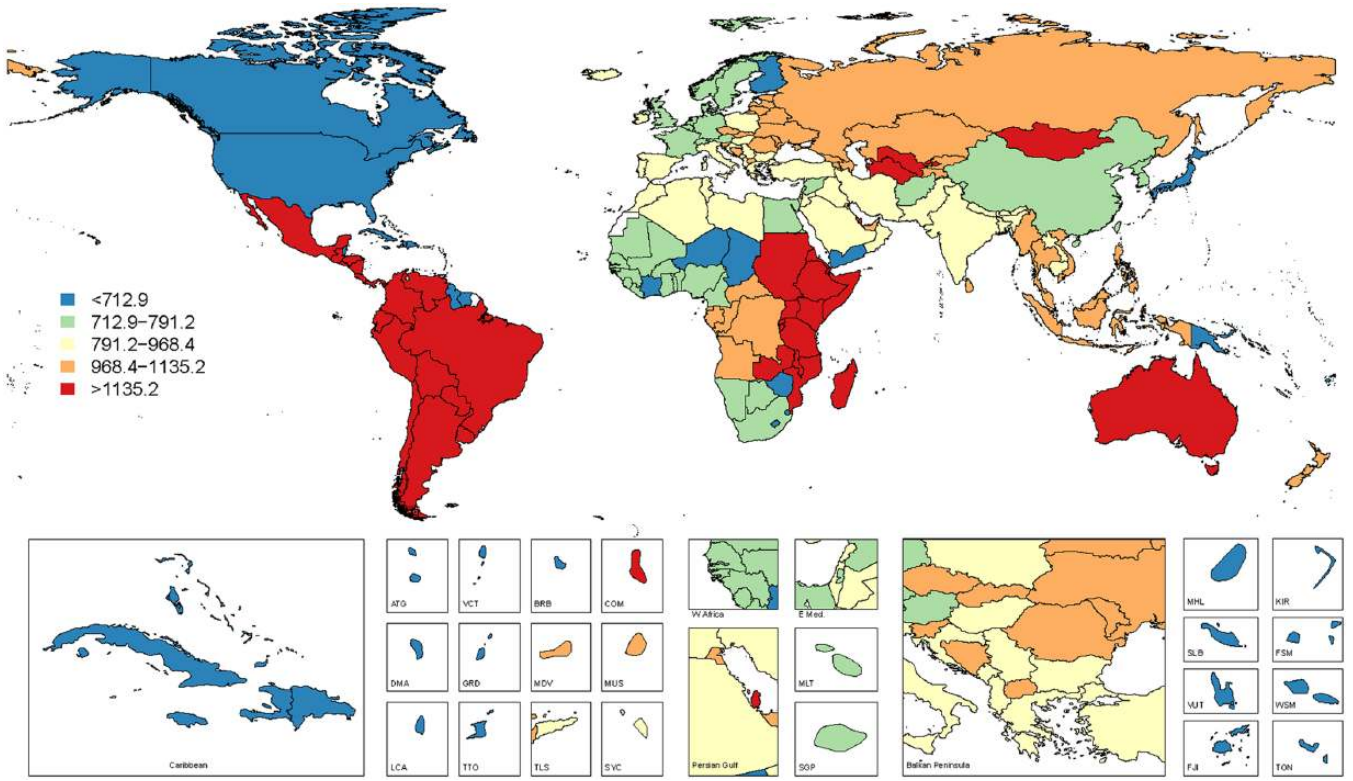

Figure 4. Age-standardized incidence (per 100,000 person-years) of severe chronic periodontitis in 2010 worldwide.

In conclusion, policy makers need to be aware of a predictable increasing burden of SP due to the growing world population associated with an increasing life expectance and a massive decrease in the prevalence of tooth loss throughout the world from 1990 to 2010 (Kassebaum *et al.*, 2014). These changes underscore the enormous public health challenge posed by SP and are a microcosm of the epidemiologic transition to noncommunicable diseases occurring in many countries.

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