Global epidemiology of dental caries and periodontitis – a comprehensive review

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Title Page

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Abstract (max 200 words)

Background: Dental caries and periodontitis are the most common oral diseases and major causes of tooth loss.
Aims: To perform a review of global prevalence and incidence of dental caries and periodontitis..
Methodology: Inclusion and exclusion criteria were developed. MEDLINE and EMBASE database were used to search for eligible publications using key words and MeSH terms. Additionally, WHO Data Bank was used for obtaining dental caries information and PUBMED for a search on trends of dental caries prevalence and severity.
Results: Over the last four decades, the prevalence and severity of dentine carious lesions among 5- and 12-year-olds have declined; the decay-component is very high, with the lowest prevalence among 12-year-olds in high-income countries, which also had the lowest prevalence among 35- to 44-year-olds; and the number of retained teeth has increased around the globe. The prevalence of periodontitis is high, with approximately 10% of the global population affected by severe periodontitis. Study heterogeneity and methodological issues hamper comparisons across studies and over time.
Conclusion: While the prevalence of dental caries has decreased the disease is prevalent in all age groups. The prevalence of periodontitis is high. There is insufficient evidence to conclude that the prevalence of periodontitis has changed over time.

Clinical relevance (max 100 words)

Scientific rationale for the study: This is a review regarding the global prevalence and incidence of dental caries and periodontitis.
Principal findings: Dental caries is the most common disease worldwide. The published evidence suggests that over the past decades, the prevalence and severity of dentine carious lesions have declined. Periodontitis is the sixth most common disease globally. There is insufficient evidence to suggest a decline in periodontitis incidence or prevalence over the past decades.
Practical implications: Caries and periodontitis continue to be major public health problems worldwide.

Introduction

During the last five decades, measures to combat dental caries and periodontitis have been developed, tested and implemented in many populations around the world and are thought to have benefitted millions of people. Despite the huge effort made, a large part of the world's population still suffers from these two oral diseases (Marcenes et al., 2013), which are the main causes of tooth loss.

The aim of the present paper is to systematically review the global epidemiology of dental caries and periodontitis and to report trends in the two oral diseases over time.

Material and Methods

A systematic literature review was performed to identify all existing systematic reviews of original research that presented epidemiological data on the prevalence and incidence of dental caries and periodontitis.

Electronic literature searches were carried out in MEDLINE via OVID and EMBASE via OVID, using keyword and MeSH-based searches. The initial searches were individually devised by four of the authors, and then combined to ensure that all possible terminology was covered. Furthermore, the search terminology of published systematic reviews already identified was scrutinised to inform the final search syntax. No set time period was implemented on the search databases.

Inclusion and Exclusion Criteria

Studies that satisfied the following inclusion criteria were selected: systematic review; describing periodontitis and/or dental caries prevalence/incidence; and presenting global epidemiological data. Publications that presented subgroups of communities (e.g. pregnant mothers, the elderly and patients with learning disabilities) were excluded as were regional or national data.

Selection of Studies

Records from both search engines were combined in EndNote X7 (2015). This resulted in 954 records, of which 785 remained after duplicates were removed. With the screening of titles and abstracts, 757 publications were found not to be relevant, which left 28 publications eligible for full-text review. Two of these publications met the inclusion criteria. The dental caries-related publication concerned a systematic review that only reported unmet treatment need for cavitated dentine carious lesions (Kassebaum et al., 2015). The periodontal-related publication concerned the global burden of periodontitis (Kassebaum et al., 2014a). A flowchart of the systematic review search is presented (Figure 1).

Additional Periodontal Search

As our review retrieved only one systematic review that included the published literature until December 2010 (Kassebaum et al., 2014a) , we conducted an additional search for surveys covering the period from January 2011 to August 2016, using the same search criteria. The same selection criteria were applied, with the exception that representative surveys of at least national level were included. The search identified 340 abstracts, of which 6 papers were retrieved as full-texts (Eke et al., 2015, Chung et al., 2011, Eke et al., 2012, Lorenzo et al., 2015, Chalub et al., 2016, White et al., 2012). One report (Eke et al., 2012) was excluded as the same data were reported in a later publication (Eke et al., 2015), and another paper was excluded as it did not report prevalence of periodontitis (Chalub et al., 2016). In addition, we included two recently published reports on national surveys in Spain (Carasol et al., 2016) and Germany (Jordan and Micheelis, 2016) .

Additional Dental Caries Search Pattern

The absence of systematic reviews regarding the prevalence of cavitated dentine carious lesions led to the World Health Organization (WHO) Data Bank at Malmö University Dental School being used for obtaining this information. The Data Bank contains dental caries-related data, covers several decades of information and is periodically updated. We used country dental caries prevalence, and dmf/DMF and d/D-component data from the recommended WHO age groups that covered the period 2000 to 2016. We related these data to the Gross National Income (2014), developed by the World Bank, according to high-, upper-middle-, lower-middle- and low-income countries. Trend studies were obtained through using the search strings “Trends AND Dental caries”, “Trends AND Caries prevalence”, “Trends AND Tooth loss” in PUBMED covering a period of at least 20 years during 1999 to 2016. The first two search strings resulted in 20 records of which 5 were duplicates. Of the 15 included records 10 were found suitable. The third search string produced 5 records of which one was suitable. Hand search found one additional suitable publication.

We used the median score for reporting the prevalence rates and the mean dmf/DMF scores of the various groups composed. A number of dental caries detection and assessment criteria were found to have been used for reported results in the studies selected. The criterion developed by the WHO was used most frequently (Organization, 1971). The data do not lend themselves to an analytical assessment.

Results

Results of systematic review

Two systematic reviews, one on periodontitis and one on caries met the inclusion criteria. These two reviews are by the same group of investigators and are part of the Global Burden of Disease (GBD) 2010 Study, the “largest systematic effort to describe the epidemiology of a wide array of major diseases, injuries, and risk factors ever undertaken” (Murray et al., 2012). Clearly, both studies undertook an exhaustive review of the literature using robust and thorough review methodology. The GBD 2010 study was designed to “systematically produce comparable estimates of the burden of 291 diseases and injuries and their

associated 1,160 sequelae from 1990 to 2010." To do so, a Bayesian meta-regression tool was specifically developed for the GBD 2010 study (Flaxman et al., 2012), which allowed disease prevalence or incidence to be estimated from each other and other disease parameters where available or by imposing disease specific limits using prior knowledge about the natural course of the disease. The model also allowed estimates to be produced for countries with sparse data. Details of this are beyond the scope of this review and can be found elsewhere (Murray et al., 2012); however, the reader should be aware that the reported prevalences and incidences are the outputs from a statistical meta-regression model, rather than estimates directly observed in the included studies or "grand means" in more traditional meta-analysis. Furthermore, the uncertainty around the resultant estimates was determined using Monte Carlo simulations, and is therefore reported as 'uncertainty intervals' (UI) rather than conventional confidence intervals.

An additional methodological commonality between the two GBD 2010 studies on caries and periodontitis was that prevalence estimates were adjusted for the prevalence of edentulism, if original studies had been restricted to dentate populations. For example, "if 40% of 70- to 74-y-old women were estimated to be edentate in a certain region, the corresponding estimates for untreated caries prevalence were reduced to 60% of the original value" (Kassebaum et al., 2015).

Global Burden of Periodontitis

For the purpose of their systematic review of the global burden of periodontitis, the authors used a pragmatic case definition of severe periodontitis, including a CPITN score of 4, a clinical attachment level (CAL) of more than 6 mm, or a probing depth (PD) of more than 5 mm. The review included a total of 72 studies in the final analysis, 65 of which reported periodontitis prevalence, 2 reported incidence and 5 reported mortality in relation to severe periodontitis. These studies included data from a total of 291,170 individuals aged 15-99 in a total of 37 countries.

On the basis of the analyses, the authors reported that, in 2010, severe periodontitis was the sixth most prevalent condition and that it affected 10.8% (95% UI: 10.1% to 11.6%) or 743 million people aged 15-99 worldwide. They reported that the age-standardised prevalence of severe periodontitis in the global population had remained static over the previous two decades at 11.2% (95% UI: 10.4% to 11.9% in 1990 and 10.5% to 12.0% in 2010) (Figure 3). Similarly, the age-standardised incidence of severe periodontitis had not changed significantly between 1990 and 2010, being 701 cases per 100,000 person-years in 2010 (95% UI: 599-823) and 696 cases per 100,000 person-years in 1990 (95% UI: 604-808). These age-standardised prevalences and incidences were similar for males and females. The prevalence of severe periodontitis increased with age, with a steep increase between the third and fourth decades of life, reaching peak prevalence at the age of 40 and remaining stable thereafter. There was a peak in incidence at age 38. Again, globally, these patterns did not change between 1990 and 2010.

The authors highlighted the variations by country and world region, with the lowest prevalence of severe periodontitis being 4.5% in Oceania in 2010 (95% UI: 2.4% to 7.2%) and the highest prevalence of severe periodontitis being 20.4% in Southern Latin America in 2010 (95% UI: 12.3%-31.4%). These regions also had the lowest and highest incidence of periodontitis in 2010 of 253 cases per 100,000 person-years (95% UI: 160 to 393) and 1,427

cases per 100,000 person-years (95% UI: 922 to 2,254). Between 1990 and 2010, there was no appreciable change in prevalence or incidence of periodontitis in any of the world's regions (Kassebaum et al., 2014a).

Findings from the additional periodontal search

A total of six reports describing national surveys in Korea, USA, Uruguay and the United Kingdom met the inclusion criteria (Table 7). The surveys used a variety of probing protocols and case definitions of periodontitis and included different age groups. Two reports present prevalence of periodontitis among dentate individuals (Eke et al., 2015, White et al., 2012), whereas this is unclear in othersreports (Chung et al., 2011, Lorenzo et al., 2015). All reports consistently show an increase in prevalence with increasing age and five of the six (Carasol et al., 2016, Eke et al., 2015, Jordan and Micheelis, 2016 , Lorenzo et al., 2015, White et al., 2012) show a markedly higher prevalence of periodontitis in males compared to females, with one paper not reporting gender-specific data (Chung et al., 2011). In the USA 2009-2012, prevalence of severe periodontitis using the CDC/AAP and EFP definitions was 8.9% and 12.0%, respectively. Due to the utilisation of full mouth recording on six sites per tooth, the reported prevalences are markedly higher than those reported in previous NHANES surveys (Eke et al., 2015). In the UK in 2009, 9% of the population 16 years and older had at least one periodontal pocket of 6mm or deeper (White et al., 2012). In Uruguay in 2010-2011, overall prevalence of severe periodontitis was estimated to be 9.1% (5.9% and 17.0% for adults aged 35-44 years and 65-74 years, respectively) (Lorenzo et al., 2015). In elderly participants in the Korean survey, aged 65 and over, the prevalence of periodontitis (defined as CPI≥3) was 82.1%. The prevalence of severe periodontitis was not reported in this publication (Chung et al., 2011). A representative survey of the Spanish population in employment conducted between 2008 and 2011 reported a prevalence of severe periodontitis (defined as CPI=4) of 10.1% (Carasol et al., 2016). A national representative survey in Germany conducted in 2014 (Jordan and Micheelis, 2016) found a prevalence of severe periodontitis among 35-44 year olds of 10.4% (CPI=4) and 8.2% (CDC/AAP definition) and among 65- 74 year olds of 24.6% (CPI=4) and 19.8% (CDC/AAP definition).

Global Burden of Untreated Cavitated Dentine Carious Lesions

The retrieved systematic review on the global burden of untreated cavitated dentine carious lesions reported on the prevalence and incidence of untreated cavitated dentine carious lesions for 187 countries, 20 age groups and both sexes between 1990 and 2010. The age-standardised prevalence of untreated dentine carious lesions in the primary dentition in the global population remained static over the two decades at about 9% (95% UI: 8.6% to 9.2% in 1990 and 8.5% to 9.1% in 2010) (Figure 2) and there was no significant change in the age-standardised incidence between 1990 (15,437 cases per 100,000 person-years, 95% UI: 14,354 to 16,589) and 2010 (15,205 cases per 100,000 person-years, 95% UI: 14,132 to 16,451). There were no significant differences between sexes and disease prevalence reached its peak at age 6, with no appreciable change in such age pattern since 1990. The global age-standardised prevalence of untreated dentine carious lesions was 35% (95% UI: 33.7% to 37.6% in 1990 and 33.7% to 37.3% in 2010) (Figure 2) and the global age-standardised incidence was 28,689 cases per 100,000 person-years in 1990 (95% UI: 27,069

to 30,381) and 27,257 cases per 100,000 person-years in 2010 (95% UI: 25,808 to 28,928). There were no significant differences between sexes and disease prevalence reached its peak at age 25, with a second peak later in life at around 70 years of age. No appreciable change in age pattern was observed from 1990.

The authors concluded that untreated cavitated dentine carious lesions in permanent teeth remained the most prevalent health condition across the globe in 2010, affecting 2.4 billion people, and that untreated cavitated dentine carious lesions in deciduous teeth constituted the 10th most prevalent health condition, affecting 621 million children worldwide (Kassebaum et al., 2015).

Findings from WHO database on dental caries epidemiology

Prevalence of Cavitated Dentine Carious Lesions and their Severity in Young Children

A small number of countries were included in the low-income group (Table 1). Cavitated dentine carious lesions are prevalent in all the countries included. The severity of cavitated dentine carious lesions (median dmft count) was low in the high-income group (2.0) compared to 3.9 and 4.1 in the upper-middle- and lower-middle-income groups respectively. The percentage of the d-component was high in all income groups.

Trends in Prevalence and Severity of Cavitated Dentine Carious Lesions in 4-, 5- and 5- to 6-Year-Olds

Table 2 shows trends in the prevalence of cavitated dentine carious lesions and mean dmft scores in five countries. In all the countries, prevalence and mean dmft figures decreased remarkably over time. Highest reduction rate in the prevalence of cavitated dentine carious lesions was reported for the UK-countries and Sweden: 46% and 45% respectively over 40 years. Dentine carious lesions are now concentrated in a minority of children.

Prevalence of Cavitated Dentine Carious Lesions and their Severity in 12-Year-Olds

The median prevalence of cavitated dentine carious lesions and median mean DMFT score were high, 69.4% and 2.1 respectively in the upper-middle-income group compared to the other three income groups (Table 3). The median percentage of the D-component was high in the low-income (100%), lower-middle-income (80%) and upper-middle-income groups (79%) compared to the high-income group (45.5%), which varied between 0.0% and 92.9% in the last-mentioned group.

Trends in Prevalence and Severity of Cavitated Dentine Carious Lesions in Adolescents and Adults

The results presented in Table 4 show a big reduction in the prevalence of cavitated dentine carious lesions and in mean DMFT scores over decades in the countries referred to irrespective of the continent they are situated in. The reduction in Poland is less pronounced

in numbers compared to the other countries and the prevalence of cavitated dentine carious lesions and severity scores in adolescents in 2012 are high in comparison to comparable results in the other countries. The number of sound teeth in 15-year-olds in the UK countries was 10 higher than among 16- to 24-year-olds 45 years' earlier (Murray et al. 2015).

Prevalence of Cavitated Dentine Carious Lesions, their Severity and Trends in Adults

A small number of countries was included in the low-income group (Table 5). The median mean DMFT score among 35- to 44-year-olds was high in the high-income group (13.5) and low in the low-income group (3.1). The mean percentage of the D-component was low (9.6%) in the high-income group and high (53.6%) in the low-income group.

The mean DS scores in the 50-, 65- and 75-year-olds was low and decreased significantly between 1983 and 2013 (Table 6). The difference in mean DS scores among 85-year-olds increased significantly between 2008 and 2013.

Trend in Number of Teeth Present among Adults

The mean number of teeth present among 50-, 60- and 70-year-olds from Sweden increased between 1973 and 2003 (Hugoson et al., 2005) from 21.5 to 26.1 among 50-year-olds and from 13.3 to 20.7 among 70-year-olds. Among 50-year-old Swedish women, the mean number of teeth increased from 14.6 in 1968/69 to 27.3 in 2004/05. The percentage of edentulous women decreased from 18.2 to 0.3 between 1968/69 and 2004/05 (Wennstrom et al., 2013).

Discussion

General

We identified one systematic review each on the global epidemiology of periodontitis and untreated cavitated dentine carious lesions, respectively. Both reviews are by the same group of authors and are part of the much larger Global Burden of Disease (GBD) 2010 study (Marcenes et al., 2013).

The findings of these systematic reviews demonstrate that untreated cavitated dentine carious lesions make up the single most common disease that affects humans worldwide. Severe periodontitis is not far behind, being the sixth most common disease globally. The reviews demonstrate that prevalence and incidence of periodontitis are highly age dependent and that there is marked geographic variation. The reviews also suggest that there are no meaningful sex differences and that the prevalence and incidence of periodontitis have stagnated over the past 20 years.

Periodontitis

The GBD 2010 study has several major strengths. It is undoubtedly based on an extremely thorough and comprehensive review of the available literature and utilised purpose-built modelling techniques to model global prevalence and incidence. Interestingly, the models derived incidence data from prevalence data and vice versa, using available data on additional disease parameters or reasonable assumptions regarding the course of disease. This approach yielded estimates of the age-dependent incidence of periodontitis, even though original incidence data on periodontitis are extremely scarce. The consistent approach across a whole range of conditions and diseases used in GBD 2010 also facilitates comparisons across the boundaries of medical disciplines. However, the model-based approach utilised is also a limitation of these reviews and at least some of the findings need to be interpreted with caution. Kassebaum et al. (Kassebaum et al., 2014a) state that their prevalence estimates compare "favorably with most country-level measurements of severe periodontitis prevalence at the population level" and note "many similarities with estimates reported in other global and mainly continental periodontal diseases reviews, which supports the external validity of findings". However, there are also some inconsistencies with the published literature, most notably perhaps the absence of a sex difference, as a recent systematic review of the sex differences found overwhelming evidence of a higher prevalence of periodontitis in men than in women (Shiau and Reynolds, 2010).

The results of the four national surveys published after the GBD 2010 study are overall consistent with the GBD 2010 results. Even though the overall prevalence estimates for severe periodontitis derived from three of the four surveys (Eke et al., 2015, Lorenzo et al., 2015, White et al., 2012) are remarkably similar at 9% in all three surveys, a closer look also highlights that comparisons across studies are at best challenging given that all three studies used different periodontal recording protocols, case definitions and surveyed different age groups.

The methodological challenges of measuring and quantifying periodontitis in epidemiologic studies are now well recognised (Dye, 2012, Garcia and Dietrich, 2012, Leroy et al., 2010). These challenges are rooted in studies' heterogeneity with regard to periodontal recording protocols (in terms of what type of periodontal probe is used, how many sites are probed and on which and how many teeth) and case definitions, i.e.~~,~~ which periodontal parameters (e.g., probing depth~~,~~ or attachment~~s~~ level) are used in what way to establish a diagnosis of periodontitis. Kassebaum et al. (Kassebaum et al., 2014a), quite reasonably, took a pragmatic 'hierarchical' approach to defining periodontitis as a CPITN score of 4, a CAL of more than 6 mm or a PD of more than 5 mm. However, issues such as number and position of sites probed were ignored. These parameters can have marked effects on estimates of periodontitis prevalence~~,~~ and their effect on the estimates derived by Kassebaum et al. (Kassebaum et al., 2014a) is unclear, although they clearly pose a challenge to comparisons across studies and the analyses of trends over time.

The excellent and detailed review by Holtfreter et al. (Holtfreter et al., 2014) of several studies that allow trend analyses demonstrates how this methodological heterogeneity makes analyses of time trends difficult if not impossible. The authors reviewed five national (England, Germany, New Zealand, USA, Greece) and five regional (Pomerania [North-East Germany], Thun [Switzerland], 's-Hertogenbosch [The Netherlands], Jönköping [Sweden], Oslo [Norway]) epidemiologic studies allowing trend analyses. Consideration was given to several methodological issues including but not limited to heterogeneity of periodontal recording protocols, non-response and examiner reliability – demonstrating inconsistencies within most of the included surveys. Another issue

highlighted by the authors is that current operationalisations of periodontitis (i.e., case definitions and extent and severity indices) do not account for changes in the number of missing teeth. However, it is recognised that given the overwhelming evidence for increased tooth retention across all age groups globally (Kassebaum et al., 2014b), a larger proportion of the population is 'at risk' of presenting with periodontal sites satisfying a diagnostic threshold. Notwithstanding these limitations, the authors found that most surveys indicated a declining prevalence of periodontitis and concluded that "reviewed studies support the assumption that periodontal disease prevalence is declining, though to a varying degree". Further analysis of data from regional (Schuetzhold et al., 2015) and recent national (Jordan and Micheelis, 2016) surveys in Germany also suggest a decline in periodontitis prevalence over recent years. In contrast, recent data from Spain do not seem to support such a decline (Carasol et al., 2016). The highest quality data on periodontitis trends arguably derives from the series of NHANES surveys conducted by the US National Center for Health Statistics (NCHS) , Beginning with NHANES III (1988-1994) and continuing with the NHANES surveys since 1999 (Albandar et al., 1999, Borrell et al., 2005, Borrell and Talih, 2012, Eke et al., 2015, Eke et al., 2012) , the NCHS have made every effort to employ consistent methodology to facilitate the analyses of trends over time (by employing a consistent minimal set of measurements on a consistent set of periodontal sites using calibrated examiners). The data suggest a marked decline in the prevalence of periodontitis in the US (Dye, 2012). Indeed, such a decline would not come as a surprise given the decline in the prevalence of cigarette smoking, arguably the strongest risk factor for periodontitis (Hujoel et al., 2003). However, the NHANES data do not support this explanation, as the prevalence has declined across all risk factor strata, findings that are difficult to reconcile (Dye, 2012). In contrast, GBD 2010 reported no meaningful change in periodontitis prevalence between 1990-2010 in any of the geographic regions, including North America. However, as noted, GBD 2010 included data from a wide variety of heterogeneous sources.

In our opinion, given the many methodological challenges, no firm conclusions with regards to a declining trend in periodontitis prevalence can be drawn at this time.

Dental Caries

Similar methodological concerns as expressed for periodontitis are relevant to the assessment of dental caries in epidemiological studies, as different indices and disease thresholds are used. A methodological limitation that affects the epidemiological study of both untreated cavitated dentine carious lesions and periodontitis is the lack of consensus about whether current disease or current and past disease experience should be measured and, a related but distinct issue, the lack of consensus regarding and statistical tools to deal with the effect of tooth loss on estimates of disease prevalence.

Kassebaum et al. (Kassebaum et al., 2015) purposively restricted their review to untreated cavitated dentine carious lesions (current disease), recognising that common dental caries assessment indices such as the DMFT index measure both present and past disease. They argue that current (untreated) cavitated dentine carious lesions are "more important for the assessment of disease burden and planning dental care services". The rationale is the assumption that treated diseases do not cause a burden. This may be a somewhat controversial proposition, in particular with regard to tooth loss, as most individuals, including dental professionals, would probably consider tooth loss a disease burden. However, tooth loss also affects the 'denominator' of many epidemiological

measures. For example, the more teeth are present, the higher the chance that at least one tooth will meet the disease threshold. This factor makes the analyses of trends more challenging in the presence of increased tooth retention over time (Kassebaum et al., 2014b).

As trend studies were not included in the GBD Study 1990-2010, a separate search on trends in dental caries prevalence and severity was performed. Despite the limited number of trend studies retrieved, those studies that were reviewed show that the prevalence of cavitated dentine carious lesions has reduced tremendously as has its severity in young children, adolescents and adults over the last 30 to 40 years. Some evidence of this trend in various continents is present. The decline is due to improved biofilm control, reduced sugar intake, increased use of fluoride, particularly in toothpaste, and an increase in regular check-ups in a number of countries. In children, the current dental caries situation can be characterised by the presence of the disease in a minority of children and adolescents (Constante et al., 2014, Murray et al., 2015).

Few trend data for the elderly population were available and those reported originated from Sweden. In the elderly population, the number of teeth in Swedes increased over many decades, resulting in most individuals older than 50 having more than 27 teeth. The increase in number of teeth over many decades corroborates the finding from a review on tooth loss in Europe that showed the number of teeth lost decreasing over the last decades before 2006 (Muller et al., 2007). This outcome is echoed in the conclusion of a systematic review and meta-analysis of this topic, which states that "a significant decline in the prevalence and incidence of severe tooth loss between 1990 and 2010 is present at the global, regional and country level" (Kassebaum et al., 2014b) and in the predicted number of edentulous people in the USA in 2050 which will be 30% lower than in 2010 (Slade et al., 2014).

The limitation of the present study lies in the incompleteness of the data in the WHO Data Bank, the few studies included for the low-income countries' group and the elderly, and in the different methodology used in the studies included. But, despite these inconsistencies, the results of the present review show that dental caries is very prevalent in young children, adolescents and in adults. Variations exist in prevalence and severity between high- and low-income countries and in the prevalence of open cavitated dentine carious lesions. The latter is less prevalent in high-income than in low- and lower-middle-income countries among adolescents and adults. Overall, the burden of untreated cavitated dentine carious lesions in the world remained static but high between 1990 and 2010 but there appears to be evidence that there is a shift in this burden from children to adults (Kassebaum et al., 2015). This observation is in line with the conclusion that levels of cavitated dentine carious lesions increase~~s~~ with age and that they remain problematic in adults (Bernabe and Sheiham, 2014). So, although dental caries has declined, because of the increase in people at old age having more teeth, the burden of dental caries has not. The Dunedin-birth cohort study (1972/73) reported, over a period of 38 years, an annual increase in number of tooth surfaces affected by cavitated dentine carious lesions of 0.8 (Broadbent et al., 2013). This finding supports the conclusion of the previously referred to study.

The WHO Data Bank does not collect data of (severe) early childhood caries. However, studies have reported high prevalence values of cavitated dentine carious lesions in the very young: 38% and 44.1% for Canadian (Schroth et al., 2015) and Thai 3-year-olds (Peltzer and Mongkolchati, 2015), respectively.

Dental caries is a life-long disease. The two main aetiological factors, management and frequency of free sugar intake, and regular removal of dental biofilm, should be taught at a young age and be applied throughout life into old age.

Conclusion

There is limited evidence from systematic reviews on the global epidemiology of caries and periodontitis. The prevalence of dental caries and severe periodontitis is high, with untreated dental caries being the most common disease affecting humans worldwide. There is evidence that the prevalence and severity of cavitated dentine carious lesions among 5- and 12-year-olds have declined over the last decades; that the decay component among these age groups is very high, with a lower prevalence among 12-year-olds and among 35- to 44-year-olds in high-income countries. There is evidence that the number of teeth present at older age has increased over the last four decades and that this may be due to fewer teeth being extracted because of dental caries.
Due to methodological heterogeneity and concerns, firm conclusions regarding the geographic variation and time trends of the incidence and prevalence of periodontitis cannot be drawn from the available evidence.

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Table 1. Median prevalence of cavitated dentine carious lesions (Prev) in 5- and 6-year-olds, median of mean dmft scores and range interval, and proportion of d-component and range interval by category of country income, using WHO Data Bank data from 2000-2015

Country income	N	Prev	range %	N	dmft median	range %	N	d-comp %	range %
Low	3	64.4	49.2-93.1	3	4.4	3.0-9.0	2	96.1	93.3- 98.9
Lower-middle	12	83.4	64.0-88.6	16	4.1	1.4-8.0	9	96.4	91.3-100
Upper-middle	13	76.4	53.4-93.2	15	3.9	2.4-6.7	11	88.0	78.6- 97.3
High	33	49.0	21.0-93.4	33	2.0	0.3-6.7	22	75.0	33.3-100

N=Number of countries

Table 2. Trends in the prevalence of cavitated dentine carious lesions and in mean dmft scores in 4-, 5- and 5- to 6-year-olds over decades in a number of countries

Country Period	Age yrs	Prevalence %	dmft mean
South Africa (Cleaton-Jones and Fatti, 2009)	5-6		
1947		88	6.7
2002		57	3.1
Sweden (Stecksen-Blicks et al., 2008)	4		
1967		83	4.0
2007		38	3.4
UK (Murray et al., 2015)	5		
1973		72	4.0 (dft)
2013		26	0.7
China (Zhang et al., 2016)	5		
1987-1994		80	-
2010-2013		56	-
Czech Republic (Lencova et al., 2012)			
1994	5	76	3.5
2006		58	2.7

Table 3. Median prevalence of cavitated dentine carious lesions (Prev) in 12-year-olds, median of mean DMFT scores and range interval, and median proportion of D-component and range interval by category of country income, using WHO Data Bank data from 2000-2015

Country income	N	Prev %	range %	N	DMFT median	range %	N	D-comp %	range median %
Low	5	42.2	19.1-97.3	9	0.9	0.3-5.5	3	100	
Lower-middle	15	41.9	22.4-75.7	21	1.4	0.4-4.5	13	80.0	66.6-100
Upper-middle	20	69.4	37.0-87.0	27	2.1	1.1-4.9	16	79.0	36.4-94.1
High	36	46.6	22.3-84.0	44	1.3	0.4-4.8	27	45.5	0.0-92.9

N=Number of countries

Table 4. Trends in the prevalence of cavitated dentine carious lesions and in mean DMFT scores in adolescents, young adults and 35- to 44-year-olds, and number of sound teeth over decades in a number of countries

Country Period	Prevalence %	DMFT mean	Prevalence %	DMFT mean
South Africa (Cleaton-Jones and Fatti, 2009)	*11-13 (yrs) (urban)*		*14-17 (yrs) (urban)*	
1977	70	4.4	95	7.5
2002	37	1.5	50	2.0
Brazil (Constante et al., 2014)	*12-13 (yrs)*			
1971	98	9.2		
2011	37	0.7		
Norway (Haugejorden and Birkeland, 2006)	*12 (yrs)*			
1985	81	3.4		
2004	60	1.7		
UK (Murray et al., 2015)	*15 (yrs)*		*N sound teeth*	
1968			16.3 (16-24-yr olds)	
1973	97	8.4		
2013	42	1.2	26.6 (15 yrs)	

Poland (Gaszynska et al., 2014)	*12 (yrs)*		*35-44 (yrs)*	
1978	98	6.3	25.0	
2012	84	3.5	17.0	

The Netherlands (Schuller et al., 2014)	*9 (yrs)*		*14 (yrs)*		*20 (yrs)*	
Low SES	Prev	DMFS	Prev	DMFS	Prev	DMFS
1990	28	3.0	67	6.3	94	14.7
2009	23	2.5	51	4.1	74	7.7
High SES						
1990	26	2.9	75	3.1	94	9.4
2009	15	1.8	38	3.5	70	6.7

Americas (Beltran-Aguilar et al., 1999)	*North*	*Central and Caribbean*	*South (12 yrs)*
	Median mean DMFT (range)		
1970s	4.4 (2.6-5.3)	5.1 (4.8-5.6)	5.8 (1.2-8.6)
1990s	1.6 (1.4-1.8)	2.9 (1.1-4.9)	3.1 (1.3-4.7)

Table 5. Median mean DMFT scores and range interval among 35- to 44-year olds, proportion of D-component and range interval by category of country income, using WHO Data Bank data from 2000-2015

Country income	N	DMFT median	range	N	D-comp median	range %
Low	3	3.1	2.9-4.7	2	53.6	45.1-62.0
Lower-middle	6	7.5	2.6-14.6	5	39.7	24.0-54.0
Upper-middle	8	11.4	6.0-14.8	7	17.9	13.3-52.6
High	20	13.5	6.8-20.0	16	9.6	3.4-27.9

N=Number of countries

Table 6. Trend in mean DS score by different ages and year of investigation (Edman et al., 2016)

	Age (yrs)			
Year investigation	50 DS (SD)	65 DS (SD)	75 DS (SD)	85 DS (SD)
1983	2.0 (3.1)	2.1 (3.0)	1.9 (3.3)	
2008				1.2 (2.4)
2013	1.1 (3.3)	1.2 (3.2)	0.9 (2.4)	2.4 (8.0)

SD=Standard Deviation

Table 7: Findings from additional search of periodontal literature (2011-2016)

Authors	Year published	Country	Survey	Time period	Age	Probing protocol	Case definition of periodontitis	Overall and by gender prevalence of periodontitis
Chung, et al.	2011	Korea	Korean National Oral Health Survey (KNOHS) 2006	2006	65 years and older	Ten teeth were examined #17, #16, #11, #26, #27, #37, #36, #31, #46 and #47	Good periodontal condition: CPI scores <3 Poor periodontal condition: CPI scores ≥ 3	82.1% had poor periodontal condition
White, et al.	2012	U.K.	Adult Dental Health Survey (ADHS) 2009	2009	16 years and older	Two interproximal sites per tooth (lingually on mandibular and buccally on maxillary teeth). Worst probing depth per sextant was recorded according to the following categories: Score 1: 0-3.5mm Score 2: 4-5.5mm Score 3: 6-8.5mm Score 4: ≥ 9mm A single tooth in a sextant, was not recorded and the tooth was included in the adjacent sextant	Composite measure of periodontal health: no bleeding on probing, no calculus, no periodontal pocketing of 4 mm or more and, for adults aged 55 years and over, no loss of periodontal attachment of 4 mm or more.	Periodontally healthy tissues 17% Females:19% Males: 14% Pocketing>=4mm: 45% Pocketing >=6mm: 9%

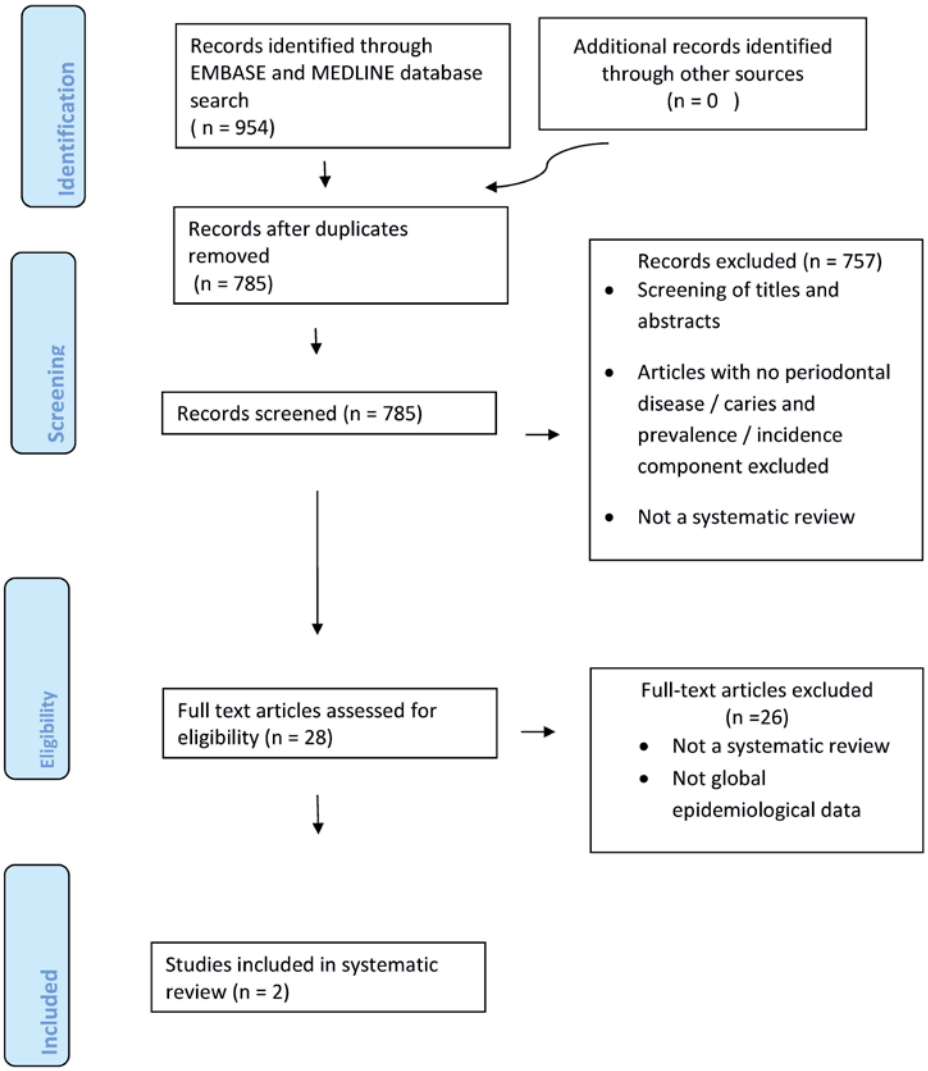
						In addition, bleeding on probing and presence of calculus were recorded per sextant.		
Eke, et al.	2015	USA	National Health and Nutrition Examination Survey (NHANES) 2009-2010 and NHANES 2011-2012	2009-2012	30 years and over	Six sites per tooth, all teeth excluding third molars	CDC/AAP classification *Severe periodontitis*: two or more interproximal sites with ≥ 6 mm CAL (not on the same tooth) AND one or more interproximal site(s) with ≥ 5mm PPD. *Other periodontitis*, Moderate: two or more interproximal sites with ≥ 4 mm clinical CAL (not on the same tooth) OR two or more interproximal sites with PPD ≥ 5 mm, not on the same tooth.	CDC/AAP case definition: Total prevalence 45.9% ±1.6% (S.E) Severe periodontitis 8.9% ± 0.6% (S.E.) Other Periodontitis 37.1% ± 1.5% (S.E.) *Females*: Total prevalence 37.4% ±1.8% Severe periodontitis 4.7% ± 0.5% (S.E.) Other Periodontitis 32.7% ± 1.7% (S.E.) *Males*: Total prevalence 54.9% ±1.6% Severe periodontitis 13.3% ±0.9 (S.E.) Other Periodontitis 41.6% ± 1.7% (S.E.)

							Mild: ≥ 2 interproximal sites with ≥ 3mm CAL and ≥ 2 interproximal sites with ≥ 4mm PPD (not on the same tooth) or 1 site with ≥ 5mm. EFP classification: Severe Periodontitis: proximal attachment loss of ≥5 mm in ≥30% of teeth present Incipient periodontitis: proximal attachment loss of≥3 mm in ≥2 non-adjacent teeth	EFP case definition: Severe periodontitis 12.0% ± 0.7% (S.E.) Incipient Periodontitis 65.8% ± 1.0% (S.E.) *Females*: Severe periodontitis 7.6% ± 0.6% (S.E.) Incipient Periodontitis 63.6% ± 1.1% (S.E.) *Males*: Severe periodontitis 16.5% ±0.9 (S.E.) Incipient Periodontitis 68.1% ± 1.3% (S.E.)
Lorenzo, et al.	2015	Uruguay	National Oral Health Survey	2010-2011	35-44 years	Index teeth in each sextant were probed at 6 sites	Periodontal disease was defined as: (i)	Total prevalence of periodontal disease: 21.8% (95%CI:17.9-26.3)

					and 65-74 years		moderate to severe when PPD ≥ 4mm and CAL ≥ 4mm); (ii) severe when PPD ≥ 4mm and CAL ≥ 6mm).	Prevalence of severe periodontitis: 9.12% (95%CI: 6.8-12.1%) *Females*: Total: 12.9% (95%CI: 9.7-17.0%) Severe periodontitis: 6.5% (95%CI: 4.5-9.4%) *Males*: Total: 30.1% (95%CI: 23.8-38.2%) Severe periodontitis: 11.7% (95%CI: 7.8-17.2%)
Carasol et al.	2016	Spain	Workers' Oral Health Study	2008-2011	All adult ages	Ten index teeth were probed at 6 sites	Worst CPI scores and worst CAL reported	Total prevalence of: CPI≥3: 38.4% (*Males*: 43.2%, *Females*: 31.6%) CPI=4: 10.1% (*Males*: 12.8%, *Females*: 6.3%) CAL≥4mm: 21.4% (*Males*: 25.5%, *Females*: 15.9%) CAL≥6mm: 7.7% (*Males*: 10.2%, *Females*: 4.3%)
Jordan & Micheelis	2016	Germany	Fifth German Oral Health Study	2013-2014	35-44 years and	Twelve index teeth were probed at 6 sites, 10% random	CDC/AAP definition of severe periodontitis	35-44 year olds: CPI≥3: 58.7% CPI=4: 10.4%

			(DMS V)		65-74 years	subsample received full-mouth probing	CPI≥3, CPI=4	Severe periodontitis (CDC/AAP): 8.2% 65-74 year olds: CPI≥3: 75.4% CPI=4: 24.6% Severe periodontitis (CDC/AAP): 19.8%

Figure 1. Flowchart of the systematic review search



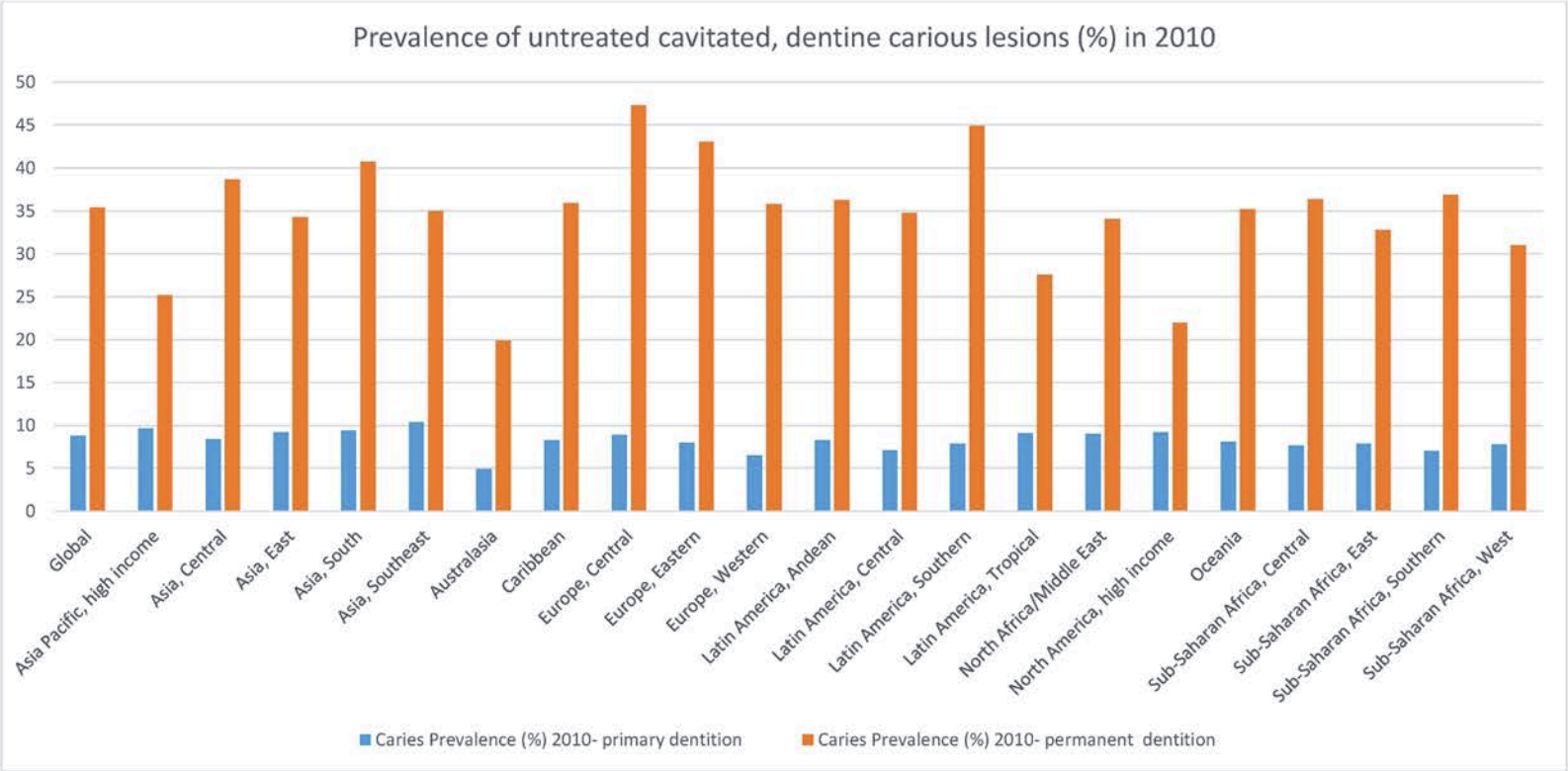


Figure 2: Prevalence of untreated cavitated, dentine carious lesions (%), by region in 2010, in primary and permanent dentition (data from (Kassebaum et al., 2015))

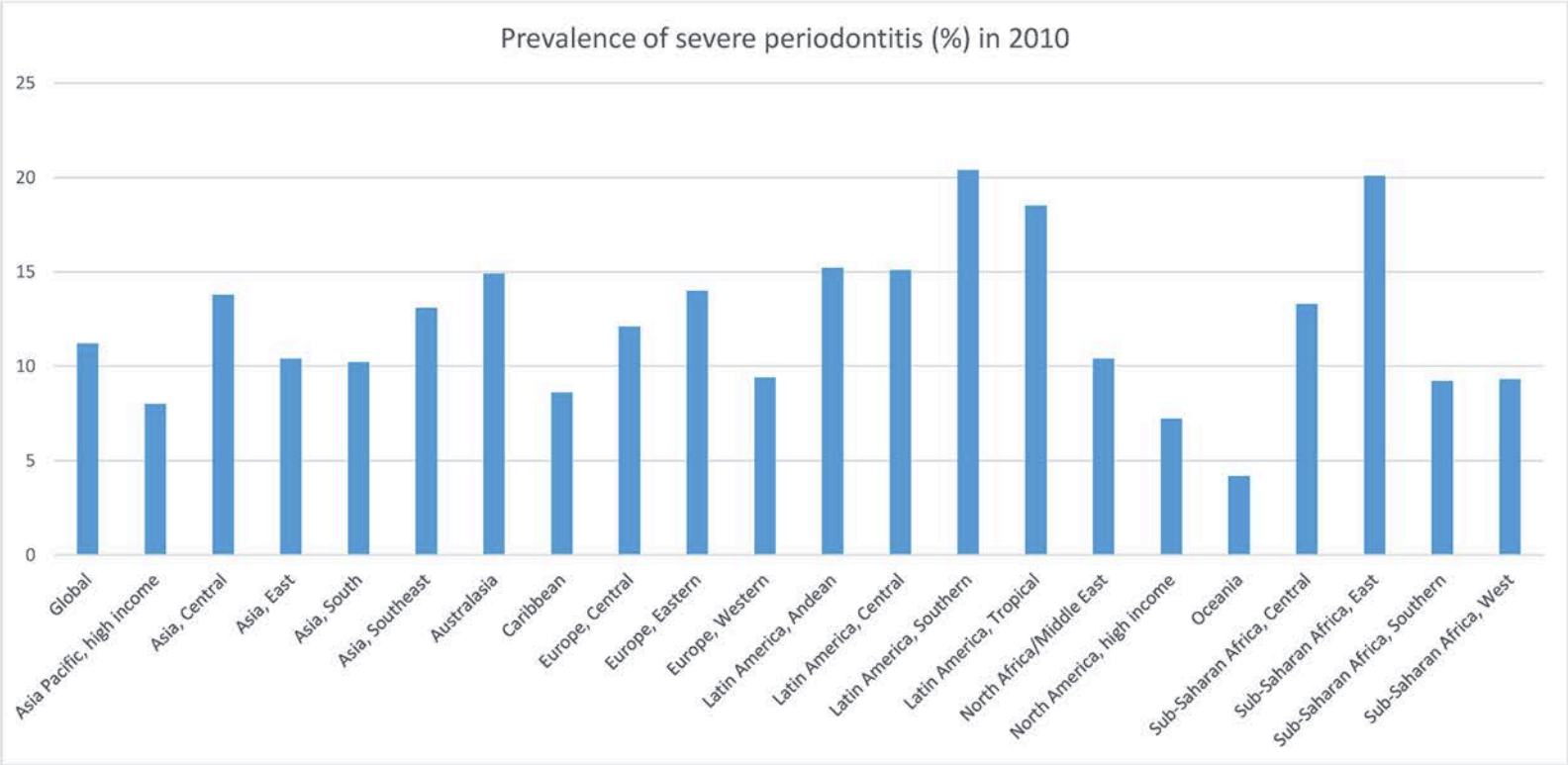


Figure 3: Prevalence of severe periodontitis (%) by region in 2010 (data from (Kassebaum et al., 2014a))