Introduction

Chronic periodontitis is a bacterially induced inflammatory disease of the soft and hard tissues which support the tooth root [1]. It is caused by an accumulation of dental plaque, organized as a biofilm on the surface of the tooth crown and root [2], which leads to the destruction of periodontal connective tissue and alveolar bone; without treatment this results in tooth loss. Periodontitis may have long term consequences for health by increasing the risk of type 2 diabetes (T2D) [3], obesity [4], metabolic syndrome [5], cardiovascular diseases (CVD) and pulmonary diseases [6–8], adverse pregnancy outcomes [9], and premature mortality [8]. The condition is common, affecting up to 20% of the adult population in industrialised countries [10].

Chronic periodontitis is a multifactorial disease. However, the contribution of the different risk factors/indicators associated with the disease remains unclear. In addition to a role for oral hygiene, age, cigarette smoking [11] and T2D [3] in the aetiology of this disorder, a further risk factor may be poor social circumstances. There are good prima facie reasons to anticipate a relationship between low socio-economic status and chronic periodontitis, not least the strong link between socio-economic status and various health behaviours including smoking and diet [12]. Socio-economic adversity is also related to higher rates of a range of other important chronic diseases, including CVD [13] selected cancers [14], and mental illness [15].

Socio-economic status is typically characterised by income, occupational prestige, and educational achievement. Of these, educational attainment influences risk of periodontitis in adults aged 35+ years in the general population. The authors have declared that no competing interests exist. 

Conclusions: In the studies reviewed, low educational attainment was associated with an increased risk of periodontitis. Although this evidence should be cautiously interpreted due to methodological problems in selected studies, efforts to eliminate educational inequalities in periodontitis should focus on early life interventions.

Abstract

Background: The impact of socioeconomic inequalities on health is well-documented. Despite the links of periodontal disease with cardiovascular diseases, adverse pregnancy outcomes and diabetes, no meta-analysis of socioeconomic variations in periodontal disease exists. This meta-analytic review was conducted to determine the extent to which education attainment influences risk of periodontitis in adults aged 35+ years in the general population.

Methods: The authors searched studies published until November 2010 using EMBASE and MEDLINE databases. References listed were then scrutinised, our own files were checked, and, finally, we contacted experts in the field. The authors included only general population-based studies conducted in adults aged 35 years and more. All articles were blind reviewed by two investigators. In the case of disagreement, a third investigator arbitrated. Using PRISMA statement, two reviewers independently extracted papers of interest.

Results: Relative to the higher education group, people with low education attainment experience a greater risk of periodontitis (OR: 1.86 [1.66–2.10]; p<0.00001). The association was partially attenuated after adjustment for covariates (OR: 1.55 [1.30–1.86]; p<0.00001). Sensitivity analyses showed that methods used to assess periodontitis, definition of cases, study country and categorization of education are largely responsible for the heterogeneity between studies. No significant bias of publication was shown using both the Egger (p = 0.16) and rank correlation tests (p = 0.35).

Conclusions: In the studies reviewed, low educational attainment was associated with an increased risk of periodontitis. Although this evidence should be cautiously interpreted due to methodological problems in selected studies, efforts to eliminate educational inequalities in periodontitis should focus on early life interventions.
Inclusion Criteria

Identification of Studies

Following the PRISMA statement [19], we performed a systematic review of all published observational studies conducted in individuals aged 35 and older, which investigated the association between level of education and risk of periodontitis. (Table S1)

Two independent reviewers trained in online article searches (AB and BEH) searched English language papers published before November 2010. We used a four-pronged approach to identifying papers. First, the MEDLINE and EMBASE searches were conducted using the MeSH and EMTREE. For MEDLINE, we used the following strategy: (“Periodontal diseases” [MeSH] OR “periodontitis” [MeSH] OR “chronic periodontitis” [MeSH] OR “periodontal attachment loss” [MeSH] OR “periodontal pocket” [MeSH] OR “alveolar bone loss” [MeSH]) AND (“education” [MeSH] OR “educational status” [MeSH] OR “marital status” [MeSH] OR “occupations” [MeSH] OR “income” [MeSH] OR “socioeconomic factors” [MeSH] OR “social class” [MeSH]). Limits: Human, English. For EMBASE, search strategy was: (“periodontal disease” [EMTREE] OR “periodontitis” [EMTREE] OR “chronic periodontitis” [EMTREE] OR “periodontal pocket” [EMTREE] OR “alveolar bone loss” [EMTREE]) AND (“education” [EMTREE] OR “educational status” [EMTREE] OR “marital status” [EMTREE] OR “occupation” [EMTREE] OR “income” [EMTREE] OR “socioeconomics” [EMTREE] OR “social status” [EMTREE]). Limits: Human, English. Second, references listed in articles of interest were scrutinised. Third, we checked our own files. Fourth, we contacted selected experts in the field.

Inclusion Criteria

We included all observational studies conducted in adults aged 35+ years in the general population with 1) case definition of periodontitis (probing or radiographic assessment, self-reported data) [Text S1], 2) a variable describing the level of education, 3) a quantitative assessment of the relationship between these two variables. Studies conducted in non-representative populations (e.g. samples of attendees in dental settings) were excluded to maximise external validity. When more than one report used the same data, studies resulting in lowest power were excluded except when prospective data were available. In the case of disagreement, the two investigators discussed the article and tried to find agreement. When consensus was not reached, a third investigator (P.B.) was involved until agreement was found.

Data Abstraction

Two investigators (AB, BEH) independently extracted and tabulated basic information on each study: design, country where the study was conducted, sample size, number of cases, age range, definition of chronic periodontitis, partial or full-mouth recording, categories of level of education. Crude odds ratios (OR), or the data to compute them when crude estimates were unavailable, were also identified and extracted. Adjusted effect measures, including the covariates features in the multivariable model, were tabulated.

Data Analysis

We transformed OR by taking their natural logarithms and calculating standard errors and corresponding confidence intervals [20]. Effects measures and their standard errors were pooled using an inverse variance method with random effects to account for statistical heterogeneity between studies. We calculated pooled OR and accompanying 95% confidence interval (95% CI) for the lowest versus the highest categories of education. Heterogeneity was assessed with the I² statistic [21]. We carried out sensitivity analyses based on study design (longitudinal versus cross-sectional studies), year of publication (≤2000 versus >2000), region where the study was conducted (US versus non-US countries), sample size (≤1000 versus >1000), age (≥35 versus older) (≥65), periodontal assessment method (partial-mouth versus full-mouth recording), definition of cases (combined clinical attachment loss (CAL) and periodontal probing depth (PPD) versus single probing measurement), number of categories of education (2 versus >2).

Significance was set at p<0.05 and 95% CI were quoted throughout [18]. The Kappa statistic was used to assess interrater reliability between the two independent reviewers [22]. Publication bias was assessed by visually examining a funnel plot with asymmetry being formally assessed with both the Egger test [23] and the rank correlation test [24]. The data were analysed using Review Manager (RevMan, version 5.0, The Cochrane Collaboration, 2008). Bias of publication was measured using CMA (Comprehensive Meta Analysis, version 2.2.0.55, Biostat, 2010).

Results

Study characteristics

The electronic search yielded 6048 publications, including 1288 duplicates. From the 4760 potentially relevant articles identified, 4528 were excluded. Among the 232 remaining papers, hand-searching of references was performed, resulting in 35 additional papers. From the 267 eligible articles, 249 were excluded resulting in 18 studies, which met all the inclusion criteria and were included in the analyses (Figure 1) [25–42]. The kappa coefficient between examiners was 0.78 (0.75–0.80) demonstrating a substantial agreement [43]. Characteristics of the included studies are presented in Table 1–3. The combined population resulted in 40783 participants. Only two studies were longitudinal [31–32]. The included studies were performed in the following countries (n = 10): Australia, Brazil, Canada, Denmark, Iran, Norway, Sweden, USA, Taiwan, and Thailand. Crude effect estimates were computed in ten studies [27,29–31,33,34,37,39,41–42]. Eight studies met criteria of inclusion, but were excluded because they were conducted in duplicate surveys [44–51].

Four out of 18 studies did not use full-mouth clinical examination [29,35,37,41]. Only six studies, exhibiting a quite different level of adjustment, gave adjusted effect measures [26,29,32,35,38,40]. Two studies were performed on samples of male [28,41]; whereas two other studies were performed on samples of female [30,39]. One study has separated the outcomes...
Figure 1. Flow chart for identifying eligible studies.
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| Study name                  | Study size (of interest/original) | Age (yrs) | Study design | Outcome (No of cases in education groups of interest/Total No of cases) | Comparison groups for education | Variables in multiple adjustment |
|-----------------------------|----------------------------------|-----------|--------------|-----------------------------------------------------------------------|--------------------------------|----------------------------------|
| Beck et al. 1990, USA [25]. | 689/689                           | ≥65       | CS           | At least 4 sites with CAL ≥ 5 mm with at least one of those sites with PPD ≥ 4 mm. n = 224/224. | < versus ≥ 12 years of education. | None.                            |
| Borrell et al. 2006, USA [26]. | 3,240/5,677                      | ≥52       | CS           | At least two sites with CAL ≥ 6 mm and at least 1 site with PPD ≥ 5 mm. n = 545/963. | < High School versus College. | Age, gender, center, neighborhood socio-economic score, income. |
| Dietrich et al. 2006, USA [28]. | 462/469                           | 47-92     | CS           | At least one tooth with CAL and PPD ≥ 5 mm. n = 86/86. | ≤ versus > High School. | None.                            |
| Dye et al. 2009, USA [29].   | 4,014/5,747                       | ≥40       | CS           | At least one tooth with CAL ≥ 3 mm and PPD ≥ 4 mm. n = 843/1,063. | < High School versus College. | Age, gender, smoking, race, diabetes, periodontal pathogens. |
| Famili et al. 2005, USA [30]. | 188/202                           | ≥65       | CS           | More than 12 teeth with CAL ≥ 4 mm. n = 151/163. | ≤ versus > 16 years of education. | None.                            |
| Phipps et al. 2009, USA [41]. | 672/1210                          | ≥65       | CS           | 30% or more of teeth examined with CAL ≥ 5 mm. n = 248/463. | ≤ High School versus Graduate School | None.                            |

CAL: Clinical Attachment Loss; CPITN: Community Periodontal Index of Treatment Needs; CS: Cross-Sectional; L: Longitudinal; PPD: Periodontal Pocket Depth; t0: Baseline data; Un: Unknown.
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Table 2. Characteristics of selected non-US cross-sectional studies in a meta-analysis of education level and chronic periodontitis.

| Study name                      | Study size (of interest/original) | Age (yrs) | Study design | Outcome (No of cases in education groups of interest/Total No of cases) | Comparison groups for education | Variables in multiple adjustment |
|--------------------------------|-----------------------------------|-----------|--------------|------------------------------------------------------------------------|-------------------------------|---------------------------------|
| Brennan et al. 2007, Australia  | 709/709                           | 45–54     | CS           | 2 or more sites with CAL≥5 mm and one or more sites with PPD≥4 mm, n = 139/139 | Primary, Secondary, Certificate versus Diploma or degree | None.                           |
| Hessari et al. 2007, Iran       | 2,764/7,949                       | 35–44     | CS           | At least one sextant with CPITN score 4 (PPD>5.5 mm). Men: n = 136/457. Women: n = 158/360. | Illiterate versus any university education. | None.                           |
| Krustrup et al. 2006, Denmark   | 386/1052                          | 35–44; 65–74 | CS          | At least one tooth with CAL≥6 mm. n = 22/50. | ≤10 versus ≥15 years of education. | None.                           |
| Lai et al. 2007, Taiwan         | 4,347/8,462                       | 35–44     | CS           | CPITN score 4 (PPD>5.5 mm). n = Un/414. | ≤ Junior High School versus College. | None.                           |
| Locker et al. 1993, Canada      | 624/624                           | ≥50       | CS           | Mean CAL≥3.83. n = Un. | ≤ versus >High School. | None.                           |
| Mucci et al. 2004, Sweden       | 14,736/26,690                     | ≥42       | CS           | Self-reported. Diagnosed by a dentist to have periodontal disease or ever had tooth mobility. n = 2,956/5,527. | Elementary versus University | None.                           |
| Nicolau et al. 2007, Brazil     | 224/224                           | 39,01 (4,70) | CS          | More than 42% of teeth with loss of attachment. n = 90/90. | ≤ versus >4 years of education. | Age, smoking, plaque, emotional support, conditions during childhood. |
| Paulander et al. 2004, Sweden   | 549/549                           | 50; 55    | CS           | Highest 20% of the CAL distribution (mean CAL: 2.4–7.1). n = 110/110. | ≤ versus >7 years of education. | None.                           |
| Peres et al. 2007, Brazil       | 6,086/11,342                      | 35–44     | CS           | At least one site with PPD≥4 mm and at least one site with CAL≥4 mm. n = 542/1,018. | ≤4 versus ≥12 years of education. | Age, gender, race, income.      |
| Torrungruang et al. 2009, Thailand | 453/453                        | 39–59     | CS           | 3 or more sites with PPD≥5 mm. n = 164/164. | ≤ versus >High School. | None.                           |

CAL: Clinical Attachment Loss; CPITN: Community Periodontal Index of Treatment Needs; CS: Cross-Sectional; L: Longitudinal; PPD: Periodontal Pocket Depth; t0: Baseline data; Un: unknown.
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Table 3. Characteristics of selected longitudinal studies in a meta-analysis of education level and chronic periodontitis.

| Study name                      | Study size (of interest/original) | Age (yrs) | Study design | Outcome (No of cases in education groups of interest/Total No of cases) | Comparison groups for education | Variables in multiple adjustment |
|--------------------------------|-----------------------------------|-----------|--------------|------------------------------------------------------------------------|-------------------------------|---------------------------------|
| Gilbert et al. 2005, USA        | 559/560                           | ≥45       | L            | At least one site with a 48-month worst attachment level 3 mm or more than the baseline worst attachment level on that same tooth. n = 133/123. | < versus ≥High School. | None.                           |
| Hansen et al. 1993, Norway      | 81/81                             | 35 (10)   | L            | Increased in the number of C-scored quadrants (PTNS) from 1973 to 1988 (at least one site with PPD>5 mm). N = 16/16. | ≤ versus >10 years of education. | Missing teeth, last dental visit, oral preventive behaviours, socioeconomic proxies, social class. |

CAL: Clinical Attachment Loss; CPITN: Community Periodontal Index of Treatment Needs; CS: Cross-Sectional; L: Longitudinal; PPD: Periodontal Pocket Depth; t0: Baseline data; Un: unknown.
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Summary estimates

The summary estimates of OR for each study were pooled to give a total estimate of risk (Figure 2). The overall OR (95% CI) for chronic periodontitis was 1.86 (1.66 to 2.10), indicating an increased risk of periodontitis associated with a low level of education when compared with the highest level of education. The effect size among studies showed a moderate to substantial heterogeneity (I² = 55%).

for each gender [33]. Cases were defined by a combination of CAL and PPD conditions in six studies [25–29,40]; by a single CAL criterion in seven studies [30,31,34,36,38,39,41]; by CPITN score (Community Periodontal Index of Treatment Needs) in two studies [33,35]; and by self-reported assessment in one study (for more informations about periodontal indices, see supplemental material) [36]. No study with radiographic assessment met criteria of inclusion.
Secondary analyses

Results of the primary analysis were not changed in the sensitivity analysis (Table 4). Two exceptions were the alternative meta-analysis including longitudinal studies and those conducted before year 2000, which enhanced the overall odds ratio (respectively 2.11 (1.22 to 3.63) and 2.57 (1.87 to 3.53)). Within the sensitivity analyses, we examined also various variables as potential sources of heterogeneity. There was evidence of significant heterogeneity across studies that may be explained by geographical differences (Non US: $I^2 = 42\%$ versus US: $I^2 = 68\%$), the extent of the clinical assessment (partial-mouth ($I^2 = 89\%$) versus full-mouth ($I^2 = 22\%$)), and the definition of cases (clinical attachment loss and periodontal probing pocket combined ($I^2 = 74\%$) versus probing pocket depth solely ($I^2 = 0\%$)). Other sources of heterogeneity have to be interpreted with caution because of the differences in the number of studies in each category. The sensitivity analyses with one by one exclusions showed that one study had a significantly effect on heterogeneity (Data not shown) [29]. When excluded, heterogeneity between studies was nearly non significant (p = 0.04, $I^2 = 39\%$).

When pooling studies with adjusted estimates, results were unchanged (OR = 1.55 (1.30 to 1.86); p < 0.00001) but low heterogeneity between studies was found (p = 0.04, $I^2 = 38\%$) (Figure 3). On the contrary, pooling crude estimates for same studies conducted to both an higher heterogeneity ($I^2 = 77\%$) and a higher risk estimate (OR = 1.88 (1.46 to 2.42)) (Data not shown). Funnel plot showed no asymmetry. No significant bias was shown using both the Egger (p = 0.16) and rank correlation tests (p = 0.35).

Discussion

Principal finding

The present analysis of studies conducted in the general population of adults reveals that individuals with a low level of education have an excess risk of chronic periodontitis when compared with adults with high level of education.

A number of mechanisms may explain this effect. Indirect mechanisms include the link between education and the two main risk factors for chronic periodontitis: smoking [52] and diabetes type 2 [53]. Lower educational attainment, which is a close correlate of IQ, may also directly lead to poorer coping strategies [54], higher BMI [55], lower levels of dental services use [56], low degree of periodontal health awareness [57], and irregular oral self-care practices [58], that in themselves are linked to poor oral hygiene habits may lead to higher levels of dental plaque [59]. Only one study which met our criteria of inclusion showed a significant decrease of the risk to develop chronic periodontitis in the low educated subgroup after adjustment for oral health behaviors [32].

Theories in social epidemiology could also explain such an association. The “pathway model” suggests circumstances in early-life influence social trajectories into and through adulthood, so increasing chronic disease risk [60]. Moreover, low education level is likely to lead to low prestige and low pay occupations, and residing in deprived area. The impact of environmental conditions on periodontal health has been widely described such that individuals living in a neighborhood in the most socially
Table 4. Results of sensitivity analyses to investigate differences between studies included in the meta-analysis (random-effects model).

| Included studies | No of studies | OR  | 95% CI | Residual heterogeneity (I²) |
|------------------|---------------|-----|--------|----------------------------|
| Study design     |               |     |        |                            |
| Longitudinal     | 2             | 2.11* | 1.22, 3.63 | 17%                        |
| Cross-sectional  | 16            | 1.85*** | 1.64, 2.09 | 58%                        |
| Baseline data    |               |     |        |                            |
| ≥2000            | 3             | 2.57*** | 1.87, 3.53 | 0%                         |
| >2000            | 15            | 1.79*** | 1.58, 2.03 | 61%                        |
| Study region     |               |     |        |                            |
| US               | 6             | 1.89*** | 1.51, 2.37 | 68%                        |
| Non US           | 12            | 1.83*** | 1.58, 2.11 | 42%                        |
| Sample size      |               |     |        |                            |
| ≤1000            | 12            | 1.78*** | 1.49, 2.12 | 31%                        |
| >1000            | 6             | 1.94*** | 1.65, 2.27 | 70%                        |
| Age (years)      |               |     |        |                            |
| No limitation    | 15            | 1.85*** | 1.62, 2.10 | 60%                        |
| Olders only (≥65) | 3             | 1.98**  | 1.41, 2.78 | 29%                        |
| Oral examination |               |     |        |                            |
| Partial-mouth    | 3             | 1.85*  | 1.18, 2.91 | 89%                        |
| Full-mouth       | 14            | 1.81*** | 1.59, 2.06 | 22%                        |
| Periodontal      |               |     |        |                            |
| CAL and PPD      | 6             | 1.93*** | 1.52, 2.46 | 74%                        |
| CAL or PPD       | 11            | 1.70*** | 1.49, 1.94 | 0%                         |
| N of classes for education | | | | |
| 2                | 10            | 1.81*** | 1.46, 2.24 | 42%                        |
| 2                | 8             | 1.91*** | 1.66, 2.20 | 63%                        |

*P<0.01.  **P<0.001.  ***P<0.0001.
Higher level of education as reference. Random-effects model and inverse variance method.
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Figure 3. Results of primary meta-analysis: adjusted risk of periodontal diseases for individuals with low education. Legend: Higher level of education as reference. Weights for individual studies calculated with random effects models and inverse variance method. The centre of each black square is placed at the point estimate, the area of the square is proportional to the sample size, and each horizontal line shows the 95% confidence interval for the estimate for each study. Pooled OR (95% CI): 1.55 (1.30–1.86), p<0.00001.
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Education as a Predictor of Chronic Periodontitis

Marginalised areas experience twice the risk of periodontitis relative to those in the most affluent [61].

Exploration for heterogeneity

The pooled OR should be interpreted with caution, given the substantial heterogeneity detected between studies. Sensitivity analyses showed that several factors seem to account for this heterogeneity, including the region where the study was conducted, the extent of oral examination, the definition of cases and the number of categories for education level assessment. Taken together these factors might help us to improve our understanding of circumstances under which education interacts with periodontal health. In addition, the heterogeneity indicates that efforts should be made to adopt a standardised methodological approach when studying the association between periodontal diseases and socioeconomic factors.

Partial-mouth examinations may underestimate the prevalence of periodontal diseases [62,63]. Additionally, methods used in partial-mouth examination are numerous. Both result in a lower heterogeneity between studies when excluding studies with partial-mouth examination. For same reasons, exclusion of studies using both CAL and PPD to define periodontitis results in a low heterogeneity between studies. As an illustration, the heterogeneity between studies became non-significant when we conducted a one-study removed sensitivity analysis excluding Dye study ($I^2 = 39\%$) [29]. In this cross-sectional study using data from NHANES III survey, cases of periodontitis were defined as a combination of clinical attachment loss and probing pocket depth criteria after a full-mouth examination.

The impact of education on periodontal status does not seem the same according to the geographic area. Heterogeneity was higher for US studies than for studies conducted in other countries. One explanation might be that the US studies were not focused on same spatial units, several using census data, whereas others were conducted in counties or neighbourhoods.

Heterogeneity could also be due to differences in the classification of education attainment. In the sensitivity analyses, we compared studies with two classes of education with other studies. When only studies separating education level into two classes were included in the analysis, a lower heterogeneity was found. This may be due to the method we used. We compared individuals from extreme categories of education attainment. Including studies with more than two classes of education; we excluded all individuals with an intermediate level of education. Further, the classification of education attainment differs between studies. Some authors use corresponding diploma; other authors use years of schooling to categorize the level of education. Both resulted in a higher heterogeneity between studies with more than two classes of education.

Pooling of studies with adjusted estimates showed a decrease in heterogeneity between studies. Confounders such as race, diabetes or smoking are a source of heterogeneity between studies, and no adjustment result in an overestimated association between education and chronic periodontitis [18].

Strengths and limitations

The present study has limitations inherent to meta-analyses. First, the results should be interpreted with caution and should not be considered as causal evidence because all studies were observational and most cross-sectional. Only two prospective studies met our criteria of inclusion [31–32]. Thus, associations are suggestive at best.

Secondly, there was significant heterogeneity between the included studies so overall conclusions must be regarded with caution. When we carried out sensitivity analyses to investigate possible sources of heterogeneity the results highlight a call for standardisation when studying social epidemiology in periodontal health, in particular concerning definition of cases. However, exclusion of only one study [29] resulted in a decrease of heterogeneity between studies, which became non significant ($p = 0.04$). Then, only six studies gave adjusted results for confounders [26,29,32,33,38,40], and two studies were adjusted for smoking [29,35], whereas it was described as a confounding factor [18].

Finally, because the physiopathology mechanisms for aggressive periodontitis differ from those involved in the development of chronic periodontitis [64] a priori, we elected not to include studies which captured the former outcome. This may have caused us to misclassify as unaffected some individuals with localized periodontitis. This is likely to have diluted the overall strength of the education-periodontal disease association.

However, our study has several strengths. It is the first, to our knowledge, including such a number of individuals (more than 40000), which quantifies the association between education attainment and periodontal diseases. The analysis is centred on chronic periodontitis, which is the most common form of periodontitis in adults. A previous systematic review has already shown a higher prevalence of periodontitis in a low socioeconomic group but the effect was not quantified [18]. The reason why no meta-analysis was performed in the above study maybe due [1] to the wide range of age (≥19 year-old) that may include different diagnosis such as aggressive and chronic periodontitis, [2] to the difficulty to evaluate the socio-economic level in younger populations, and [3] to the low number of studies available when this review was conducted (our Medline search identified a nearly 60% increase in the number of studies from April 2004 to November 2010). Our search was conducted on multiple databases, and references listed in retrieved articles were adequately scrutinised according to the standards guidelines for systematic reviews. Finally, both Egger and rank correlation tests showed no significant bias of publication.

Conclusions and implications

Results from our meta-analysis support the growing body of evidence of a socioeconomic gradient in oral health. The impact is first clinical to identify at-risk patients and adopt preventive attitudes for them, such as motivation to institute healthy behaviours (smoking cessation, oral hygiene instruction, regular dental visits...). This socioeconomic gradient in periodontal health may also have several implications for public health. The association between periodontal disease and other diseases that may compromise health condition emphasises the need to identify at-risk populations. This would permit to target public health actions aiming to prevent periodontal diseases. Identifying socioeconomic at-risk populations for oral diseases enhances the effectiveness of preventive campaigns by focusing interventions, adopting specific strategies and obtaining active participation of target populations. Moreover, because of the relationships between chronic periodontitis and various risk factors/indicators for chronic periodontitis, educational attainment appears as a main target in preventing the development of chronic periodontitis. Finally, because of the relationships between chronic periodontitis and numerous systemic conditions, such approaches may lead to the reduction of the morbidity for other chronic diseases and, as a consequence, to decrease the overall healthcare costs.

To conclude, the effect of low education attainment on higher risk of periodontal diseases has a series of potential mechanisms.
References

1. Darveau RP (2010) Periodontitis: a polymicrobial disruption of host homeostasis. Nat Rev Microbiol 8(7): 481–90.

2. Kolenbrander PE, Palmer RJ, Jr., Periasamy S, Jakobovics NS (2010) Oral multispecies biofilm development and the key role of cell-cell distance. Nat Rev Microbiol 8(7): 471–90.

3. Taylor GW (2010) Bidirectional interrelationships between diabetes and periodontal diseases: an epidemiologic perspective. Ann Periodontol 16(1): 99–112.

4. Claffie B, Weston S (2010) Association Between Chronic Periodontal Disease and Obesity: A Systematic Review and Meta-Analysis. J Periodontol 81(12): 1708–24.

5. D’Aunto F, Sabbah W, Netuveli G, Donos N, Hingorani AD, et al. (2008) Association of the metabolic syndrome with severe periodontis in a large U.S. population-based study. J Clin Endocrinol Metab 93(10): 3898–94.

6. Tonetti MS, D’Ainto F, Nabila L, Donald A, Story C, et al. (2007) Treatment of periodontal disease and chronic obstructive pulmonary disease. Ann Periodontol 12(1): 7–11.

7. Li Q, Chalmers J, Czernichow S, Neal B, Taylor BA, et al. (2010) Oral disease and subsequent cardiovascular disease in people with type 2 diabetes: a prospective cohort study based on the Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified-Release Controlled Evaluation (ADVANCE) trial. Diabetologia 53(11): 2320–7.

8. Wimmer G, Flühsmann B (2008) A critical assessment of adverse pregnancy outcome and periodontal disease. J Clin Periodontol 35(8 Suppl): 393–97.

9. Gilbert GH, Shelou BJ, Freier MA (2000) Forty-eight-month periodontal attachment loss incidence in a population-based cohort study: Role of baseline status, incident tooth loss, and specific behavioral factors. J Periodontol 71(7): 1161–70.

10. Dye BA, Herrera-Abreu M, Erichsen JM, Erikson HM (1995) Changes in periodontal treatment needs: A follow-up study of Oslo citizens from the ages of 35 to 50 years. J Periodontal Res 30(6): 410–7.

11. Hessari H, Vehkalahti MM, Eghbal MJ, Murtomaa HT (2007) Oral health among 35- to 65-year-old Iranians. Med Princ Pract 16: 800–9.

12. Dye BA, Herrera-Abreu M, Vlachojannis C, Pikhokkensen L, et al. (2009) Serum antibodies to periodontal bacteria as diagnostic markers of periodontitis. J Periodontol 80(4): 534–47.

13. Lai H, Lo MT, Wang PE, Wang TT, Chen TH, et al. (2005) Forty-eight-month periodontal attachment loss incidence and subsequent cardiovascular disease in people with type 2 diabetes: a prospective cohort study based on the Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified-Release Controlled Evaluation (ADVANCE) trial. Diabetologia 48(11): 1943–9.

14. Gilbert GH, Shelou BJ, Freier MA (2000) Forty-eight-month periodontal attachment loss incidence in a population-based cohort study: Role of baseline status, incident tooth loss, and specific behavioral factors. J Periodontol 71(7): 1161–70.

15. Hansen BF, Bjertness E, Eriksen HM (1995) Changes in periodontal treatment needs: A follow-up study of Oslo citizens from the ages of 35 to 50 years. J Periodontal Res 30(6): 410–7.

16. Borrell LN, Beck JD, Hess G (2006) Socioeconomic disadvantage and periodontal disease: The National dental aerosolus risk in communities study. Am J Public Health 96(2): 332–9.

17. Bretan DS, Spencer AJ, Roberts-Thomson KF (2007) Periodontal disease among 45–54-year-olds in Adelaide, South Australia. Aust Dent J 52(1): 53–60.

18. Pihlstrom BL, Kornman KS, Van Dyke T, Garcia RJ (2006) Gingivitis susceptibility and its relation to periodontitis in men. J Dent Res 85(12): 1134–7.

19. Dye BA, Herrera-Abreu M, Leresche-Schim J, Vlachojannis C, Pikhokkensen L, et al. (2009) Serum antibodies to periodontal bacteria as diagnostic markers of periodontitis. J Periodontol 80(4): 534–47.
47. Hansen BF, Bjertness E, Gjermo P (1990) Changes in periodontal disease indicators in 35-year-old Oslo citizens from 1973 to 1984. J Clin Periodontol 17(4): 249–54.
48. Hansen BF, Bjertness E, Gronnesby JK (1993) A socio-ecologic model for periodontal diseases. J Clin Periodontol 20(3): 584–90.
49. Hessari H, Vehkalahti M, Eghbal M, Murtomaa H, Hessari H, et al. (2009) Lifetime exposure to smoking and oral health among 35- to 44-year-old Iranians. Oral Health Prev Dent 7(1): 61–8.
50. Torrinsuang K, Tasmailom S, Rojanasomsith K, Sudhibhisal S, Nisapakultorn K, et al. (2005) Risk indicators of periodontal disease in older Thai adults. J Periodontol 76(4): 538–65.
51. Tsai C, Hayes G, Taylor GW (2002) Glycemic control of type 2 diabetes and severe periodontal disease in the US adult population. Community Dent Oral Epidemiol 30(3): 182–92.
52. Huisman M, Van Lenthe FJ, Giskes K, Kamphuis CB, Brug J, et al. (2011) Explaining socio-economic inequalities in daily smoking: a social-ecological approach. Eur J Public Health. In press.
53. Kavanagh A, Bentley RJ, Turrell G, Shaw J, Dunstan D, et al. (2010) Socioeconomic position, gender, health behaviours and biomarkers of cardiovascular disease and diabetes. Soc Sci Med 71: 1150–60.
54. Christensen U, Schmidt L, Kriegbaum M, Hougaard CO, Holstein BE (2006) Coping with unemployment: does educational attainment make any difference? Scand J Public Health 34: 363–70.
55. Molarsis A, Seidell JC, van S, Tuomilehto J, Kuulasmaa K (2000) Educational level, relative body weight, and changes in their association over 10 years: an international perspective from the WHO MONICA Project. Ann J Public Health 90: 1260–68.
56. Lang IA, Gibbs SJ, Steel N, Melzer D (2008) Neighbourhood deprivation and dental service use: a cross-sectional analysis of older people in England. J Public Health 30: 472–78.
57. Alsodai HA, Al-Jundi SH (2005) Periodontal disease awareness among pregnant women and its relationship with socio-demographic variables. Int J Dent Hyg 3: 74–82.
58. Petersen PE, Alekseejuniene J, Christensen LB, Eriksen HM, Kalo I (2000) Oral health behavior and attitudes of adults in Lithuania. Acta Odontol Scand 38: 243–48.
59. Zini A, Sgan-Cohen HD, Marcenes W (2011) Socio-economic position, smoking, and plaque: a pathway to severe chronic periodontitis. J Clin Periodontol 38: 229–35.
60. Graham H (2002) Building an inter-disciplinary science of health inequalities: the example of life-course research. Soc Sci Med 55: 2005–16.
61. Borrell LN, Bart BA, Warren RC, Neighbors HW (2006) The role of individual and neighborhood social factors on periodontitis: the third National Health and Nutrition Examination Survey. J Periodontol 77: 444–53.
62. Eaton KA, Duffy S, Griffiths GS, Gihurstoe MS, Johnson NW (2001) The influence of partial and full-mouth recordings on estimates of prevalence and extent of lifetime cumulative attachment loss: a study in a population of young male military recruits. J Periodontol 72(2): 140–5.
63. Borges-Yanez SA, Maupome G, Jimenez-Garcia G (2004) Validity and reliability of partial examination to assess severe periodontitis. J Clin Periodontol 31(2): 112–8.
64. Lang N, Bartold PM, Cuillimau M, Jeffcoat M, Bombelli A, et al. (1999) Consensus Report: Aggressive Periodontitis. Ann Periodontol 4: 53.