Oral health, academic performance, and school absenteeism in children and adolescents

A systematic review and meta-analysis

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ABSTRACT

Background. The authors conducted a systematic review and meta-analysis to provide a summary estimate of the association between oral health and academic performance.

Types of Studies Reviewed. The authors conducted a systematic search of PubMed, Embase, and Google Scholar for studies on oral health, school absence, and academic achievement published in English from January 1945 through December 2017. Exposures included subjectively or objectively measured caries, oral pain, and periodontitis. Outcomes included school absence and school achievement.

Results. The authors screened a total of 2,041 studies, from which they extracted data from 14 studies of 139,989 children (12 cross-sectional studies, 1 case-control study, and 1 longitudinal study). Five studies had school absence as the primary outcome, and 7 studies had student achievement as the primary outcome. Three studies included both outcomes. The authors found no studies for periodontitis. The average modified Newcastle-Ottawa Scale score was 3.93. The authors rated 10 studies as having a low risk of bias and 4 as having a high risk of bias. Qualitative synthesis suggested that poor oral health may have negative effects on student absenteeism and achievement, but study quality was highly variable. Results from meta-analyses indicated that poor oral health was significantly associated with increased odds of poor academic performance (pooled odds ratio, 1.52; 95% confidence interval, 1.20 to 1.83) and absenteeism (pooled odds ratio, 1.43; 95% confidence interval, 1.24 to 1.63).

Conclusions and Practical Implications. Increased focus on the broader implications of improvements in oral health for children, such as educational or socioemotional development, is of further interest to practicing dentists owing to the greater connection between oral health and general health. The authors of this study found that caries or tooth pain had a negative association with academic achievement and school absenteeism. However, study quality was limited by inconsistent exposure and outcome definitions and a predominance of cross-sectional designs. Thus, causal conclusions are not supported.

Key Words. Oral health; caries; periodontitis; education; academic performance; absenteeism; child; adolescent; meta-analysis.
local and systemic factors, such as plaque or malnutrition. Although the overall prevalence of periodontitis among adolescents in the United States is less than 1%, the burden of disease is higher in other countries. Furthermore, a 2002 review indicated that the US prevalence of prepubertal periodontitis ranged from less than 1% through 27% in case reports, and the prevalence was higher in black children.

In addition to infection and pain, poor oral health can have long-lasting, detrimental effects on school attendance and academic performance. Conceptually, children with unmet dental needs may be absent owing to oral pain or to visit a dentist for treatment and may have difficulty paying attention in class. Preliminary evidence suggests that children with caries identify emotional impacts from dental pain and negative esthetic aspects to be primary mechanisms through which caries negatively affects quality of life. Overall, the burden of chronic illness can result in increased absenteeism and, later, reductions in performance. A number of studies corroborate the impact of dental health on absenteeism. Although the existing epidemiologic literature on oral health and student achievement is limited, results are largely consistent: research data show that children with poor oral health have reduced academic performance and pain-associated school absence is negatively associated with achievement.

Demonstrating a consistent relationship between oral health and educational outcomes could lead to greater investment in dental interventions and support the evaluation of academic success in existing school-based dental programs. Thus, our purpose in this study was to conduct a systematic review and meta-analysis of the published literature on the potential association between oral health, school attendance, and academic performance in children aged 5 through 18 years.

METHODS

Data sources and eligibility
We included any cohort, case-control, or cross-sectional study of children or adolescents (aged 5 through 18 years) that included measures of caries, periodontitis, or gingivitis (“poor oral health”) as exposures and academic achievement, school absence, or both, as outcomes from January 1945 through December 2017. We purposefully selected the January 1945 start date to coincide with the onset of community water fluoridation in the United States. We did not exclude randomized clinical trials in search strategies, but they were not applicable to the research question. We defined oral health as objectively measured presence of caries through clinical evaluation of decayed, missing, and filled teeth (DMFT) or periodontitis or as subjectively reported presence of dental problems, including caries, tooth pain, or periodontitis, by child or parent. To be comprehensive in measuring caries, we left the indices for caries assessment included in search strategies undefined so as to include any measure of caries (for example, DMFT index, decayed or filled surfaces in permanent teeth, decayed or filled surfaces in primary teeth, untreated caries, and International Caries Detection and Assessment System). We defined academic performance objectively by means of grade point average or other standardized methods such as standardized tests or by means of subjective child or parent perception of school performance obtained through questionnaires. We defined school attendance by means of objective attendance registers or subjective parent questionnaires that assessed whether there had been missed school days owing to dental illness. We defined terms in search strategies for educational outcomes broadly (for example, achievement, measurement, absenteeism, academic performance), and this resulted in a wide range of potential outcomes including passing grades, average school performance, and number of missed school days, and missed school and poor performance self-reported by teachers, parents, and students.

We identified studies using PubMed and Embase via controlled-language searches and Education Resources Information Center and Cumulative Index to Nursing and Allied Health Literature via natural-language searches (see supplementary data available online at the end of this article for specific electronic search strategies). In addition, we searched Google Scholar using natural language. We conducted a final hand search of potential articles using references cited in an existing nonsystematic review that were not captured through our search strategy. There were no language restrictions when we conducted the database searches; however, we included only articles published in English in the systematic review. We created a flow diagram for study identification using the recommended approaches from the Preferred Reporting Items for
Systematic Reviews and Meta-Analyses guidelines. Database search terms included combinations of oral health (for example, caries, periodontal diseases, gingivitis), population (for example, child, adolescent, pediatrics), and educational (for example, students, educational measurement, academic achievement) key words.

Data extraction and assessment of quality
We extracted data from each identified study using a modified version of a standardized form (obtained from the Cochrane Effective Practice and Organization of Care group). Captured data included design, geographic location, year of study, sample size, participant information, outcome measures, exposure type, and results. Specific data items extracted by category are provided in the supplemental data, available online at the end of this article. Two trained investigators (S.S.R., A.T.) independently extracted the data. Disagreements were resolved by a third reviewer (R.R.R.).

We assessed the quality of included studies using a modified version of the Newcastle-Ottawa Scale (NOS) for nonrandomized studies. Quality domains included representativeness of participants (exposed), selection of control participants (nonexposed), sample size, comparability of the included groups based on design or analysis, and ascertainment of oral health, and assessment of school performance and absenteeism. Studies were considered to be at low risk of bias (≥ 4 points) or high risk of bias (< 4 points). Owing to the low number of studies used in quantitative syntheses, we conducted no subgroup analyses of bias scores, but we did assess the risk of bias across studies using funnel plots from meta-analyses.
<table>
<thead>
<tr>
<th>STUDY</th>
<th>STUDY DESIGN</th>
<th>COUNTRY</th>
<th>PARTICIPANTS, NO.</th>
<th>AGE OR GRADE LEVELS</th>
<th>EXPOSURE</th>
<th>OUTCOME</th>
<th>RESULTS</th>
<th>NEWCASTLE-OTTAWA SCALE SCORE</th>
<th>RISK OF BIAS</th>
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<tbody>
<tr>
<td>Petridou and Colleagues, 1996</td>
<td>Cross-sectional</td>
<td>Greece</td>
<td>380</td>
<td>12-17 years</td>
<td>Clinically evaluated DMFT* and DMFS†</td>
<td>School performance: objectively measured grades on a 10-grade scale</td>
<td>Children performing better by 1 grade (10-grade range) had a lower prevalence of DMFT by 0.2 ($P = .02$) and DMFS by 0.6 ($P &lt; .001$)</td>
<td>3 High</td>
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<tr>
<td>Jiang and Colleagues, 2005</td>
<td>Cross-sectional</td>
<td>China</td>
<td>2,662</td>
<td>11, 13, 15 years</td>
<td>Subjectively measured dental health status reported by adolescents</td>
<td>School performance: subjectively measured performance in school</td>
<td>Compared with children who were high performing, low school performance was associated with reduced self-reported dental health (OR, 0.65; $P &lt; .01$)</td>
<td>3 High</td>
<td></td>
</tr>
<tr>
<td>David and Colleagues, 2006</td>
<td>Cross-sectional</td>
<td>India</td>
<td>838</td>
<td>12 years</td>
<td>Clinically evaluated DMFT and Oral Hygiene Index-Simplified</td>
<td>School performance: subjectively measured child report of teacher perceptions of performance</td>
<td>Children with poor oral health had increased odds of poor school performance (OR, 2.5; 95% CI, 1.6 to 3.8)</td>
<td>3 High</td>
<td></td>
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<tr>
<td>Pongpichit and Colleagues, 2008</td>
<td>Longitudinal</td>
<td>Thailand</td>
<td>1,211</td>
<td>Grade 5 (9-13 years)</td>
<td>Subjectively measured oral pain using parent questionnaires</td>
<td>Absenteeism: objectively measured school attendance records</td>
<td>Children were recorded as having missed 159 hours of school owing to dental reasons (117 for dental appointments, 42 for oral pain)</td>
<td>4 Low</td>
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<tr>
<td>Jurgensen and Colleagues, 2009</td>
<td>Cross-sectional</td>
<td>Laos</td>
<td>621</td>
<td>12 years</td>
<td>Clinically evaluated caries (using DMFT), caries prevalence, and toothache</td>
<td>Absenteeism: subjectively reported number of missed school days in previous 12 months</td>
<td>Mean caries index score was 2.6 for children reporting missing school several times ($P &lt; .001$) compared with peers (mean decay index score was 2.0 for 1 missed day, 0.2 for no missed days)</td>
<td>4 Low</td>
<td></td>
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<tr>
<td>Guarnizo-Herreno and Wehby, 2012</td>
<td>Cross-sectional</td>
<td>United States</td>
<td>46,750</td>
<td>6-17 years</td>
<td>Subjectively measured dental health status reported by parents</td>
<td>Both outcomes: subjectively measured parent survey (National Survey of Children’s Health)</td>
<td>Children with dental problems were more likely to have problems at school (OR, 1.52; 95% CI, 1.37 to 1.72), more likely to miss school (OR, 1.42; 95% CI, 1.23 to 1.64), and were less likely to complete homework (OR, 0.76; 95% CI, 0.68 to 0.85)</td>
<td>4 Low</td>
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<tr>
<td>Piovesan and Colleagues, 2012</td>
<td>Cross-sectional</td>
<td>Brazil</td>
<td>312</td>
<td>12 years</td>
<td>Clinically evaluated dental caries</td>
<td>Both outcomes: objectively measured performance on language examinations and number of school absences from school registers</td>
<td>Compared with children with DMFT = 0, those with DMFT &gt; 0 had lower performance on language examinations by 2.2 points ($P = .33$) and missed an average of 1.5 more school days ($P = .09$). Both were not significant</td>
<td>4 Low</td>
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* DMFT: Decayed, missing, and filled teeth. † DMFS: Decayed, missing, and filled surfaces. ‡ OR: Odds ratio. § CI: Confidence interval. § GPA: Grade point average.
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<th>STUDY</th>
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<tr>
<td>Seirawan and Colleagues, 2012</td>
<td>Cross-sectional</td>
<td>United States</td>
<td>1,495</td>
<td>Elementary, high school</td>
<td>Clinically evaluated dental caries and subjective parent survey of child dental pain</td>
<td>Both outcomes: objectively measured school attendance and GPA</td>
<td>For objective dental caries, no significant association with school absence (OR, 1.5; 95% CI, 0.9 to 2.7) or GPA (OR, 1.1; 95% CI, 0.7 to 1.8). For subjective dental pain, effects were significant for absences (OR, 5.7; 95% CI, 3.5 to 9.3) and GPA (OR, 3.7; 95% CI, 1.8 to 7.6)</td>
<td>4</td>
<td>Low</td>
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<tr>
<td>Krisdapong and Colleagues, 2013</td>
<td>Cross-sectional</td>
<td>Thailand</td>
<td>1,874</td>
<td>12, 15 years</td>
<td>Clinically evaluated DMFT, severe caries, and toothache</td>
<td>Absenteeism: subjectively measured questionnaire on school absence</td>
<td>For children aged 12 years and 15 years separately, severe caries was not associated with absences in adjusted models (adjusted OR, 1.7; 95% CI, 0.8 to 3.7) and (adjusted OR, 2.5; 95% CI, 0.9 to 6.8, respectively)</td>
<td>4</td>
<td>Low</td>
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<tr>
<td>Detty and Oza-Frank, 2014</td>
<td>Cross-sectional</td>
<td>United States</td>
<td>16,022</td>
<td>3rd grade</td>
<td>Clinically evaluated untreated caries</td>
<td>School performance: objectively measured school-level performance</td>
<td>Prevalence of untreated caries at the school-level was significantly associated with lower school performance (mean score, 0.065 lower; ( P = .088 ))</td>
<td>5</td>
<td>Low</td>
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<tr>
<td>Agaku and Colleagues, 2015</td>
<td>Cross-sectional</td>
<td>United States</td>
<td>65,680</td>
<td>6-17 years</td>
<td>Subjectively measured presence of an unmet dental need</td>
<td>Absenteeism: subjectively measured questionnaire on school absenteeism</td>
<td>Mean number of days of school absence, 0.25 higher (95% CI, 0.16 to 0.34) among students with unmet need due to dental condition compared to those with no unmet need</td>
<td>4</td>
<td>Low</td>
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<tr>
<td>de Paula and Colleagues, 2015</td>
<td>Cross-sectional</td>
<td>Brazil</td>
<td>515</td>
<td>12 years</td>
<td>Clinically evaluated DMFT</td>
<td>School performance: objectively measured whether child did or did not pass the current grade</td>
<td>Children with poor oral health had increased odds of poor school performance (OR, 5.19; 95% CI, 2.16 to 12.47)</td>
<td>5</td>
<td>Low</td>
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<tr>
<td>Paula and Colleagues, 2016</td>
<td>Case Control</td>
<td>Brazil</td>
<td>1,149</td>
<td>8-10 years</td>
<td>Clinically evaluated carious lesions without treatment</td>
<td>School performance: objectively measured final participant performance, averaged across classrooms (participants: final participant scores [for example, math] below the student average; control participants: above the mean); no matching performed</td>
<td>Children with untreated carious lesions had below-average school performance (OR, 1.51; 95% CI, 1.17 to 1.96)</td>
<td>5</td>
<td>Low</td>
</tr>
<tr>
<td>Shaikh and Colleagues, 2016</td>
<td>Cross-sectional</td>
<td>Saudi Arabia</td>
<td>480</td>
<td>16-18 years</td>
<td>Subjectively measured dental pain</td>
<td>Absenteeism: objectively measured school attendance records</td>
<td>Overall prevalence of absenteeism due to tooth pain was 19%; most instances of absenteeism (55%) resulted in 2 or more days of school lost</td>
<td>3</td>
<td>High</td>
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Data synthesis and analysis
We calculated risk estimates of oral health on academic performance and absenteeism by means of pooling study-specific estimates using random-effects meta-analysis (DerSimonian and Laird method) to account for between-study heterogeneity. Principal summary measures included odds ratios and risk ratios. We quantified between-study heterogeneity through the use of χ² tests and the I² statistic. We assessed publication bias using funnel plots. We did not conduct any sensitivity tests, subgroup analyses, or meta-regression procedures. We performed all analyses using Stata Version 14.0 using a 2-sided test with a significance of P < .05. There is no protocol or registration number for this systematic review.

RESULTS
After conducting database searches and removing duplicate records, we screened 2,041 studies and assessed 29 full-text articles for eligibility. Fourteen full-text studies did not meet eligibility criteria, and 1 was unavailable, yielding 14 studies that we included in the systematic review (Figure 1; Table). Twelve of the included studies were conducted using a cross-sectional design, 1 using a case-control design, and 1 using a prospective longitudinal cohort design for a total sample size of 139,989 children. There were 8 studies in which researchers used objective measures for caries after clinical examination and 5 studies in which researchers reported subjective measures, such as questionnaires assessing perceptions of dental health. One study included both objective and subjective measures of oral health. For educational outcomes, researchers in 6 studies reported on school performance and in 5 reported on absenteeism. In 3 studies, researchers reported both academic outcomes. Seven of the 8 studies with objective measures of caries had an NOS score of 4 or higher and had a low risk of bias, and 4 of the 7 studies with subjective measures of academic performance were rated as having a high risk of bias. The total average NOS score across all included studies was 3.9.

School performance
In 9 studies, researchers reported outcomes of academic achievement. Overall, the findings of these studies suggest that poor oral health is negatively associated with achievement, regardless of age or demographic area. For studies with objectively measured dental status, a 2014 study of 838 schoolchildren found that increases in clinically evaluated DMFT were associated with reduced school performance in Indian schools, and a cross-sectional study of third grade students in the United States found that clinically evaluated caries prevalence, aggregated at the school level, was associated with lower achievement. de Paula and colleagues reported that both clinically evaluated prevalence of carious lesions (based on DMFT) and perceptions of parents about their child’s oral health were negatively associated with school performance. They further reported that children had difficulty paying attention in class owing to their teeth or mouth status. Similarly, a study of 380 Greek adolescents aged 12 through 17 years found that for every 1-point increase in DMFT, there was an 18% decrease in the likelihood of receiving higher grades. Finally, Paula and colleagues reported results from a case-control study in Brazilian children aged 8 through 10 years that showed children with poor academic performance were significantly more likely to have caries as measured through a clinical examination. In contrast, a study of 12-year-old Brazilian children by Piovesan and colleagues found that although children with caries in more teeth had lower test performance and higher absenteeism, the effects were not statistically significant, and Seirawan and colleagues found that objectively measured caries was not significantly associated with either school absences or grade point average in primary and secondary schoolchildren in the United States. However, subjectively evaluated dental pain as reported by parents was strongly associated with negative impacts on both.

Among the studies that used subjective measures of dental health, Guarnizo-Herreno and Wehby used a nationally representative survey from the United States to show that children with parent-reported dental problems were more likely to have problems in school, more likely to miss school, and less likely to complete required homework assessments. A cross-sectional study of Chinese youth found that perceived dental health was significantly associated with poor school performance; however, the authors did not provide variance estimates for effect measures. As above, subjective dental pain reported by Seirawan and colleagues was significantly associated with poor performance and absenteeism.
School attendance
In 8 studies, researchers assessed oral health and school absence. Among studies with objectively measured oral health, a study of Laotian children found that those who missed more school had a significantly higher mean caries index score (primary and permanent dentition) and higher caries experience as measured via a clinical examination. In contrast, Krisdapong and colleagues conducted an analysis of the association between DMFT and severe caries and school absenteeism and found that in both 12-year-old and 15-year-old student cohorts in Thailand, there was no significant association between higher DMFT scores or severe caries and absenteeism in adjusted models. Similarly, the results of a cross-sectional study in Brazil showed that although children with caries had a higher total number of school absences, the effects were not statistically significant. As was the case for school performance, Seirawan and colleagues found no significant associations between objectively measured caries and school absences but did find that subjectively measured dental pain was strongly associated.

For subjective exposures, on the basis of data from the National Survey of Children’s Health and weighted to be representative of the US population aged 0 through 17 years, Agaku and colleagues reported that untreated oral health care needs in children were significantly associated with the number of school days missed. This finding was replicated in a separate study of US children aged 6 through 17 years. Finally, researchers in 2 studies in Thailand and Saudi Arabia reported that children were found to miss school days owing to tooth pain, but they did not conduct any formal hypothesis tests.

Meta-analysis
Researchers in 5 studies on oral health and academic performance reported similar measures of association, and we included these studies in a random-effects meta-analysis. The DerSimonian and Laird pooled odds ratio was 1.52 (95% confidence interval, 1.20 to 1.83), with larger effects indicating increased odds of poor achievement (Figure 2). Heterogeneity across studies for student achievement was not statistically significant (χ² = 7.22; P = .125), and the total variation in effect size attributable to heterogeneity as measured via I² was 44.6%. A funnel plot of publication bias is included in eFigures 1 and 2, available online at the end of this article. Results suggest a lack of small studies in the available literature, but the number of studies used in this analysis was low.

We included 4 studies in a random-effects meta-analysis of the association between oral health and school absenteeism. One study included 2 independent samples of children aged 12 and 15 years old, and we included them in the meta-analysis as separate studies. Pooled effects (Figure 3) suggest that poor oral health is significantly associated with increased odds of having school absences (pooled odds ratio, 1.43; 95% confidence interval, 1.24 to 1.63). Heterogeneity across studies was not statistically significant (χ² = 0.66; P = .882), and there was no variation in effect size attributable to heterogeneity. However, a large proportion of study weights contributing to the
overall pooled effect size was owing to 1 study. Corresponding funnel plots for oral health and school absence is available in the supplementary figures available online at the end of this article (eFigure 1 and eFigure 2, respectively).

The review search strategy, extraction guide, scoring template, and excluded study list are available in the supplementary data available online at the end of this article.

DISCUSSION

In this systematic review, we evaluated the association between oral health and student academic performance. Oral health was defined as caries, dental pain, or periodontitis in children or adolescents, and performance was defined as academic achievement and school absenteeism. We included both subjective and objective measures in the review and meta-analyses. We hypothesized that students with poor oral health face substantial barriers to academic success, often missing school, having difficulty paying attention in class, or both. Chronic absenteeism, often owing to a persistent health problem, is considered by most states to be an indicator of school performance. Missing school thus places students at risk of falling behind academically. As untreated caries and other persistent oral infections are prevalent in disadvantaged children of primary and secondary school age, the connection between oral health and education is an important issue in dental research.

The results of our systematic review suggest that poor oral health is negatively associated with student performance and school absenteeism in both qualitative syntheses and meta-analyses. This finding is consistent with theories of psychosocial development in children experiencing dental or other craniofacial differences. Each of the studies included in meta-analyses found increased odds of poor academic achievement and absences owing to caries or tooth pain; however, over 44% of between-study variation (as measured via I²) owing to heterogeneity remained in student achievement. This may be a result of the limited number of studies included, the lack of alternative study designs, or variability in measurement and may suggest that there is some inconsistency across the studies used in the meta-analysis for student achievement. As previously described, study heterogeneity can limit interpretation of meta-analysis results owing to possible methodological variation, clinical variation, or both, in trials as well as possible intervention effects. However, the observed proportion of heterogeneity lies somewhere between small and moderate variation. Furthermore, it has been argued that the I² statistic is not an absolute measure of heterogeneity and thus should not be interpreted as actual variation in effect sizes across studies but only as the proportion of variance remaining if sampling error were removed.

Although there was no between-study heterogeneity for school absences, an examination of forest plots shows that 1 study accounted for most of the weight in calculating pooled effect sizes across studies. This particular study was a cross-sectional design with an exceptionally large sample size, dominating the calculation of the pooled-effect size for the meta-analysis. Thus, the overall pooled effect is mostly owing to this sole study; however, none of the included studies for this analysis had effects that were significantly different from one another. This is supported by the lack of between-study heterogeneity for this outcome and leads to a more precise measure of the overall effect, as shown in Figure 3.
there is little to no between-study heterogeneity included in the error term for confidence intervals.  

The interpretation of the results from the meta-analyses is limited owing to the high degree of variability observed between included studies for both exposure and outcome definitions. Although most of the included studies used clinical measures for oral health, such as DMFT or decayed or filled primary teeth, others used subjective measures such as parent surveys or child questionnaires. Objective measures of student performance used in the studies included measures for grade point average, school-level achievement, participant performance, or grade scales. Subjective measures included teacher perceptions of student performance, parent surveys, and adolescent self-reports. Furthermore, owing to the nature of child education, there is a lack of standardization in assessment of achievement across county, state, and district levels. As a result, although effects may be able to be pooled across studies, individual effects may not reflect the same level of impact. Given that the validity and reliability of the included measures for academic outcomes cannot be properly determined as they were not reported, the use of subjective measures for each may bias results. Ideally, a standardized measure of student aptitude, such as nationwide testing with established psychometric properties, would be preferable. Furthermore, there is limited information on the sensitivity and specificity of the measures, diagnostic criteria, or both, used for exposures in each study. Although there is evidence that self-reported measures for child oral health may be valid and reliable for use in epidemiologic research, this may be limited to specific types of afflictions and is not consistent across caries and periodontal disease. Notably, this heterogeneity in exposure and outcome definition has been encountered previously in systematic reviews of oral health education and limits the generalizability of pooled results.

An additional limitation of this study is a lack in study variability and study quality. In particular, nearly all of the included studies used a cross-sectional design, and 30% of those studies were considered to have a high risk of bias. In addition, we identified 12 studies for full review, but they were excluded for a number of identified reasons (Figure 1). Some of these studies reported an association between oral health and education and were well designed but were not included owing to a failure to meet exposure or outcome criteria. For example, Jackson and colleagues explored the impact of poor oral health on school attendance and academic performance, finding that children with poor oral health were substantially more likely to miss school and have reduced achievement. However, the authors assessed academic outcomes subjectively using parent surveys and measured oral health using Likert scales, comparing children with “poor,” “fair,” or “good” oral health with children with “very good” to “excellent” oral health. They did not report the reason for including children with good oral health together with those reporting fair or poor health. Finally, despite a comprehensive search of the literature, we found no studies on the association between periodontitis or gingivitis and academic achievement or school absence. Due to the small number of studies eligible for inclusion, analysis was limited. For example, the included studies were not uniform with respect to the age of participants. It is possible that specific age ranges may be more or less susceptible to the negative academic consequences of poor oral health, but we could not conduct subgroup analysis via age group. Furthermore, subgroup analyses using Newcastle-Ottawa scores would provide an interesting look at how the association between oral health and academic performance varies across study bias.

Other potential limitations include publication bias, validity and reliability concerns regarding measurement of educational outcomes, and confounders in meta-analyses. Publication bias is a frequent limitation encountered in systematic reviews and was expected in our study. Failure by investigators to publish null or negative findings can result in nonrepresentative meta-analyses and may lead to inadequate evidence in systematic reviews. This bias is further compounded by the limited quality of studies evaluated in our review. As a result, we recommend caution in interpreting the results. Educational outcomes included in our review ranged from objective performance, such as test scores to subjective measures including teacher and parent self-reporting. It is well known that bias is common in subjective measures in behavioral research, but even objective measures have poor validity and reliability. Often, the psychometric properties of educational assessments are available only for nationally recognized batteries (for example, standardized aptitude tests), and we were not able to evaluate them in this review. Thus, the results from our systematic review and meta-analyses may not be generalizable without more rigorously controlled designs.

Owing to the preponderance of cross-sectional studies identified, the results may be biased owing to residual or unobserved confounding. In particular, the researchers in the identified studies failed
to control for socioeconomic status or access to care, both of which may be substantial confounders in the linkage between oral health and educational outcomes. As a result, the implications for academic performance, absenteeism, or both, may be due in part to variation in socioeconomic status, rather than being completely attributable to caries or periodontitis. Access to effective oral health care is a particular limitation for children in rural areas, where distance to health care providers and financial limitations are substantial barriers to obtaining oral health care. According to the National Advisory Committee on Rural Health and Human Services, geographic isolation combined with a lack of adequate transportation can reduce the number of oral health care professionals in rural areas and limits the ability of rural residents, particularly those living in low-income households, to access care providers. Furthermore, owing to low reimbursement rates, those from low socioeconomic backgrounds may have added difficulty in identifying providers who accept Medicaid or Children’s Health Insurance Program participants.

The potential connections between oral health and education suggest that wider use of school-based dental programs focusing on preventing oral diseases potentially could lead to improvements in both oral health and academic performance, overcoming the access and financial barriers. Notably, multiple federal organizations and institutions in the United States recommend school-based dental programs to reduce oral health inequity, and the comparative effectiveness of such programs is recognized as a top research priority by the National Academy of Medicine (formerly the Institute of Medicine). School-based caries prevention has the potential to improve the quality of care received by children and improve access while minimizing cost burdens. School-based health programs can improve several mediating outcomes that may influence student academic performance, such as health status, resilience, classroom attention, and school climate. In addition, children who use school-based health centers have significant increases in attendance. Thus, school-based caries prevention or other dental programs may have downstream effects on educational outcomes. Finally, leveraging such school-based dental programs can also improve the quality of data in the available literature. Many ongoing studies of school-based programs are longitudinal, and if they are expanded to include an assessment of academic performance, they can provide a more comprehensive understanding of the association between oral health and academic success.

Increased focus on the broader implications of improvements in oral health for children, such as educational development, is of further interest to practicing dentists owing to the greater connection between oral health and general health. Both the Mayo Clinic and the American Dental Association highlight the links between dental and general health, with oral diseases potentially influencing systemic diseases or other conditions such as cardiovascular disease and diabetes. More broadly, this connection may generalize to other areas of child development, such as psychosocial functioning, cognition, quality of life, and educational performance. Thus, heightened awareness of oral diseases in children may contribute to a more holistic approach to child development.

CONCLUSIONS
Evidence from our systematic review and meta-analysis suggests that poor oral health may be associated with adverse impacts on academic performance and school attendance. However, a preponderance of cross-sectional studies, concerns regarding validity and reliability of outcomes, and high risk of bias in some of the included studies limit the strength and generalizability of our findings. Thus, multiple open questions remain regarding the role of oral health in education, which presents opportunities for more sophisticated research. For example, understanding the differential association of individual oral diseases (for example, caries experience, untreated caries, and symptomatic teeth) with adverse educational outcomes would be useful in the design and implementation of targeted interventions for specific conditions. Furthermore, understanding the role of diseases in primary versus permanent dentition could inform the timing of interventions or be used to identify the optimal period in which oral health most directly impacts educational performance. It may also support interventions targeted at those oral conditions most directly attributable to adverse educational outcomes.

SUPPLEMENTAL DATA
Supplemental data related to this article can be found at: https://doi.org/10.1016/j.adaj.2018.09.023.
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Available at: http://epoc.cochrane.org/epoc-specific-resources-review-authors, Accessed October 10, 2016.

eFigure 1. Funnel plot of effect estimates for individual studies of achievement against precision, with pseudo 95% confidence limits.

eFigure 2. Funnel plot of effect estimates for individual studies of school absences against precision, with pseudo 95% confidence limits.
**eTable. Modified Newcastle-Ottawa scoring guide.**

<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>SCORING</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representativeness of the Sample</td>
<td>1 point: Population contained a mixture of specialties at multiple sites</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 point: Population contained single specialty at a single site</td>
<td></td>
</tr>
<tr>
<td>Sample Size</td>
<td>1 point: Sample size was greater than 200 participants</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 point: Sample size was less than 200 participants or a convenience sample</td>
<td></td>
</tr>
<tr>
<td>Nonrespondents</td>
<td>1 point: Comparability between respondent and nonrespondent characteristics was established, and the response rate was satisfactory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 point: The response rate was unsatisfactory, the comparability between respondents and nonrespondents was unsatisfactory, or there was no description of the response rate or the characteristics of the responders and the nonrespondents</td>
<td></td>
</tr>
<tr>
<td>Ascertainment of Depression</td>
<td>1 point: Validated measurement tool using a validated cutoff score</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 point: Nonvalidated measurement tool, or validated measurement tool with nonvalid cutoff score, or 2-item PRIME-MD (scored as such due to its low specificity)</td>
<td></td>
</tr>
<tr>
<td>Quality of Descriptive Statistics Reporting</td>
<td>1 point: Reported descriptive statistics to describe the population (for example, age, sex) with proper measures of dispersion (for example, standard deviation, standard error, range)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 point: Descriptive statistics were not reported, were incomplete, or did not include proper measures of dispersion</td>
<td></td>
</tr>
</tbody>
</table>

6. Total Score

7. Notes:

**eBox 1. Search strategy used in the systematic review and meta-analysis.**

1) PubMed (yielding 1834 entries):


2) EMBASE (yielding 655 entries):

‘dental caries’/exp OR ‘periodontal disease’/exp OR periodont*:ab,ti OR ‘gingivitis’/exp AND ‘academic achievement’/exp OR ‘educational status’/exp OR ‘learning’/exp OR ‘absenteeism’/exp OR ((school OR academic) NEAR/3 (performance OR achievement)):ab,ti OR absenteeism:ab,ti OR ((school* OR class OR classes) NEAR/3 (missing OR absent OR absence*)):ab,ti AND (‘child’/exp AND ‘pediatrics’/exp OR child*:ab,ti OR adolescent*:ab,ti OR toddler*:ab,ti OR infant*:ab,ti OR newborn*:ab,ti OR neonat*:ab,ti OR teen*:ab,ti OR boy:ab,ti OR boys:ab,ti OR girl*:ab,ti OR pediatric*:ab,ti OR paediatric*:ab,ti OR youth*:ab,ti OR student*:ab,ti OR youth*:ab,ti OR juvenile*:ab,ti)

3) Google Scholar: An additional 5 papers were found through natural language keywords and ‘related articles’ function searches.

4) de Paula and colleagues, 2013: An additional 17 papers were found through listed references from an existing systematic review.
**eBox 2. Extracted data items by category.**

1. **Eligibility:** Type of study, participants, types of exposure, types of outcome measures, decision, reason for exclusion
2. **Study Characteristics:** Aim of study, population description, study design, inclusion criteria, exclusion criteria, methods of recruitment of participants
3. **Participants:** Total population at start of study, withdrawals and exclusions, age, sex, race/ethnicity, severity of illness, comorbidities, other relevant sociodemographic information, subgroups measured, subgroups reported
4. **Exposure:** Exposure name, number of people, description and timing of exposure
5. **Outcome:** Outcome name, timing, outcome definition, person measuring/reporting, scales (upper and lower limits) and whether the outcome instrument was validated
6. **Results:** Results (dichotomous: cases/exposed number of events and participants, control/nonexposed number of events and participants), results (continuous: cases/exposed number, mean, standard deviation, standard error, control/nonexposed number, mean, standard deviation, standard error), effect measure, confounding, statistical methods used and appropriateness of these methods
7. **Quality Assessment:** Representativeness of the cases/exposed, selection of controls/nonexposed, sample size, comparability of the 2 groups based on design or analysis, ascertainment of oral health, assessment of school performance/absenteeism

**eBox 4. Full-text article excluded owing to unavailability.**