

Original Contributions

Systematic Review

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

A systematic review and meta-analysis

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Supplemental material
is available online.

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.

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Oral diseases are a persistent unmet need for children and adolescents. Untreated caries is the most common preventable childhood disease in the world, being over 5 times as common as asthma among children aged 5 through 17 years.¹ In the United States, untreated caries is present in approximately 15% of children and adolescents, rising to 20% in minority children and 25% among those from below 100% of the federal poverty threshold,^{2,3} reflecting profound geographic, ethnic, and income disparities.^{4,5} Periodontitis is a direct consequence of both

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local and systemic factors, such as plaque or malnutrition.^{6,7} Although the overall prevalence of periodontitis among adolescents in the United States is less than 1%,⁸ the burden of disease is higher in other countries.⁹ Furthermore, a 2002 review indicated that the US prevalence of pre-pubertal periodontitis ranged from less than 1% through 27% in case reports, and the prevalence was higher in black children.¹⁰

In addition to infection and pain, poor oral health can have long-lasting, detrimental effects on school attendance and academic performance.¹¹⁻¹⁵ 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.¹⁶ A number of studies corroborate the impact of dental health on absenteeism.^{16,17} 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^{13,18} and pain-associated school absence is negatively associated with achievement.¹⁶

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.¹⁵ 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

ABBREVIATION KEY

DMFT: Decayed, missing, and filled teeth.

NOS: Newcastle-Ottawa Scale.

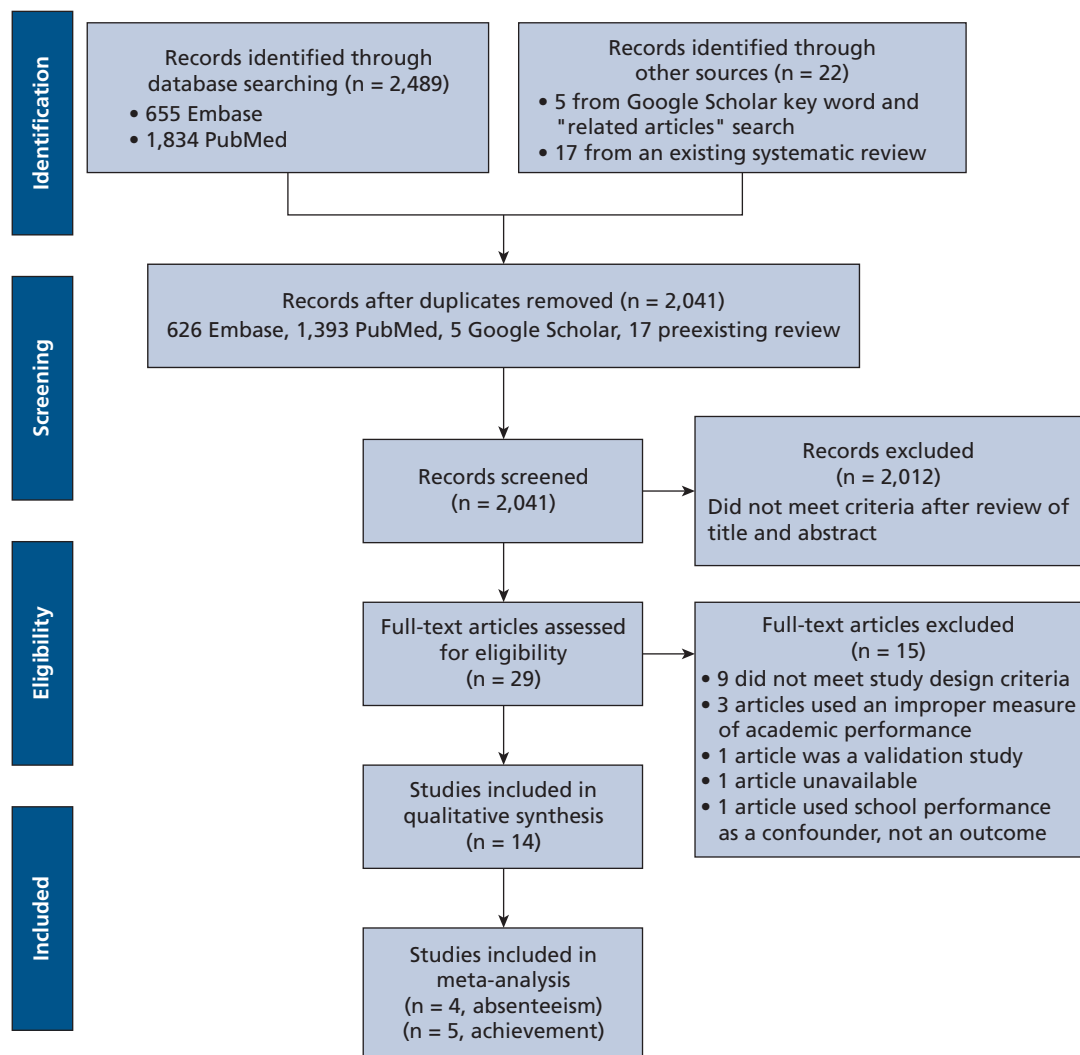


Figure 1. Flow diagram for identifying studies on the association between oral health, academic performance, and school attendance among school-aged children.

Systematic Reviews and Meta-Analyses guidelines.¹⁹ 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 group²⁰). 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.²¹ 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. Selected characteristics of included studies.

STUDY	STUDY DESIGN	COUNTRY	PARTICIPANTS, NO.	AGE OR GRADE LEVELS	EXPOSURE	OUTCOME	RESULTS	NEWCASTLE-OTTAWA SCALE SCORE	RISK OF BIAS
Petridou and Colleagues,³¹ 1996	Cross-sectional	Greece	380	12-17 years	Clinically evaluated DMFT* and DMFS†	School performance: objectively measured grades on a 10-grade scale	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 ($P < .001$)	3	High
Jiang and Colleagues,²⁷ 2005	Cross-sectional	China	2,662	11, 13, 15 years	Subjectively measured dental health status reported by adolescents	School performance: subjectively measured performance in school	Compared with children who were high performing, low school performance was associated with reduced self-reported dental health (OR, ‡ 0.65; $P < .01$)	3	High
David and Colleagues,²⁴ 2006	Cross-sectional	India	838	12 years	Clinically evaluated DMFT and Oral Hygiene Index-Simplified	School performance: subjectively measured child report of teacher perceptions of performance	Children with poor oral health had increased odds of poor school performance (OR, § 2.5; 95% CI, § 1.6 to 3.8)	3	High
Pongpichit and Colleagues,³³ 2008	Longitudinal	Thailand	1,211	Grade 5 (9-13 years)	Subjectively measured oral pain using parent questionnaires	Absenteeism: objectively measured school attendance records	Children were recorded as having missed 159 hours of school owing to dental reasons (117 for dental appointments, 42 for oral pain)	4	Low
Jurgensen and Colleagues,²⁸ 2009	Cross-sectional	Laos	621	12 years	Clinically evaluated caries (using DMFT), caries prevalence, and toothache	Absenteeism: subjectively reported number of missed school days in previous 12 months	Mean caries index score was 2.6 for children reporting missing school several times ($P < .001$) compared with peers (mean decay index score was 2.0 for 1 missed day, 0.2 for no missed days)	4	Low
Guarnizo-Herreno and Wehby,²⁶ 2012	Cross-sectional	United States	46,750	6-17 years	Subjectively measured dental health status reported by parents	Both outcomes: subjectively measured parent survey (National Survey of Children's Health)	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)	4	Low
Piovesan and Colleagues,³² 2012	Cross-sectional	Brazil	312	12 years	Clinically evaluated dental caries	Both outcomes: objectively measured performance on language examinations and number of school absences from school registers	Compared with children with DMFT = 0, those with DMFT > 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	4	Low

* DMFT: Decayed, missing, and filled teeth. † DMFS: Decayed, missing, and filled surfaces. ‡ OR: Odds ratio. § CI: Confidence interval. ¶ GPA: Grade point average.

Table. Continued

STUDY	STUDY DESIGN	COUNTRY	PARTICIPANTS, NO.	AGE OR GRADE LEVELS	EXPOSURE	OUTCOME	RESULTS	NEWCASTLE-OTTAWA SCALE SCORE	RISK OF BIAS
Seirawan and Colleagues,¹³ 2012	Cross-sectional	United States	1,495	Elementary, high school	Clinically evaluated dental caries and subjective parent survey of child dental pain	Both outcomes: objectively measured school attendance and GPA [†]	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)	4	Low
Krisdapong and Colleagues,²⁹ 2013	Cross-sectional	Thailand	1,874	12, 15 years	Clinically evaluated DMFT, severe caries, and toothache	Absenteeism: subjectively measured questionnaire on school absence	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)	4	Low
Detty and Oza-Frank,¹⁴ 2014	Cross-sectional	United States	16,022	3rd grade	Clinically evaluated untreated caries	School performance: objectively measured school-level performance	Prevalence of untreated caries at the school-level was significantly associated with lower school performance (mean score, 0.065 lower; $P = .088$)	5	Low
Agaku and Colleagues,²³ 2015	Cross-sectional	United States	65,680	6-17 years	Subjectively measured presence of an unmet dental need	Absenteeism: subjectively measured questionnaire on school absenteeism	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	4	Low
de Paula and Colleagues,²⁵ 2015	Cross-sectional	Brazil	515	12 years	Clinically evaluated DMFT	School performance: objectively measured whether child did or did not pass the current grade	Children with poor oral health had increased odds of poor school performance (OR, 5.19; 95% CI, 2.16 to 12.47)	5	Low
Paula and Colleagues,³⁰ 2016	Case Control	Brazil	1,149	8-10 years	Clinically evaluated carious lesions without treatment	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	Children with untreated carious lesions had below-average school performance (OR, 1.51; 95% CI, 1.17 to 1.96)	5	Low
Shaikh and Colleagues,³⁴ 2016	Cross-sectional	Saudi Arabia	480	16-18 years	Subjectively measured dental pain	Absenteeism: objectively measured school attendance records	Overall prevalence of absenteeism due to tooth pain was 19%; most instances of absenteeism (55%) resulted in 2 or more days of school lost	3	High

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.²² Principal summary measures included odds ratios and risk ratios. We quantified between-study heterogeneity through the use of χ^2 tests and the I^2 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).^{13,14,23-34} 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.^{13,26,32} 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,²⁴ 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.¹⁴ de Paula and colleagues²⁵ 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.³¹ Finally, Paula and colleagues³⁰ 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 colleagues³² 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 colleagues¹³ 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 Wehby²⁶ 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.²⁷ As above, subjective dental pain reported by Seirawan and colleagues¹³ was significantly associated with poor performance and absenteeism.

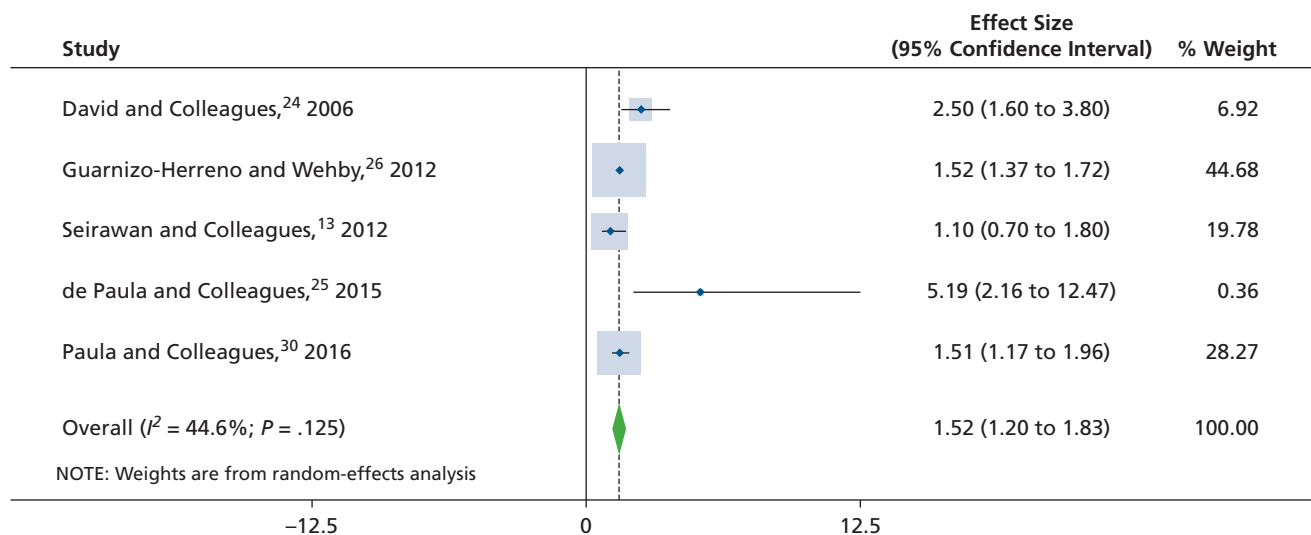


Figure 2. Meta-analysis results for student achievement.

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.²⁸ In contrast, Krisdapong and colleagues²⁹ 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 colleagues¹³ 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 colleagues²³ 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.²⁶ 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.^{33,34}

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 ($\chi^2 = 7.22$; $P = .125$), and the total variation in effect size attributable to heterogeneity as measured via I^2 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.²⁹ 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 ($\chi^2 = 0.66$; $P = .882$), and there was no variation in effect size attributable to heterogeneity. However, a large proportion of study weights contributing to the

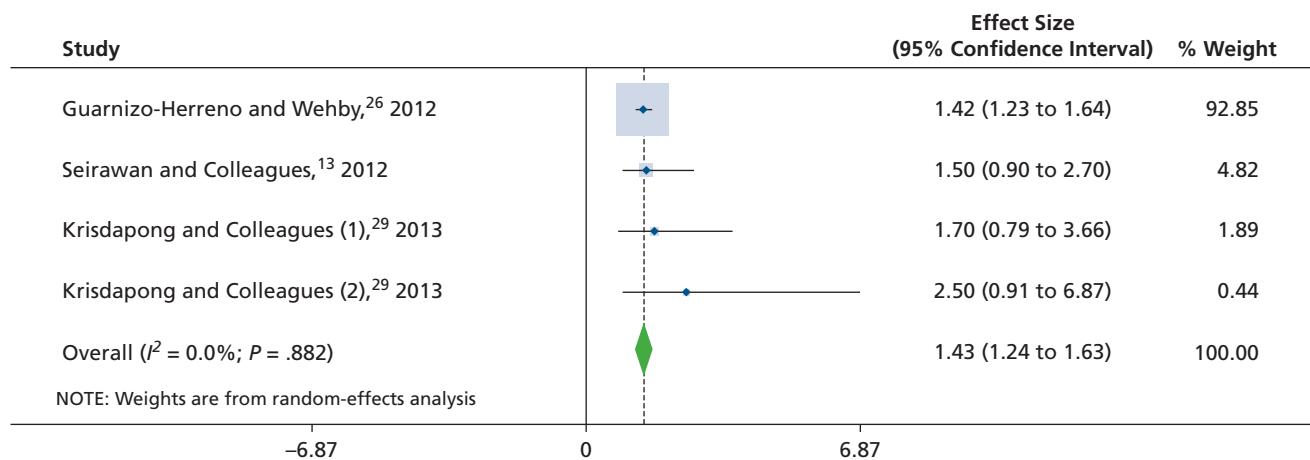


Figure 3. Meta-analysis results for school absenteeism.

overall pooled effect size was owing to 1 study.²⁶ 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.³⁵ 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.^{36,37} 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 I^2) 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.³⁸ However, the observed proportion of heterogeneity lies somewhere between small and moderate variation.³⁹ Furthermore, it has been argued that the I^2 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.⁴⁰

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

there is little to no between-study heterogeneity included in the error term for confidence intervals.²²

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,⁴¹ this may be limited to specific types of afflictions and is not consistent across caries and periodontal disease.⁴² Notably, this heterogeneity in exposure and outcome definition has been encountered previously in systematic reviews of oral health education^{43,44} 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 colleagues¹⁶ 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.^{45,46} 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,⁴⁷ 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.⁴⁸ 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,⁴⁹ 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).⁵⁰ 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.^{51,52} In addition, children who use school-based health centers have significant increases in attendance.⁵³ 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,⁵⁴ 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.⁵⁵ 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.^{55,56} 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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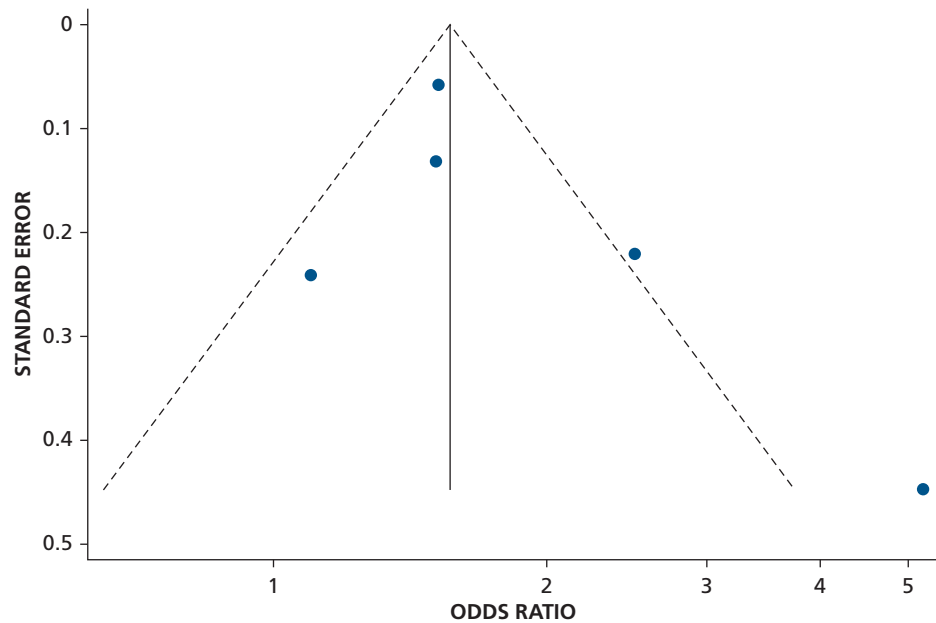
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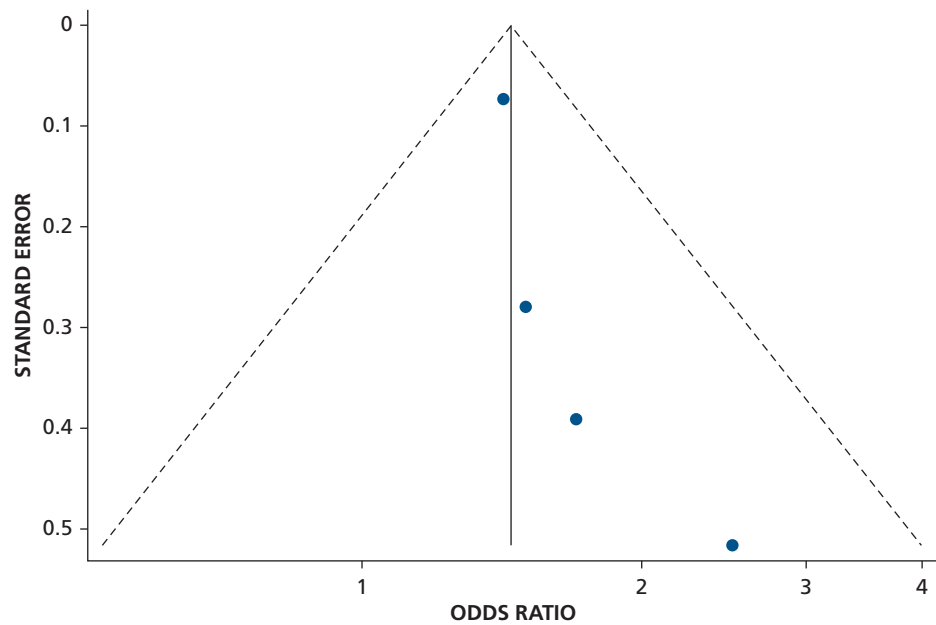
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eFigure 1. Funnel plot of effect estimates for individual studies of achievement against precision, with pseudo 95% confidence limits.



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.

DOMAIN	SCORING	SCORE	LOCATION IN TEXT PAGE AND FIGURE/TABLE
1. Representativeness of the Sample	1 point: Population contained a mixture of specialties at multiple sites 0 point: Population contained single specialty at a single site		
2. Sample Size	1 point: Sample size was greater than 200 participants 0 point: Sample size was less than 200 participants or a convenience sample		
3. Nonrespondents	1 point: Comparability between respondent and nonrespondent characteristics was established, and the response rate was satisfactory 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 nonresponders		
4. Ascertainment of Depression	1 point: Validated measurement tool using a validated cutoff score 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)		
5. Quality of Descriptive Statistics Reporting	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) 0 point: Descriptive statistics were not reported, were incomplete, or did not include proper measures of dispersion		
6. Total Score			
7. Notes:			

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

1) PubMed (yielding 1834 entries):

("Oral Health"[Mesh] OR "Periodontal Diseases"[Mesh] OR "Dental Caries"[Mesh] OR oral health[tiab] OR periodont*[tiab] OR gingivitis[tiab] OR caries[tiab] OR cavities[tiab] OR tooth decay[tiab])

AND

("Child"[MeSH Terms] OR "Infant"[mesh] OR "Adolescent"[MeSH Terms] OR "Pediatrics"[MeSH] OR child*[tiab] OR infant*[tiab] OR newborn*[tiab] OR neonat*[tiab] OR adolescen*[tiab] OR toddler*[tiab] OR teen*[tiab] OR boy[tiab] OR boys[tiab] OR girl*[tiab] OR pediatric*[tiab] OR paediatric*[tiab] OR youth*[tiab] OR student*[tiab] OR youth*[tiab] OR juvenile*[tiab])

AND

((("Achievement"[mesh] AND "Students"[mesh]) OR "Educational Measurement" OR "Educational Status"[mesh] OR "Learning"[mesh] OR "Absenteeism"[mesh] OR school performance[tiab] OR academic performance[tiab] OR academic achievement[tiab] OR absenteeism[tiab] OR ((school*[tiab] OR class[tiab]) AND (missing[tiab] OR absent[tiab] OR absence*[tiab])))

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 adolescen*: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,²⁵ 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 3. Full-text articles excluded due to not meeting eligibility criteria.

1. Astrom AN, Okullo I. Validity and reliability of the Oral Impacts on Daily Performance (OIDP) frequency scale: a cross-sectional study of adolescents in Uganda. *BMC Oral Health*. 2003;3(1):5.
2. Bernabe E, Flores-Mir C, Sheiham A. Prevalence, intensity and extent of Oral Impacts on Daily Performances associated with self-perceived malocclusion in 11-12-year-old children. *BMC Oral Health*. 2007;7:6.
3. Bernabe E, Tsakos G, Sheiham A. Intensity and extent of oral impacts on daily performances by type of self-perceived oral problems. *Eur J Oral Sci*. 2007;115(2):111-116.
4. Blumenshine SL, Vann WF, Jr., Gizlice Z, Lee JY. Children's school performance: impact of general and oral health. *J Public Health Dent*. 2008;68(2):82-87.
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7. Freire MC, Sheiham A, Netuveli G. Relationship between height and dental caries in adolescents. *Caries Res*. 2008;42(2):134-140.
8. Garg N, Anandakrishna L, Chandra P. Is there an association between oral health status and school performance? A preliminary study. *Int J Clin Pediatr Dent*. 2012;5(2):132-135.
9. Gift HC, Reisine ST, Larach DC. The social impact of dental problems and visits. *Am J Public Health*. 1992;82(12):1663-1668.
10. Jackson SL, Vann WF, Jr., Kotch JB, Pahel BT, Lee JY. Impact of poor oral health on children's school attendance and performance. *Am J Public Health*. 2011;101(10):1900-1906.
11. Pourat N, Nicholson G. Unaffordable dental care is linked to frequent school absences. *Policy Brief UCLA Cent Health Policy Res*. 2009;PB2009(10):1-6.
12. Holt K, Barzel R. Oral health and learning: when children's oral health suffers, so does their ability to learn. Available at: <https://www.mchoralhealth.org/PDFs/learningfactsheet.pdf>. Accessed November 4, 2016.
13. Maharani DA, Adiatman M, Rahardjo A, Burnside G, Pine C. An assessment of the impacts of child oral health in Indonesia and associations with self-esteem, school performance and perceived employability. *BMC Oral Health*. 2017;17(1):65.

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

1. Hananda M. The relation between dental caries and health of school children: dental caries morbidity and absence from school. *Igaku Kenkyu*. 1957;27(8):1819-1821.