# Rural and Urban Disparities in Caries Prevalence in Children with Unmet Dental Needs: The New England Children's Amalgam Trial

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**Abstract**

***Objectives:*** *To compare the prevalence of caries between rural and urban children with unmet dental health needs who participated in the New England Children's Amalgam Trial.* ***Methods:*** *Baseline tooth and surface caries were clinically assessed in children from rural Maine (n = 243) and urban Boston (n = 291), who were aged 6 to 10 years, with two or more posterior carious teeth and no previous amalgam restorations. Statistical analyses used negative binomial models for primary dentition caries and zero-inflated models for permanent dentition caries.* ***Results:*** *Urban children had a higher mean number of carious primary surfaces (8.5 versus 7.4) and teeth (4.5 versus 3.9) than rural children. The difference remained statistically significant after adjusting for sociodemographic factors and toothbrushing frequency. In permanent dentition, urban children were approximately three times as likely to have any carious surfaces or teeth. However, rural/urban dwelling was not statistically significant in the linear analysis of caries prevalence among children with any permanent dentition caries. Covariates that were statistically significant in all models were age and number of teeth. Toothbrushing frequency was also important for permanent teeth.* ***Conclusions:*** *Within this population of New England children with unmet oral health needs, significant differences were apparent between rural and urban children in the extent of untreated dental decay. Results indicate that families who agree to participate in programs offering reduced cost or free dental care may present with varying amounts of dental need based on geographic location.*

*Key Words: dental caries, child, rural health, urban health, oral health, New England, zero-inflated models*

## Introduction

Dental caries remains the single most common chronic disease of childhood, despite an overall decline in the mean level of clinically detectable caries over the past three decades in the United States (1). A primary concern is that substantial disparities exist in oral health status. Eighty percent of teeth affected by caries are found in roughly 25 percent of 5- to 17-year-old children and adolescents, predominantly those from lower socioeconomic status (SES) groups (2). While factors such as oral hygiene practices, fluoride history, diet, and genetic predisposition are directly related to caries experience in children, factors such as race, education level of parents, and access to dental care may indirectly influence caries experience as well (3).

Community-level factors are increasingly becoming understood as important correlates of individual SES and health (4,5). One such measure is the geographic variable of rural versus urban dwelling. For caries prevalence, however, studies examining rural and urban dwellings have had discordant results. For example, studies from China, Burkina Faso, and Sweden found higher caries prevalence in urban settings (6-8). On the other hand, a recent multilevel analysis of caries in Brazilian schoolchildren found that living in a rural area almost doubled the odds of caries (9). Conflicting results may be because of the limitations inherent in population studies, such as an inability to analyze individual-level data, or a lack of comparability of rural and urban settings across nations. For example, less developed nations often report lower caries in rural areas and correlate this finding with a lack of refined sugars in the rural diets (10,11). A population-level analysis of 109 countries found that factors such as sugar consumption and health expenditures can have a positive or negative impact on mean number of decayed, missing, or filled teeth (DMFT) in children, depending on the stage of development of the country (12). Thus, when nations plan caries prevention policies, the contextual setting of various regions are important to consider. Area-based measures not only identify subgroups with poor health, but also

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allow for geographic targeting of dental services (13).

In the United States, data from the 1988-94 National Health and Nutrition Examination Survey (NHANES-III) and 1997-98 National Health Interview Survey revealed that, while rural children had less dental care access and utilization and more self-reported unmet needs for dental care, the overall difference in caries experience between urban and rural children was not significant (14). Although national surveys provide valuable general measures of caries experience, an understanding of the extent of disease and contextual variations in precisely those children and families who not only need dental care but are also willing to participate in dental care programs is important to guide policies aimed at decreasing oral health disparities in children. The US government's Healthy People 2010 goals, for example, strive to reach children with unmet dental needs, generally by targeting lower income and high-risk ethnic groups (15). Yet even within these target groups, the extent of needed care may vary by community-level factors such as rural versus urban setting.

The purpose of this paper was to compare the extent of untreated caries at baseline in rural and urban children who agreed to participate in a trial providing free dental care, the New England Children's Amalgam Trial (NECAT). Because NECAT participants are typical of the target group of many oral health initiatives, an examination of the prevalence and demographic correlates of untreated caries in NECAT's rural and urban children helps to ascertain the extent of dental needs that may be encountered when providing dental care to underserved children.

## Methods

**Study Participants: The NECAT.** The data presented in this paper were obtained as part of the NECAT, a prospective randomized clinical trial that was conducted from 1997-2005 to examine the health effects of dental amalgam restorations among 534 children, each followed for approximately 5 years. The details of this study design were previously reported (16), as were the main results of the trial (17). Briefly, children were recruited from two geographic areas: an urban area with fluoridated public drinking water (Boston, MA), and a rural area (Farmington, ME), where the majority of participants used well water, for which estimates of naturally occurring fluoride are unavailable but are likely to be at the lower bound of the target range for fluoridation (18). Eligibility criteria were aged 6 to 10 at last birthday, no prior amalgam restorations, two or more posterior teeth with occlusal surface caries, English-speaking, and no major neuropsychologic or renal health disorders. Of 5,116 children screened, 598 met the eligibility criteria, and 534 consented and were randomly assigned to either amalgam or composite restoration material. The participants were offered free comprehensive dental care for 5 years. The study was approved by the institutional review boards of all participating sites.

Baseline caries status was measured during the initial dental exams, which were performed by two calibrated NECAT dentists in each study site. Family and demographic data were collected by an interview with a parent or guardian at the initial clinic visits. All interviewers were trained and certified at the New England Research Institutes' Survey Research Center (Watertown, MA).

**Data Analysis.** Descriptive demographic characteristics were calculated for the urban and rural populations. Four separate caries outcomes were evaluated: carious primary teeth, carious primary surfaces, carious permanent teeth, and carious permanent surfaces. Separation of teeth and surface caries allowed alternate views of the extent of the caries burden in each child. The primary reason for separating primary and permanent teeth was to assess the possibility of a different risk profile for teeth that were relatively newly erupted (i.e., permanent teeth), compared to teeth that had been exposed for at least 5 years (i.e., primary teeth), and therefore had more time at risk and during younger ages to develop caries. Children who had no primary dentition ($n = 11$) were excluded from the analyses of primary dentition. Children who had no permanent dentition ($n = 38$) were excluded from the analyses of permanent dentition.

Among the 523 children who had any primary dentition at baseline, caries prevalence was compared between urban and rural populations using the negative binomial model. Model fit was assessed with deviance statistics, and the negative binomial was well suited to handle the overdispersion of caries counts. Among the 496 children who had any permanent dentition, 210 (42 percent) had no caries in permanent teeth at the time of recruitment. Zero-inflated models allow for the possibility that some children had no carious permanent teeth or surfaces because their teeth were very newly erupted, while others had no caries for reasons such as their demographic/behavioral risk profile. Zero-inflated models produce two sets of coefficients and *P*-values: one based on the probability of having no caries, as in a logistic regression, and another based on the probability of the number of carious lesions, as in the Poisson or negative binomial regression (19-22). As determined by the graphic comparisons and the statistical Vuong test, the zero-inflated Poisson model was appropriate to model the prevalence of permanent teeth caries, while the zero-inflated negative binomial was better suited to model the prevalence of permanent surface caries.

Adjusted means for caries prevalence were calculated first from models adjusting only for number of primary or permanent teeth, and then from fully adjusted multivariate models including additional terms for age (continuous years), gender, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, or other race/ethnicity), education of primary caregiver (<high school,

**Table 1**
**Demographic Characteristics of 534 Children in the New England Children's Amalgam Trial by Study Site***

| | Boston ($n$ = 291) | Maine ($n$ = 243) |
|---|---|---|
| Age in years, mean ± SD | 7.9 ± 1.3 | 7.9 ± 1.4 |
| Gender, $n$ (%) | | |
| Male | 141 (48.5) | 106 (43.6) |
| Female | 150 (52.6) | 137 (56.4) |
| Race, $n$ (%) | | |
| Non-Hispanic White | 86 (29.6) | 237 (97.6) |
| Non-Hispanic Black | 97 (33.3) | 1 (0.4) |
| Hispanic | 38 (13.1) | 0 (0) |
| Other and multiracial | 70 (24.0) | 5 (2.1) |
| Frequency of toothbrushing† | | |
| <1/day | 13 (4.7) | 22 (9.1) |
| 1/day | 110 (39.6) | 112 (46.3) |
| ≥2/day | 155 (55.8) | 108 (44.6) |
| Education level of primary caregiver, $n$ (%) | | |
| <High school | 55 (18.9) | 18 (7.4) |
| High school graduate | 100 (34.4) | 135 (55.6) |
| Any post high school education | 136 (46.7) | 90 (37.0) |
| Total household income, $n$ (%) | | |
| ≤$20,000 | 104 (35.4) | 64 (26.3) |
| $20,001-40,000 | 115 (39.5) | 119 (49.0) |
| ≥$40,000 | 72 (24.7) | 60 (24.7) |
| At or below poverty threshold, %‡ | 92 (33.2) | 54 (22.3) |

* Study site "Boston" (Massachusetts) is an urban community, whereas study site "Maine" (based in Farmington, ME) is a rural community.
† One participant in Maine and 13 in Boston were missing information on frequency of toothbrushing.
‡ Poverty threshold is determined from weighted poverty thresholds 1997-99 and is based on family size and family income, as is used for all official poverty population figures (original source of data: US Bureau of the Census, Current Population Survey). One participant in Maine and 14 in Boston were missing information on poverty threshold.

high school, or any post high school), and frequency of toothbrushing (<1/day, 1/day, or 2+/day). Data on drinking water source (e.g., well versus municipal supply, bottled versus tap), gum-chewing frequency, household income, welfare use, maternal smoking status, breastfeeding history, and the primary caregiver's dental care utilization were considered as potential covariates, but did not affect the association between rural/urban setting and caries prevalence, so were not included in final models. Data on children's prior dental care utilization were not collected, as NECAT tried to minimize participant burden by omitting questions that were unlikely to provide much information and were not directly related to its primary aim (comparison of amalgam versus composite). That is, considering the eligibility criteria of untreated caries and the consent to have NECAT provide dental care during follow-up, it is unlikely that most children had regular dental care prior to the trial.

Descriptive analyses were conducted using SAS 9.1 (SAS Institute, Cary, NC, USA), and negative binomial and zero-inflated analyses were conducted using Stata 7.0 (StataCorp, College Station, Texas, USA).

## Results

The sociodemographic characteristics of the sample stratified by rural or urban site are described in Table 1. Sites differed considerably in racial/ethnic composition; almost all children in Maine were White, while children in Boston were racially diverse. Family income and education level of the primary caregiver were generally higher in Maine, though there were more caregivers with a college education in the Boston site. Boston families more often lived at or below the Census Bureau poverty threshold.

The overall caries burden of participants at each site is displayed for surfaces and teeth in Figure 1a,b, respectively. Figure 1a shows that the Maine children were better represented among children with less than 10 carious surfaces. Boston children, on the other hand, were better represented among children with 15 or more decayed surfaces. A similar pattern was apparent for decayed teeth (Figure 1b), with more carious teeth among the Boston children. Overall, the percentage of children who had five or more carious teeth was higher in the urban Boston group compared to the rural Maine group (65 versus 42 percent).

Adjusting only for the number of primary teeth in the mouth, urban children had more carious teeth (4.5 versus 3.9, $P = 0.001$) and carious surfaces (8.5 versus 7.4, $P = 0.006$) compared to the rural children (data not shown). As seen in Table 2, additional adjustment for sociodemographic characteristics and toothbrushing frequency barely affected the magnitude of the difference in primary dentition caries, and rural/urban site remained statistically significant for both teeth ($P = 0.002$) and surfaces ($P = 0.02$). Of the additional covariates, age was the only statistically significant correlate of caries count (teeth $P = 0.01$, surfaces $P = 0.03$), with older children having fewer primary dentition caries (data not shown).

In the permanent dentition, urban children again had more carious teeth (1.7 versus 1.0) and surfaces (2.2 versus 1.5), with or without control for covariates (Table 3). In the logistic portion of the zero-inflated models adjusting only for number of permanent teeth, Boston children were four times as likely as Maine children to have any surface caries [odds ratio (OR) = 4.0, 95 percent confidence interval (CI) = 2.3 to 7.1, $P < 0.001$, data not shown]. In the full multivariate model (Table 3, "logistic portion"), Boston children had three times the odds of any

**Figure 1**
**(a) Distribution of baseline carious surfaces in New England Children's Amalgam Trial (NECAT). (b) Distribution of baseline carious teeth in NECAT**

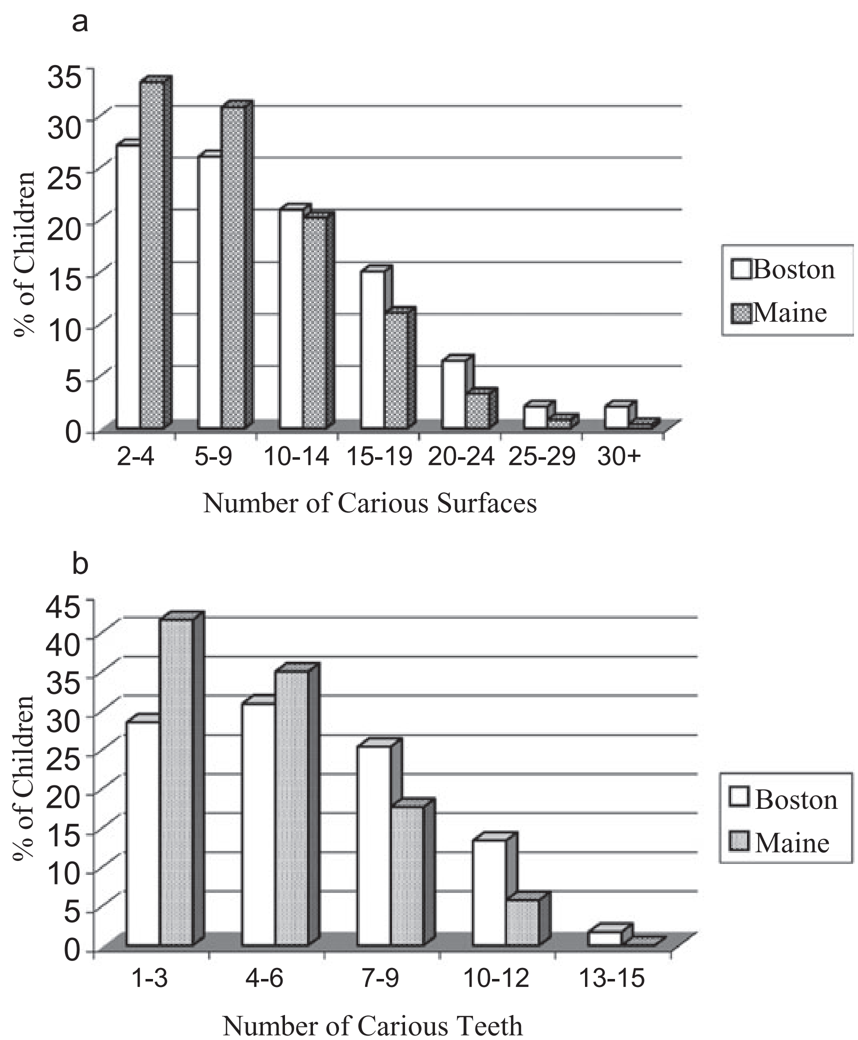


**Table 2**
**Carious Primary Dentition among 523 Children with Primary Teeth at Enrollment in the New England Children's Amalgam Trial by Study Site***

| | Mean (Standard Deviation) | | |
|---|---|---|---|
| | Boston ($n$ = 285) | Maine ($n$ = 238) | $P$-value |
| Carious primary teeth | 4.5 (1.1) | 3.9 (0.9) | 0.002 |
| Carious primary surfaces | 8.5 (2.2) | 7.3 (1.9) | 0.02 |

* Means were adjusted for number of primary teeth, age, gender, race/ethnicity, education of primary caregiver, and frequency of toothbrushing. The unadjusted mean number of primary teeth was 13.1 (±3.8) in Boston and 14.0 (±4.2) in Maine.

surface caries (OR = 3.0, 95 percent CI = 1.4 to 6.5, $P$ = 0.004). The results were similar for prevalence of carious teeth, for which Boston children had an approximately three-fold greater odds of having any permanent teeth caries (permanent-teeth-adjusted OR = 3.8, $P$ < 0.001; multivariate OR = 2.8, 95 percent CI = 1.1 to 6.8, $P$ = 0.03).

Despite the greater odds of having any permanent dentition caries among Boston children, there was no statistically significant linear association between caries rate and rural/urban setting (Table 3, "linear portion"). Rather, the only statistically significant predictors of the number of carious permanent surfaces were age ($P$ = 0.02, older children having more caries) and number of permanent teeth ($P$ = 0.03). In addition, a lower frequency of toothbrushing ($P$ = 0.03, ≤1/day versus 2+/day) was associated with a greater number of carious permanent teeth.

## Discussion

Upon enrollment into NECAT, children from the urban area of Boston, MA, had significantly more dental caries than did children from the rural area of Farmington, ME, and individual sociodemographic factors did not account for this difference between the urban and rural participants. NECAT's eligibility requirement of two or more posterior teeth with untreated caries resulted in all participants having relatively high levels of unmet oral health needs. Considering that a minority of children account for a majority of caries prevalent in the United States today, such focused research is imperative and serves to provide rationale for targeted public health efforts through evidence-based measures (23). In this analysis, the measure of unmet dental needs was untreated decay; however, the participants were also in need of preventive care (e.g., sealants), and these unmet needs are likely to be indicative of numerous other oral health needs, such as orthodontic treatment and trauma-related treatment. Our results reveal that even within this group of children with unmet needs desiring free dental care, substantial community-level differences exist in terms of the extent of dental care need.

To our knowledge, this is the first study to compare the prevalence of caries in a cohort of children from

**Table 3**
**Carious Permanent Dentition among 496 Children with Permanent Teeth at Enrollment in the New England Children's Amalgam Trial by Study Site***

| | Mean (standard deviation) | | *P*-value | |
|---|---|---|---|---|
| | Boston (*n* = 273) | Maine (*n* = 223) | Logistic portion† | Linear portion‡ |
| Carious permanent teeth | 1.7 (0.8) | 1.0 (0.8) | 0.03¶ | 0.38 |
| Carious permanent surfaces | 2.2 (1.0) | 1.5 (1.2) | 0.004§ | 0.87 |

* Adjusted for the number of permanent teeth, age, gender, race/ethnicity, education of primary caregiver, primary caregiver, and frequency of toothbrushing, using zero-inflated models. The unadjusted mean number of permanent teeth was 10.6 (±4.5) in Boston and 9.7 (±5.2) in Maine.
† *P*-values were obtained from the logistic portion of the zero-inflated model that represents the probability of having no carious permanent teeth or surfaces. Among children with permanent dentition, the percentages of participants with no caries in permanent dentition were 57% (*n* = 128) in Maine and 30% (*n* = 82) in Boston.
‡ *P*-values were obtained from the linear portion of the zero-inflated model that represents the probability of having an additional carious tooth or surface, given that there were any permanent dentition caries. The linear portion was modeled using a Poisson model for carious teeth and a negative binomial model for carious surfaces.
¶ Odds ratio: 2.8, 95% confidence interval: 1.1 to 6.8.
§ Odds ratio: 3.0, 95% confidence interval: 1.4 to 6.5.

both rural and urban areas of one region of the United States using the same methods and measurement with standard operating procedures. Our findings are consistent with rural/urban differences observed in studies conducted in China, Sweden, Burkina Faso, and Senegal, which found higher caries prevalence among children and adolescents living in urban areas (6-8,24). However, studies in other countries may not be comparable because of particular sociobehavioral factors and economic differences, and population-based studies are limited by their analysis of secondary data and inability to assess individual-level factors. In the United States, an analysis of NHANES-III data found that rural areas tended to have lower dental care utilization, but there was no difference in self-reported poor dental status and no statistically significant difference in DMFT or the number of decayed and filled primary teeth by rural versus urban setting (14).

Although national surveys are useful to grasp the scope of the problem of oral disease, an understanding of the extent of disease in precisely those individuals and families who not only need services but are also willing to use them is fundamental to policy and program development. Our results suggest that within this target group, not only do statistically significant differences in caries prevalence exist by rural/urban location, but also that the direction of the association may differ from that observed among children in the general population. It may be that among all children in the United States, those in rural areas tend to have lower access and utilization of dental care (14), but that among the population of those with unmet needs, the urban setting puts children and families in need at an even greater disadvantage. That is, rural areas generally have fewer dentists per population and more poverty, which together limits dental care access for rural children. The lack of a difference in caries prevalence in the general US child population comparing urban and rural areas suggests that urban children have other disadvantages that balance the caries treatment needs of rural and urban children (14). These disadvantages may stem from more complicated social settings and competing priorities with limited resources and support among lower income urban children (e.g., nontraditional family structures and barriers such as work schedules or reliance on public transportation) (25). Indeed, among populations targeted for having unmet needs, such disadvantages for urban children may put them at even greater risk than rural children.

Numerous multilevel factors are involved within the community realm, including factors such as education, race, social support networks, community and cultural norms, beliefs, behaviors, and financial resources. Interestingly, in all of our multivariate models of carious dentition, the variables of race, drinking water source, household income, education, and other caregiver factors were less important than rural/urban dwelling. In addition to the importance of rural/urban dwelling itself, it may be that this variable is an efficient statistical marker for some of these other related factors. However, it is unlikely that fluoridated water was the reason for the rural/urban difference, because the drinking water source for Boston-area children was most often the fluoridated municipal supply, in contrast to the well water used in rural Maine, which was likely to be at the lower bound of the target range for water fluoridation (18). Furthermore, even after thoroughly considering all the individual level factors, rural/urban dwelling remained strongly association with caries prevalence.

Diet is an important factor in caries development, but NECAT had limited data on participant nutritional factors related to caries, such as sugar consumption. However, a recent study of sociodemographic determinants of added sugar intake in a representative sample of US preschool children found no association between rural/urban dwelling and sugar consumption (26). Rather, only when limiting the sample to families eligible for food stamps (income <130 percent of the poverty line) was there an association, in which urban residence was marginally predictive of lower sugar intake. Thus, it is unlikely that our findings were positively biased by added sugar consumption. Dietary factors may still partly explain our finding that older children had more permanent dentition caries. As children and adolescents gain independence, they may be more likely to consume refined sugars in food and beverages (27,28), thereby increasing risk for caries over and above the age-related longer time of dentition at risk. The finding that older age was inversely associated with primary dentition caries, on the other hand, may be because of residual confounding between age and number of primary teeth.

Despite the fact that 93 percent of NECAT participants had permanent teeth, with an average of 10 per child, 42 percent had no caries in permanent teeth. We used zero-inflated models to consider the possibility that children with no permanent dentition caries represented different processes; that is, some may have had very newly erupted permanent teeth with less time at risk to have developed caries, while others may have had behavioral or sociodemographic characteristics that lowered their risk of developing permanent dentition caries. Zero-inflated models also allowed us to assess the probabilities of having no carious permanent teeth and of having more carious teeth given that there were any. This statistical approach to modeling count data has been shown to be useful in cross-sectional studies of dental disease in children (21,29). Our results showed that rural/urban dwelling was an important correlate of having any caries in permanent dentition. On the other hand, rural/urban dwelling was not associated with the number of caries among children, given that there were any permanent dentition caries. The fact that the only statistically significant predictors of the number of permanent teeth caries were age and the number of permanent teeth suggests that our participants may not have had their permanent teeth long enough for other factors to contribute substantially to caries development. At the same time, however, toothbrushing frequency was significantly associated with the number of permanent teeth caries, but not primary dentition caries, which suggests that the rate of caries in permanent teeth may be more affected by individual-level oral health behavior.

Improving oral health requires a focused effort by professional and governmental organizations that takes into account both the individual characteristics and larger community situations of their targeted populations. In our study, we found that children who were willing to participate in a program that offered free dental care differed substantially in their unmet caries treatment needs based on rural or urban setting. Our results from two areas in New England suggest that the geographic location of potential participants is an important factor to consider when developing program policy and when reserving or allocating resources.

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